1.2.1 SLOPE STABILITY　ANALYSIS

1.2.1.1　Normal and Seismic Conditions

(6)　R10+960

Circular Slip Surface

R+10960

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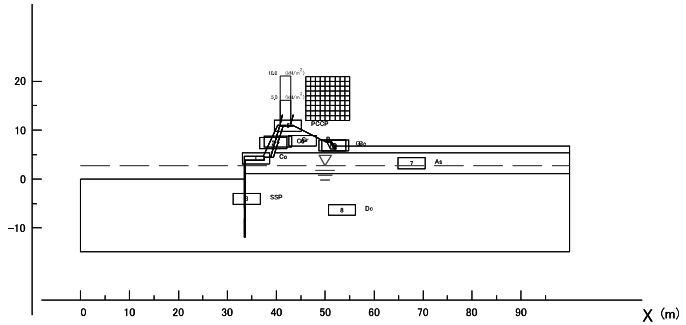
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1. Input data list

// Design section //



// Design level of reliability design method //

Level of reliability design ..... Level 1(Design for value, part coefficient method)

// Combination of action //

// Setting of action //

Action	Action name	Seismic inertia	Newmark No.	Same hydraul-ic line
1	normal			
2	seismic	○		

// Partial coefficient concerning analytical technique γ_α //

Action No.	Partial coefficient concerning analytical technique γ_α
1	1.00
2	1.00

// Partial coefficient concerning W,C,ϕ $\gamma w, \gamma c, \gamma \tan\phi$ //

No.	Action 1			Action 2										
	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$
1	1.00	1.00	1.00	1.00	1.00	1.00						
2	1.00	1.00	1.00	1.00	1.00	1.00						
3	1.00	1.00	1.00	1.00	1.00	1.00						
4	1.00	1.00	1.00	1.00	1.00	1.00						
5	1.00	1.00	1.00	1.00	1.00	1.00						
6	1.00	1.00	1.00	1.00	1.00	1.00						
7	1.00	1.00	1.00	1.00	1.00	1.00						
8	1.00	1.00	1.00	1.00	1.00	1.00						
9	1.00	1.00	1.00	1.00	1.00	1.00						
10	1.00	1.00	1.00	1.00	1.00	1.00						

$$M = \Sigma [C_d l + \{ (W_d' + q_d) \cos\theta - K_k W_d \sin\theta \} \tan\phi_d]$$

$$W_d' = \gamma_w W_k'$$

$$C_d = \gamma_c C_k$$

$$\tan\phi_d = \gamma_{\tan\phi} \tan\phi_k$$

M : Resistance moment

γ_w : Partial coefficient concerning weight

W_d' : Effective weight of slice of amount for each unit length splinter (value for design) (kN/m)

W_k' : Effective weight of slice of amount for each unit length splinter (characteristic value)(kN/m)

q_d : Perpendicular action because of the upper part of amount of slice (kN/m)

γ_c : Partial coefficient concerning Cohesion

C_d : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (value for design) (kN/m^2)

C_k : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (characteristic value) (kN/m^2)

l : Length in base of amount of Slice (m)

$\gamma_{\tan\phi}$: Partial coefficient concerning shearing resistance angle

ϕ_d : 0 in case of viscous land board. Shearing resistance angle in drain condition in case of the sandy soil ground etc.(value for design)(°)

ϕ_k : 0 in case of viscous land board. Shearing resistance angle in drain condition in case of the sandy soil ground etc.(characteristic value)(°)

// Partial coefficient of partial coefficient γ_{vl} to distribution load (Think as well as the ground) and inertia force γ_{vlEQ} //

Action No.	Load1		Load2							
	Load	Inertia force	Load	Inertia force	Load	Inertia force	Load	Inertia force	Load	Inertia force
1	1.00	1.00	−	−						
2	−	−	1.00	1.00						

$$M_{r,vl} = K \cdot r \Sigma (FR \cdot \gamma_{vl,i} - K_{hp} \cdot FO \cdot \gamma_{vlEQ,i}) \cdot \tan\phi$$

$$M_{d,vl} = r \Sigma (FO \cdot \gamma_{vl,i} + K_{hp} \cdot FR \cdot \gamma_{vlEQ,i})$$

$$FR = F \cdot \cos\theta$$

$$FO = F \cdot \sin\theta$$

$M_{r,vl}$: Resistance moment of distribution load (Think as well as the ground)

$M_{d,vl}$: Sliding moment of distribution load (Think as well as the ground)

K : Resistance power coefficient

r : Radius of slipping circular arc

F : Distribution load i

FR : Slipping line orthogonalization direction load value of load i

FO : Slipping line direction load value of load i

θ : Angle that slice bottom (slide surface) does to the horizontal

$\gamma_{vl,i}$: Partial coefficient of distribution load i (Think as well as the ground).

K_{hp} : The horizontal seismic intensity

$\gamma_{vlEQ,i}$: Partial coefficient of inertia force of distribution load i (Think as well as the ground).

ϕ : Internal friction angle of soil

// Partial coefficient to residual water level //

Action number	rRWL
1	1.00
2	1.00

$$RWL_d = \gamma_{RWL} RWL_k$$

γ_{RWL} : Partial coefficient concerning residual water level

RWL_d : Difference between residual water level and water level line (value for design) (m)

RWL_k : Difference between residual water level and water level line (input value) (m)

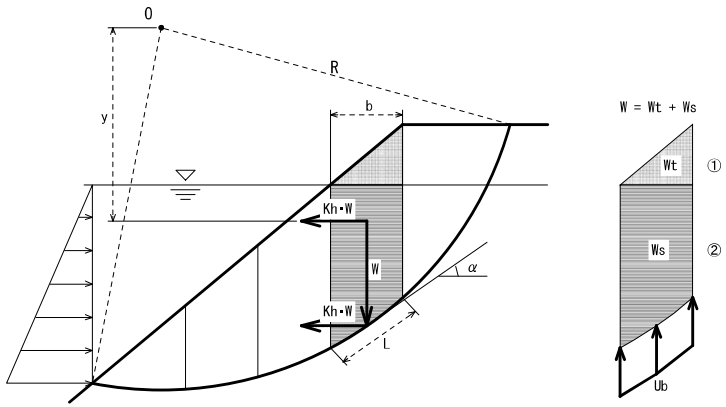
(DATA 01.)　// ANALYSIS //

Title　.....　Test of Embankment Stability
Analysis type　.....　Analysis of Bearing force Action ratio
Calculation method .....　Revised Feleniu s (Total stress)

Expression

$$\frac{R\Sigma[C_d l+\{((1+K_v)W_d-u\,b)\cos\theta-K_h W_d\sin\theta\}\tan\phi_d]}{\gamma_a R\Sigma\{(1+K_v)W_d\sin\theta+K_h W_d\cos\theta\}} \geqq 1.0$$

R	:	Radius of slipping circle of circular arc (m)
C_d	:	Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (kN/m²)
l	:	Length in base of amount of crack splinter (m)
q_d	:	Perpendicular action because of the upper part of amount of crack splinter (kN/m)
θ	:	Angle that amount of crack splinter bottom does to a horizontal plane (degree)
ϕ_d	:	0 in case of viscous land board. Shearing resistance in drain condition in case of the sandy soil ground etc.(°)
W_d	:	Full weight of crack of amount for each unit length splinter (full weight of soil and water) (kN/m)
γ_a	:	Partial coefficient concerning analytical technique
K_h	:	The horizontal seismic intensity
K_v	:	Vertical seismic coefficient
u	:	Pore pressure (kN/m²)
b	:	Width of slice (m)



Treatment of its own weight W of the resistance force
　Above the water level.....Calculate the weight Wt in Wet weight γt　①
　Below the water level.....Calculate weight Ws in Saturated weight γsat　②
Treatment of its own weight W of impetus
　Above the water level.....Calculate the weight Wt in Wet weight γt
　Below the water level.....Calculate weight in Saturated weight γsat
Water pressure acting on the slip plane.....Consider in the Ubcosα
　(Modify Fereniusu method)
Lateral hydrostatic pressure due to water storage.....Including

(DATA 02.)　// CONTROL //

Second pursuit　.....　0 (=0 No)
　(>0 Yes　)
Run　.....　0 (=0 Input data check + Analysis)
　(=1 Input data check　)

(DATA 04.) // SEISMIC LOAD //

```
Seismic load                  .....  0 ( =0 Same for the whole model )
                                     ( =1 Different on each layer  )
Condition                     .....  1 ( =0 Acts on only sliding force )
                                     ( =1 Sliding + Resisting force  )
Acting point                  .....  0 ( =0 On the slip surface              )
                                     ( =1 Center of gravity of sliding mass )
                                     ( =2 Resisting:on the slip surface
                                          Sliding  :Center of gravity of sliding mass )
Unit weight                   .....  0 ( =0 Saturated weight )
                                     ( =1 Submerged weight )
Horizontal seismic coefficient.....  0.200
Vertical seismic coefficient  .....  0.000
```


(DATA 06.) // NODAL POINT //

No.	Coordinate		Y-coordinate
	x (m)	y (m)	before settlement (m)
1	0.00	0.00	0.00
2	33.49	0.00	0.00
3	33.49	3.83	0.00
4	33.49	4.63	0.00
5	37.34	4.63	0.00
6	37.49	4.63	0.00
7	37.49	4.48	0.00
8	37.49	3.83	0.00
9	33.64	3.83	0.00
10	33.64	1.13	0.00
11	40.33	11.03	0.00
12	40.78	11.03	0.00
13	40.72	10.83	0.00
14	41.34	10.83	0.00
15	43.33	10.83	0.00
16	43.33	11.03	0.00
17	38.82	4.48	0.00
18	39.44	4.48	0.00
19	39.70	5.36	0.00
20	50.05	7.67	0.00
21	50.34	7.67	0.00
22	51.03	6.12	0.00
23	51.78	6.12	0.00
24	51.01	7.67	0.00
25	51.40	7.67	0.00
26	52.00	6.47	0.00
27	52.10	6.47	0.00
28	52.10	6.12	0.00
29	51.85	6.77	0.00
30	100.00	6.77	0.00
31	100.00	5.36	0.00
32	100.00	1.13	0.00
33	100.00	-14.85	0.00
34	33.64	-11.87	0.00
35	33.49	-11.87	0.00
36	0.00	-14.85	0.00

(DATA 07.) // WATER LEVEL //

Unit weight of water (kN/m³) = 10.00

Action No.	Water level line number
1	1
2	1

Water level line number: 1

No.	Coordinate	
	X (m)	Y (m)
1	0.00	2.77
2	100.00	2.77

Water level line number: 2

No.	Coordinate	
	X (m)	Y (m)
1	0.00	0.00
2	150.00	0.00

(DATA 08.) // LAYER //

No.	material property No.	The name of the strata
1	1	Co
2	1	Co
3	2	SSP
4	3	Gr
5	4	POCP
6	5	B
7	6	As

No.	material property No.	The name of the strata
8	7	Dc
9	1	Co
10	3	Gr

No.	Num of Node	Node numbers composing a layer	Slip existence
1	7	3 9 8 7 6 5 4	Not Slip
2	7	5 6 7 17 13 12 11	Not Slip
3	6	2 35 34 10 9 3	Not Slip
4	5	13 17 18 19 14	Not Slip
5	5	12 13 14 15 16	Slip
6	14	14 19 31 30 29 26 27 28 23 22 21	Slip
		20 16 15	
7	9	10 32 31 19 18 17 7 8 9	Slip
8	8	1 36 33 32 10 34 35 2	Slip
9	7	23 28 27 26 29 25 24	Not Slip
10	4	21 22 23 24	Slip

(DATA 09.1) // MATERIAL PROPERTIES //

No.	Nature of soil division	Saturated weight (kN/m³)	Wet weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle ϕ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	1	24.00	24.00	******	0.00	0.00	0.00	0.000	0.0
2	2	77.00	77.00	******	0.00	0.00	0.00	0.000	0.0
3	3	20.00	19.00	0.00	0.00	35.00	0.00	0.000	0.0
4	4	24.00	24.00	1.00	0.00	30.00	0.00	0.000	0.0
5	5	19.00	18.00	1.00	0.00	30.00	0.00	0.000	0.0
6	6	18.50	17.50	0.00	0.00	27.00	0.00	0.000	0.0
7	7	19.00	18.00	100.00	0.00	0.00	0.00	0.000	0.0

(DATA 09.2) // Characteristic of soil //

No.	Action Number									
	Act 1	Act 2								
1	1	1								
2	1	1								
3	2	2								
4	3	3								
5	4	4								
6	5	5								

No.	Action Number									
	Act 1	Act 2								
7	6	6								
8	7	7								
9	1	1								
10	3	3								

(DATA 11.) // GRID POINT //

No.	Slip direction	Double cutting	GX (m)	GY (m)	X-point	Y-point	X-pitch (m)	Y-pitch (m)	Dx/Dy	NEXCO Radius
1	Downstream	Rigt lump	46.00	21.00	10	10	1.00	1.00	0.000	0.000

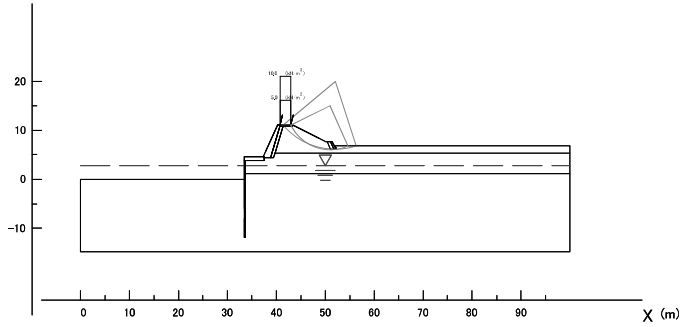
2. Check list

// Check of circular arc //

Action No.	Action name	Bearing force Action ratio	Judgment
1	normal	1.593	OK
2	seismic	1.006	OK

Action No.	Bearing force Action ratio	Partial coefficient r_a	Center of slipping circular arc X (m)	Center of slipping circular arc Y (m)	Radius of circular arc(m)	Resistance Moment (kNm)	Sliding Moment (kNm)
1	1.593	1.00	52.00	20.00	13.900	2931.6	1840.1
2	1.006	1.00	51.00	15.00	8.981	1428.9	1421.0

// Check Result chart //



3. Action01 (normal)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	1	24.00	24.00	14.00	1000.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.
0	2	1 24.0	0 24.0	0 14.0	01000.	00 0.	00 0.	00 0.	00 0.	00 0
0.0	3	2 77.	00 77.	00 67.	001000	0.00	0.00	0.00	0.00	0.00
0.0	4	3 20	0.00 1	0.00 1	0.00	0.00	0.003	0.00	0.00	0.00
0.0	5	4 24	0.00 2	0.00 1	0.00	0.00	0.003	0.00	0.00	0.00
0.0	6	5 19	0.00 1	0.00	0.00	0.00	0.003	0.00	0.00	0.00
0.0	7	6 18	0.50 1	0.50	0.50	0.00	0.002	0.00	0.00	0.00
0.0	8	7 19	0.00 1	0.00	0.0010	0.00	0.00	0.00	0.00	0.00
0.0	9	1 24	0.00 2	0.00 1	0.0010	0.00	0.00	0.00	0.00	0.00
0.0	10	3 2	0.00 1	9.00 1	0.00	0.00	0.003	5.00	0.00	0.00
0.0	@06	@06	@06	@06	@06	@06	@05	@06	@07	@06

// Distribution load that considers partial coefficient //

load No.	Left			Right			Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)			
1	40.80	11.15	10.0	43.00	11.15	10.0	0.000	0.000	0.000

// Water level line where partial coefficient of residual water level was considered //

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	2.77	
2	100.00	2.77	

Bearing force Action ratio

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
46.00	21.00	10.32	999.000	0.0	0.0	***6
46.00	20.00	9.36	999.000	0.0	0.0	***6
46.00	19.00	8.41	999.000	0.0	0.0	***6
46.00	18.00	7.46	999.000	0.0	0.0	***6
46.00	17.00	6.54	999.000	0.0	0.0	***6
46.00	16.00	5.64	999.000	0.0	0.0	***6
46.00	15.00	4.74	999.000	0.0	0.0	***6
46.00	14.00	3.85	999.000	0.0	0.0	***6
46.00	13.00	2.96	999.000	0.0	0.0	***6
46.00	12.00	2.06	999.000	0.0	0.0	***6
47.00	21.00	10.62	999.000	0.0	0.0	***6
47.00	20.00	9.69	999.000	0.0	0.0	***6
47.00	19.00	8.77	999.000	0.0	0.0	***6
47.00	18.00	7.88	999.000	0.0	0.0	***6
47.00	17.00	6.98	999.000	0.0	0.0	***6
47.00	16.00	6.09	999.000	0.0	0.0	***6
47.00	15.00	5.19	999.000	0.0	0.0	***6
47.00	14.00	4.30	999.000	0.0	0.0	***6
47.00	13.00	3.40	999.000	0.0	0.0	***6
47.00	12.00	2.51	999.000	0.0	0.0	***6
48.00	21.00	11.01	999.000	0.0	0.0	***6
48.00	20.00	10.11	999.000	0.0	0.0	***6
48.00	19.00	9.22	999.000	0.0	0.0	***6
48.00	18.00	8.32	999.000	0.0	0.0	***6
48.00	17.00	7.43	999.000	0.0	0.0	***6
48.00	16.00	6.53	999.000	0.0	0.0	***6
48.00	15.00	5.64	999.000	0.0	0.0	***6
48.00	14.00	4.74	999.000	0.0	0.0	***6
48.00	13.00	3.85	999.000	0.0	0.0	***6
48.00	12.00	2.96	999.000	0.0	0.0	***6
49.00	21.00	11.45	999.000	0.0	0.0	***6
49.00	20.00	10.56	999.000	0.0	0.0	***6
49.00	19.00	9.66	999.000	0.0	0.0	***6
49.00	18.00	8.77	999.000	0.0	0.0	***6
49.00	17.00	7.88	999.000	0.0	0.0	***6
49.00	16.00	6.98	999.000	0.0	0.0	***6
49.00	15.00	6.09	999.000	0.0	0.0	***6
49.00	14.00	5.19	999.000	0.0	0.0	***6
49.00	13.00	4.30	999.000	0.0	0.0	***6
49.00	12.00	3.40	999.000	0.0	0.0	***6

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
49.00	12.00	7.40	1.708	2448.2	1433.6	
50.00	21.00	11.90	999.000	0.0	0.0	***6
50.00	20.00	11.01	999.000	0.0	0.0	***6
50.00	19.00	10.11	999.000	0.0	0.0	***6
50.00	18.00	9.22	999.000	0.0	0.0	***6
50.00	17.00	8.32	999.000	0.0	0.0	***6
50.00	16.00	7.43	999.000	0.0	0.0	***6
50.00	15.00	6.53	999.000	0.0	0.0	***6
		9.53	1.651	2764.5	1674.3	
50.00	14.00	5.64	999.000	0.0	0.0	***6
		8.64	1.683	2404.9	1428.5	
50.00	13.00	4.74	999.000	0.0	0.0	***6
		7.74	1.684	1962.7	1165.2	
		8.74	1.745	3297.4	1889.7	
50.00	12.00	3.85	999.000	0.0	0.0	***6
		6.85	1.768	1589.9	899.4	
		7.85	1.808	2766.1	1530.2	
51.00	21.00	12.35	999.000	0.0	0.0	***6
51.00	20.00	11.45	999.000	0.0	0.0	***6
51.00	19.00	10.56	999.000	0.0	0.0	***6
51.00	18.00	9.66	999.000	0.0	0.0	***6
51.00	17.00	8.77	999.000	0.0	0.0	***6
51.00	16.00	7.88	999.000	0.0	0.0	***6
		10.88	1.681	3412.7	2030.0	
51.00	15.00	6.98	999.000	0.0	0.0	***6
		8.98	1.645	1536.2	933.6	
		9.98	1.696	2996.1	1766.7	
51.00	14.00	6.09	999.000	0.0	0.0	***6
		9.09	1.741	2586.1	1485.8	
		10.09	1.862	4335.9	2328.2	
51.00	13.00	5.19	999.000	0.0	0.0	***6
		8.19	1.835	2186.5	1191.3	
		9.19	1.917	3740.6	1951.1	
51.00	12.00	4.30	999.000	0.0	0.0	***6
		8.30	2.030	3160.3	1556.4	
		9.30	2.162	5036.7	2329.5	
52.00	21.00	12.79	999.000	0.0	0.0	***6
52.00	20.00	11.90	999.000	0.0	0.0	***6
		13.90	1.593	2931.6	1840.1	
52.00	19.00	11.01	999.000	0.0	0.0	***6

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
52.00	19.00	13.01	1.618	2735.9	1690.5	
52.00	18.00	10.11	999.000	0.0	0.0	***6
		12.11	1.662	2531.6	1523.3	
52.00	17.00	9.22	999.000	0.0	0.0	***6
		11.22	1.727	2311.7	1338.6	
		12.22	1.811	4289.7	2368.2	
52.00	16.00	8.32	999.000	0.0	0.0	***6
		10.32	1.830	2079.4	1136.3	
		11.32	1.841	3843.5	2087.3	
52.00	15.00	7.35	999.000	0.0	0.0	***6
		10.35	1.893	3259.5	1721.5	
		11.35	2.022	5409.1	2675.3	
52.00	14.00	6.36	999.000	0.0	0.0	***6
		9.36	1.992	2666.8	1338.5	
		10.36	2.069	4539.0	2193.4	
52.00	13.00	5.36	999.000	0.0	0.0	***6
		9.36	2.182	3734.8	1712.0	
		10.36	2.287	5897.7	2578.7	
52.00	12.00	4.37	999.000	0.0	0.0	***6
		9.37	2.420	4866.1	2011.0	
		10.37	2.435	7009.0	2878.4	
53.00	21.00	13.24	999.000	0.0	0.0	***6
		15.24	1.784	3739.0	2095.5	
53.00	20.00	12.35	999.000	0.0	0.0	***6
		14.35	1.833	3535.3	1928.3	
53.00	19.00	11.44	999.000	0.0	0.0	***6
		13.44	1.896	3281.0	1730.9	
53.00	18.00	10.45	999.000	0.0	0.0	***6
		12.45	1.972	2810.0	1425.3	
		13.45	1.988	5097.3	2563.5	
53.00	17.00	9.47	999.000	0.0	0.0	***6
		11.47	2.080	2373.9	1141.0	
		12.47	2.029	4405.6	2171.6	
53.00	16.00	8.48	999.000	0.0	0.0	***6
		11.48	2.112	3760.0	1780.4	
		12.48	2.206	6251.6	2833.4	
53.00	15.00	7.50	999.000	0.0	0.0	***6
		10.50	2.232	3164.6	1417.9	
		11.50	2.278	5370.4	2357.2	
53.00	14.00	6.53	999.000	0.0	0.0	***6

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
53.00	14.00	10.53	2.418	4554.6	1883.3	
		11.53	2.474	7058.1	2852.4	
53.00	13.00	5.56	999.000	0.0	0.0	***6
		10.56	2.616	6008.2	2297.1	
		11.56	2.589	8465.4	3269.4	
53.00	12.00	4.62	999.000	0.0	0.0	***6
		10.62	2.740	7225.9	2637.3	
		11.62	4.140	14960.8	3614.1	
54.00	21.00	13.58	999.000	0.0	0.0	***6
		15.58	2.100	4200.4	2000.2	
54.00	20.00	12.60	999.000	0.0	0.0	***6
		14.60	2.184	3705.1	1696.2	
		15.60	2.173	6568.5	3023.2	
54.00	19.00	11.62	999.000	0.0	0.0	***6
		13.62	2.327	3241.3	1392.8	
		14.62	2.215	5833.2	2633.9	
54.00	18.00	10.65	999.000	0.0	0.0	***6
		13.65	2.289	5140.1	2245.9	
54.00	17.00	9.69	999.000	0.0	0.0	***6
		12.69	2.416	4492.0	1859.3	
		13.69	2.454	7407.0	3017.9	
54.00	16.00	8.73	999.000	0.0	0.0	***6
		12.73	2.556	6515.3	2549.0	
54.00	15.00	7.78	999.000	0.0	0.0	***6
		11.78	2.730	5688.6	2083.7	
		12.78	2.707	8560.1	3162.6	
54.00	14.00	6.84	999.000	0.0	0.0	***6
		11.84	2.859	7490.5	2620.3	
		12.84	2.783	10312.2	3704.9	
54.00	13.00	5.93	999.000	0.0	0.0	***6
		10.93	3.082	6517.0	2114.6	
		11.93	3.451	10669.9	3091.9	
54.00	12.00	5.05	999.000	0.0	0.0	***6
		11.05	4.180	10434.1	2496.3	
		12.00	4.989	17252.2	3457.7	
55.00	21.00	13.81	999.000	0.0	0.0	***6
		15.81	2.487	4152.2	1669.8	
		16.81	2.439	7566.7	3102.8	
55.00	20.00	12.84	999.000	0.0	0.0	***6
		14.84	2.655	3689.1	1389.5	

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
55.00	20.00	15.84	2.513	6829.5	2717.3	
55.00	19.00	11.89	999.000	0.0	0.0	***6
		14.89	2.629	6133.6	2333.3	
		15.89	2.674	9856.0	3685.5	
55.00	18.00	10.94	999.000	0.0	0.0	***6
		13.94	2.809	5482.0	1951.4	
		14.94	2.762	8893.9	3220.3	
55.00	17.00	10.00	999.000	0.0	0.0	***6
		14.00	2.897	7991.0	2758.5	
55.00	16.00	9.07	999.000	0.0	0.0	***6
		13.07	3.108	7152.8	2301.3	
		14.07	2.972	10383.5	3494.1	
55.00	15.00	8.17	999.000	0.0	0.0	***6
		13.17	3.135	9289.7	2963.3	
		14.17	4.122	17166.7	4164.2	
55.00	14.00	7.23	999.000	0.0	0.0	***6
		12.23	3.390	8147.2	2403.3	
		13.23	4.478	15698.8	3505.5	
		14.00	5.021	22225.8	4426.7	
55.00	13.00	6.23	999.000	0.0	0.0	***6
		12.23	4.923	13625.2	2767.4	
		13.00	5.399	19548.0	3621.0	
55.00	12.00	5.23	999.000	0.0	0.0	***6
		12.00	6.032	17009.4	2820.0	

Table of B.A.

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Center X(m),Y(m)

Y(m)	X(m)	46.00	47.00	48.00	49.00	50.00	51.00
21.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
20.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
19.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
18.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
17.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
16.00	Fs	999.000	999.000	999.000	999.000	999.000	1.681
	R(m)	0.00	0.00	0.00	0.00	0.00	10.88
15.00	Fs	999.000	999.000	999.000	999.000	1.651	1.645
	R(m)	0.00	0.00	0.00	0.00	9.53	8.98
14.00	Fs	999.000	999.000	999.000	999.000	1.683	1.741
	R(m)	0.00	0.00	0.00	0.00	8.64	9.09
13.00	Fs	999.000	999.000	999.000	999.000	1.684	1.835
	R(m)	0.00	0.00	0.00	0.00	7.74	8.19
12.00	Fs	999.000	999.000	999.000	1.708	1.768	2.030
	R(m)	0.00	0.00	0.00	7.40	6.85	8.30

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Center X(m),Y(m)

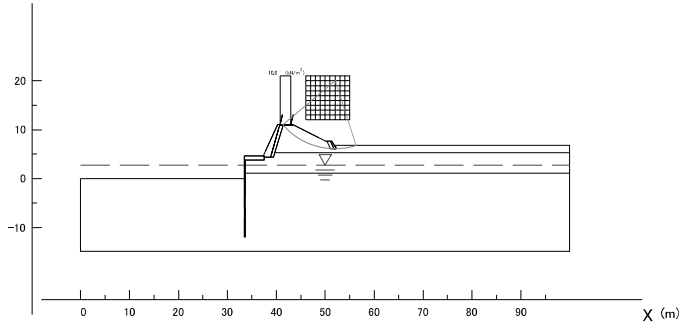
Y(m)	X(m)	52.00	53.00	54.00	55.00
21.00	Fs	999.000	1.784	2.100	2.439
	R(m)	0.00	15.24	15.58	16.81
20.00	Fs	1.593	1.833	2.173	2.513
	R(m)	13.90	14.35	15.60	15.84
19.00	Fs	1.618	1.896	2.215	2.629
	R(m)	13.01	13.44	14.62	14.89
18.00	Fs	1.662	1.972	2.289	2.762
	R(m)	12.11	12.45	13.65	14.94
17.00	Fs	1.727	2.029	2.416	2.897
	R(m)	11.22	12.47	12.69	14.00
16.00	Fs	1.830	2.112	2.556	2.972
	R(m)	10.32	11.48	12.73	14.07
15.00	Fs	1.893	2.232	2.707	3.135
	R(m)	10.35	10.50	12.78	13.17
14.00	Fs	1.992	2.418	2.783	3.390
	R(m)	9.36	10.53	12.84	12.23
13.00	Fs	2.182	2.589	3.082	4.923
	R(m)	9.36	11.56	10.93	12.23
12.00	Fs	2.420	2.740	4.180	6.032
	R(m)	9.37	10.62	11.05	12.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	1.593
Failure circle X(m)	=	52.00
Y(m)	=	20.00
R(m)	=	13.900
Resisting moment(kNm)	=	2931.6
Sliding moment(kNm)	=	1840.1
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



WARNING ***6 An arc does not cut the ground,
or An arc cuts the side of a model. count =100

4. Action02 (seismic)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	1	24.00	24.00	14.00	1000.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.
0	2	1 24.0	0 24.0	0 14.0	01000.	00 0.	00 0.	00 0.	00 0.	00 0
0.0	3	2 77.	00 77.	00 67.	001000	0.00	0.00	0.00	0.00	0.00
0.0	4	3 20	0.00 1	0.00 1	0.00	0.00	0.003	0.00	0.00	0.00
0.0	5	4 24	0.00 2	0.00 1	0.00	0.00	0.003	0.00	0.00	0.00
0.0	6	5 19	0.00 1	0.00	0.00	0.00	0.003	0.00	0.00	0.00
0.0	7	6 18	0.50 1	0.50	0.50	0.00	0.002	0.00	0.00	0.00
0.0	8	7 19	0.00 1	0.00	0.0010	0.00	0.00	0.00	0.00	0.00
0.0	9	1 24	0.00 2	0.00 1	0.0010	0.00	0.00	0.00	0.00	0.00
0.0	10	3 2	0.00 1	9.00 1	0.00	0.00	0.003	5.00	0.00	0.00
0.0	@06	@06	@06	@06	@06	@06	@05	@06	@07	@06

// Distribution load that considers partial coefficient //

load No.	Left			Right			Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)			
2	40.80	11.15	5.0	43.00	11.15	5.0	0.000	0.200	0.000

// Water level line where partial coefficient of residual water level was considered //

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	2.77	
2	100.00	2.77	

Bearing force Action ratio

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
46.00	21.00	10.32	999.000	0.0	0.0	***6
46.00	20.00	9.36	999.000	0.0	0.0	***6
46.00	19.00	8.41	999.000	0.0	0.0	***6
46.00	18.00	7.46	999.000	0.0	0.0	***6
46.00	17.00	6.54	999.000	0.0	0.0	***6
46.00	16.00	5.64	999.000	0.0	0.0	***6
46.00	15.00	4.74	999.000	0.0	0.0	***6
46.00	14.00	3.85	999.000	0.0	0.0	***6
46.00	13.00	2.96	999.000	0.0	0.0	***6
46.00	12.00	2.06	999.000	0.0	0.0	***6
47.00	21.00	10.62	999.000	0.0	0.0	***6
47.00	20.00	9.69	999.000	0.0	0.0	***6
47.00	19.00	8.77	999.000	0.0	0.0	***6
47.00	18.00	7.88	999.000	0.0	0.0	***6
47.00	17.00	6.98	999.000	0.0	0.0	***6
47.00	16.00	6.09	999.000	0.0	0.0	***6
47.00	15.00	5.19	999.000	0.0	0.0	***6
47.00	14.00	4.30	999.000	0.0	0.0	***6
47.00	13.00	3.40	999.000	0.0	0.0	***6
47.00	12.00	2.51	999.000	0.0	0.0	***6
48.00	21.00	11.01	999.000	0.0	0.0	***6
48.00	20.00	10.11	999.000	0.0	0.0	***6
48.00	19.00	9.22	999.000	0.0	0.0	***6
48.00	18.00	8.32	999.000	0.0	0.0	***6
48.00	17.00	7.43	999.000	0.0	0.0	***6
48.00	16.00	6.53	999.000	0.0	0.0	***6
48.00	15.00	5.64	999.000	0.0	0.0	***6
48.00	14.00	4.74	999.000	0.0	0.0	***6
48.00	13.00	3.85	999.000	0.0	0.0	***6
48.00	12.00	2.96	999.000	0.0	0.0	***6
49.00	21.00	11.45	999.000	0.0	0.0	***6
49.00	20.00	10.56	999.000	0.0	0.0	***6
49.00	19.00	9.66	999.000	0.0	0.0	***6
49.00	18.00	8.77	999.000	0.0	0.0	***6
49.00	17.00	7.88	999.000	0.0	0.0	***6
49.00	16.00	6.98	999.000	0.0	0.0	***6
49.00	15.00	6.09	999.000	0.0	0.0	***6
49.00	14.00	5.19	999.000	0.0	0.0	***6
49.00	13.00	4.30	999.000	0.0	0.0	***6
49.00	12.00	3.40	999.000	0.0	0.0	***6

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
49.00	12.00	7.40	1.006	2295.3	2281.1	
50.00	21.00	11.90	999.000	0.0	0.0	***6
50.00	20.00	11.01	999.000	0.0	0.0	***6
50.00	19.00	10.11	999.000	0.0	0.0	***6
50.00	18.00	9.22	999.000	0.0	0.0	***6
50.00	17.00	8.32	999.000	0.0	0.0	***6
50.00	16.00	7.43	999.000	0.0	0.0	***6
50.00	15.00	6.53	999.000	0.0	0.0	***6
		9.53	1.029	2586.2	2514.1	
50.00	14.00	5.64	999.000	0.0	0.0	***6
		8.64	1.035	2249.7	2173.1	
50.00	13.00	4.74	999.000	0.0	0.0	***6
		7.74	1.010	1832.3	1814.9	
		8.74	1.017	3097.6	3044.5	
50.00	12.00	3.85	999.000	0.0	0.0	***6
		6.85	1.025	1486.2	1449.6	
		7.85	1.030	2600.8	2524.5	
51.00	21.00	12.35	999.000	0.0	0.0	***6
51.00	20.00	11.45	999.000	0.0	0.0	***6
51.00	19.00	10.56	999.000	0.0	0.0	***6
51.00	18.00	9.66	999.000	0.0	0.0	***6
51.00	17.00	8.77	999.000	0.0	0.0	***6
51.00	16.00	7.88	999.000	0.0	0.0	***6
		10.88	1.020	3196.0	3134.7	
51.00	15.00	6.98	999.000	0.0	0.0	***6
		8.98	1.006	1428.9	1421.0	
		9.98	1.015	2804.5	2763.3	
51.00	14.00	6.09	999.000	0.0	0.0	***6
		9.09	1.020	2421.4	2373.5	
		10.09	1.058	4090.8	3865.2	
51.00	13.00	5.19	999.000	0.0	0.0	***6
		8.19	1.041	2050.4	1969.2	
		9.19	1.069	3531.6	3303.8	
51.00	12.00	4.30	999.000	0.0	0.0	***6
		8.30	1.095	2989.1	2729.4	
		9.30	1.142	4793.4	4197.4	
52.00	21.00	12.79	999.000	0.0	0.0	***6
52.00	20.00	11.90	999.000	0.0	0.0	***6
		13.90	1.016	2737.3	2694.0	
52.00	19.00	11.01	999.000	0.0	0.0	***6

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
52.00	19.00	13.01	1.021	2554.9	2503.0	
52.00	18.00	10.11	999.000	0.0	0.0	***6
		12.11	1.033	2365.6	2289.4	
52.00	17.00	9.22	999.000	0.0	0.0	***6
		11.22	1.053	2162.4	2054.1	
		12.22	1.060	4037.2	3807.8	
52.00	16.00	8.32	999.000	0.0	0.0	***6
		10.32	1.084	1948.6	1798.0	
		11.32	1.063	3617.9	3404.2	
52.00	15.00	7.35	999.000	0.0	0.0	***6
		10.35	1.072	3069.0	2862.8	
		11.35	1.112	5127.3	4612.8	
52.00	14.00	6.36	999.000	0.0	0.0	***6
		9.36	1.096	2514.1	2294.4	
		10.36	1.119	4303.2	3844.9	
52.00	13.00	5.36	999.000	0.0	0.0	***6
		9.36	1.143	3545.1	3101.7	
		10.36	1.178	5626.6	4774.4	
52.00	12.00	4.37	999.000	0.0	0.0	***6
		9.37	1.205	4648.8	3857.1	
		10.37	1.186	6711.6	5657.3	
53.00	21.00	13.24	999.000	0.0	0.0	***6
		15.24	1.095	3516.0	3210.0	
53.00	20.00	12.35	999.000	0.0	0.0	***6
		14.35	1.110	3327.2	2997.4	
53.00	19.00	11.44	999.000	0.0	0.0	***6
		13.44	1.128	3091.0	2739.2	
53.00	18.00	10.45	999.000	0.0	0.0	***6
		12.45	1.149	2649.1	2306.1	
		13.45	1.118	4822.8	4312.3	
53.00	17.00	9.47	999.000	0.0	0.0	***6
		11.47	1.183	2242.1	1895.5	
		12.47	1.125	4168.9	3705.6	
53.00	16.00	8.48	999.000	0.0	0.0	***6
		11.48	1.143	3560.9	3116.1	
		12.48	1.169	5951.2	5091.3	
53.00	15.00	7.50	999.000	0.0	0.0	***6
		10.50	1.173	3003.0	2559.2	
		11.50	1.183	5115.5	4325.3	
53.00	14.00	6.53	999.000	0.0	0.0	***6

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
53.00	14.00	10.53	1.212	4345.1	3585.4	
		11.53	1.227	6757.0	5505.4	
53.00	13.00	5.56	999.000	0.0	0.0	***6
		10.56	1.254	5759.9	4594.9	
		11.56	1.218	8126.9	6669.9	
53.00	12.00	4.62	999.000	0.0	0.0	***6
		10.62	1.242	6946.9	5592.9	
		11.62	1.866	14607.6	7826.5	
54.00	21.00	13.58	999.000	0.0	0.0	***6
		15.58	1.210	3982.4	3290.4	
54.00	20.00	12.60	999.000	0.0	0.0	***6
		14.60	1.233	3516.0	2851.0	
		15.60	1.181	6246.9	5289.9	
54.00	19.00	11.62	999.000	0.0	0.0	***6
		13.62	1.272	3081.1	2422.7	
		14.62	1.188	5549.1	4670.2	
54.00	18.00	10.65	999.000	0.0	0.0	***6
		13.65	1.203	4893.3	4066.6	
54.00	17.00	9.69	999.000	0.0	0.0	***6
		12.69	1.230	4282.5	3480.4	
		13.69	1.239	7085.4	5718.4	
54.00	16.00	8.73	999.000	0.0	0.0	***6
		12.73	1.259	6238.5	4955.6	
54.00	15.00	7.78	999.000	0.0	0.0	***6
		11.78	1.293	5456.4	4220.1	
		12.78	1.279	8225.8	6431.8	
54.00	14.00	6.84	999.000	0.0	0.0	***6
		11.84	1.304	7207.7	5529.4	
		12.84	1.253	9928.5	7926.2	
54.00	13.00	5.93	999.000	0.0	0.0	***6
		10.93	1.341	6285.1	4687.7	
		11.93	1.507	10344.0	6865.0	
54.00	12.00	5.05	999.000	0.0	0.0	***6
		11.05	1.730	10164.5	5876.6	
		12.00	2.080	16914.6	8130.8	
55.00	21.00	13.81	999.000	0.0	0.0	***6
		15.81	1.300	3963.1	3047.6	
		16.81	1.256	7234.7	5760.7	
55.00	20.00	12.84	999.000	0.0	0.0	***6
		14.84	1.340	3528.7	2633.7	

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
55.00	20.00	15.84	1.270	6534.5	5143.5	
55.00	19.00	11.89	999.000	0.0	0.0	***6
		14.89	1.293	5875.5	4542.5	
		15.89	1.301	9467.0	7278.2	
55.00	18.00	10.94	999.000	0.0	0.0	***6
		13.94	1.329	5260.7	3959.2	
		14.94	1.317	8549.5	6493.0	
55.00	17.00	10.00	999.000	0.0	0.0	***6
		14.00	1.342	7690.9	5732.8	
55.00	16.00	9.07	999.000	0.0	0.0	***6
		13.07	1.379	6896.6	5000.8	
		14.07	1.328	10014.0	7542.3	
55.00	15.00	8.17	999.000	0.0	0.0	***6
		13.17	1.350	8970.7	6646.0	
		14.17	1.780	16735.7	9402.6	
55.00	14.00	7.23	999.000	0.0	0.0	***6
		12.23	1.387	7883.1	5684.1	
		13.23	1.868	15330.0	8208.5	
		14.00	2.085	21790.1	10450.4	
55.00	13.00	6.23	999.000	0.0	0.0	***6
		12.23	1.941	13326.0	6864.0	
		13.00	2.155	19185.4	8902.6	
55.00	12.00	5.23	999.000	0.0	0.0	***6
		12.00	2.258	16720.3	7404.0	

Table of B.A.

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Center X(m),Y(m)

Y(m)	X(m)	46.00	47.00	48.00	49.00	50.00	51.00
21.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
20.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
19.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
18.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
17.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
16.00	Fs	999.000	999.000	999.000	999.000	999.000	1.020
	R(m)	0.00	0.00	0.00	0.00	0.00	10.88
15.00	Fs	999.000	999.000	999.000	999.000	1.029	1.006
	R(m)	0.00	0.00	0.00	0.00	9.53	8.98
14.00	Fs	999.000	999.000	999.000	999.000	1.035	1.020
	R(m)	0.00	0.00	0.00	0.00	8.64	9.09
13.00	Fs	999.000	999.000	999.000	999.000	1.010	1.041
	R(m)	0.00	0.00	0.00	0.00	7.74	8.19
12.00	Fs	999.000	999.000	999.000	1.006	1.025	1.095
	R(m)	0.00	0.00	0.00	7.40	6.85	8.30

Bearing force Action ratio (Group number = 1 ; LOOP = 0)

Center X(m),Y(m)

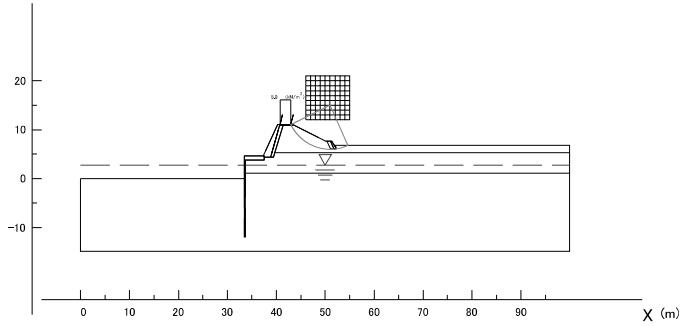
Y(m)	X(m)	52.00	53.00	54.00	55.00
21.00	Fs	999.000	1.095	1.210	1.256
	R(m)	0.00	15.24	15.58	16.81
20.00	Fs	1.016	1.110	1.181	1.270
	R(m)	13.90	14.35	15.60	15.84
19.00	Fs	1.021	1.128	1.188	1.293
	R(m)	13.01	13.44	14.62	14.89
18.00	Fs	1.033	1.118	1.203	1.317
	R(m)	12.11	13.45	13.65	14.94
17.00	Fs	1.053	1.125	1.230	1.342
	R(m)	11.22	12.47	12.69	14.00
16.00	Fs	1.063	1.143	1.259	1.328
	R(m)	11.32	11.48	12.73	14.07
15.00	Fs	1.072	1.173	1.279	1.350
	R(m)	10.35	10.50	12.78	13.17
14.00	Fs	1.096	1.212	1.253	1.387
	R(m)	9.36	10.53	12.84	12.23
13.00	Fs	1.143	1.218	1.341	1.941
	R(m)	9.36	11.56	10.93	12.23
12.00	Fs	1.186	1.242	1.730	2.258
	R(m)	10.37	10.62	11.05	12.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	1.006
Failure circle X(m)	=	51.00
Y(m)	=	15.00
R(m)	=	8.981
Resisting moment(kNm)	=	1428.9
Sliding moment(kNm)	=	1421.0
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



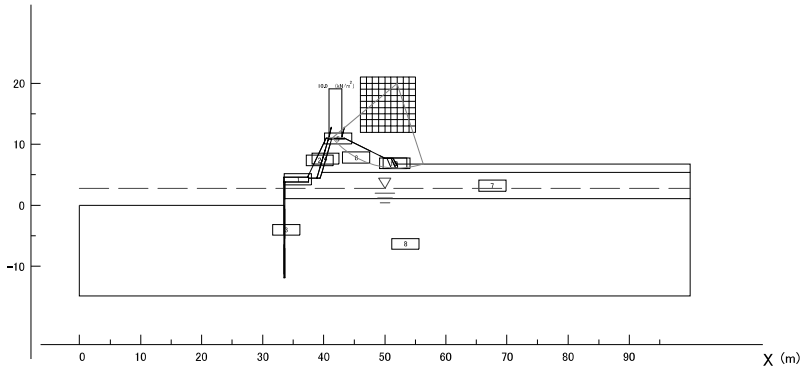
WARNING ***6 An arc does not cut the ground,
or An arc cuts the side of a model. count =100

Test of Embankment Stability

Action number = 1
Action name : normal
Examination at earthquake : It doesn't do.

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	1.593	≧ 1.0 (OK)
Center of arc	X	=	52.00	(m)
	Y	=	20.00	(m)
Radius	R	=	13.900	(m)
Resisting moment	M_R	=	2931.6	(kNm)
Sliding moment	M_D	=	1840.1	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	24.00	24.00	0.00	1000.00	0.00	0.000	0.000
2	24.00	24.00	0.00	1000.00	0.00	0.000	0.000
3	77.00	77.00	0.00	1000.00	0.00	0.000	0.000
4	20.00	19.00	35.00	0.00	0.00	0.000	0.000
5	24.00	24.00	30.00	1.00	0.00	0.000	0.000
6	19.00	18.00	30.00	1.00	0.00	0.000	0.000
7	18.50	17.50	27.00	0.00	0.00	0.000	0.000
8	19.00	18.00	0.00	100.00	0.00	0.000	0.000
9	24.00	24.00	0.00	1000.00	0.00	0.000	0.000
10	20.00	19.00	35.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)

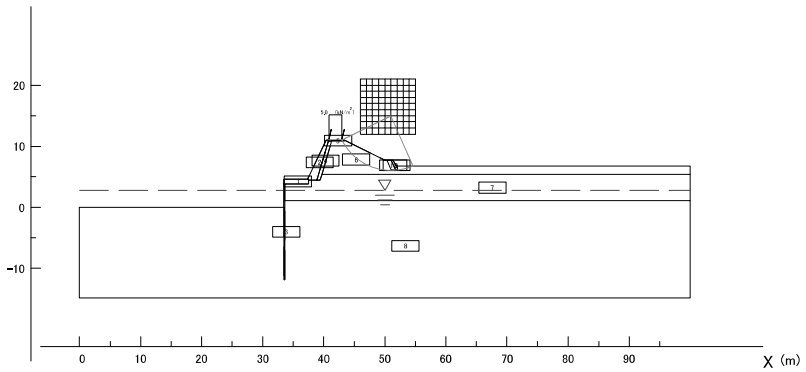
Safety Factor (Ordinary Condition)

Test of Embankment Stability

Action number = 2
Action name : seismic
Examination at earthquake : It does.

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	1.006	≧ 1.0 (OK)
Center of arc	X	=	51.00	(m)
	Y	=	15.00	(m)
Radius	R	=	8.981	(m)
Resisting moment	M_R	=	1428.9	(kNm)
Sliding moment	M_D	=	1421.0	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
2	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
3	77.00	77.00	0.00	1000.00	0.00	0.200	0.000
4	20.00	19.00	35.00	0.00	0.00	0.200	0.000
5	24.00	24.00	30.00	1.00	0.00	0.200	0.000
6	19.00	18.00	30.00	1.00	0.00	0.200	0.000
7	18.50	17.50	27.00	0.00	0.00	0.200	0.000
8	19.00	18.00	0.00	100.00	0.00	0.200	0.000
9	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
10	20.00	19.00	35.00	0.00	0.00	0.200	0.000

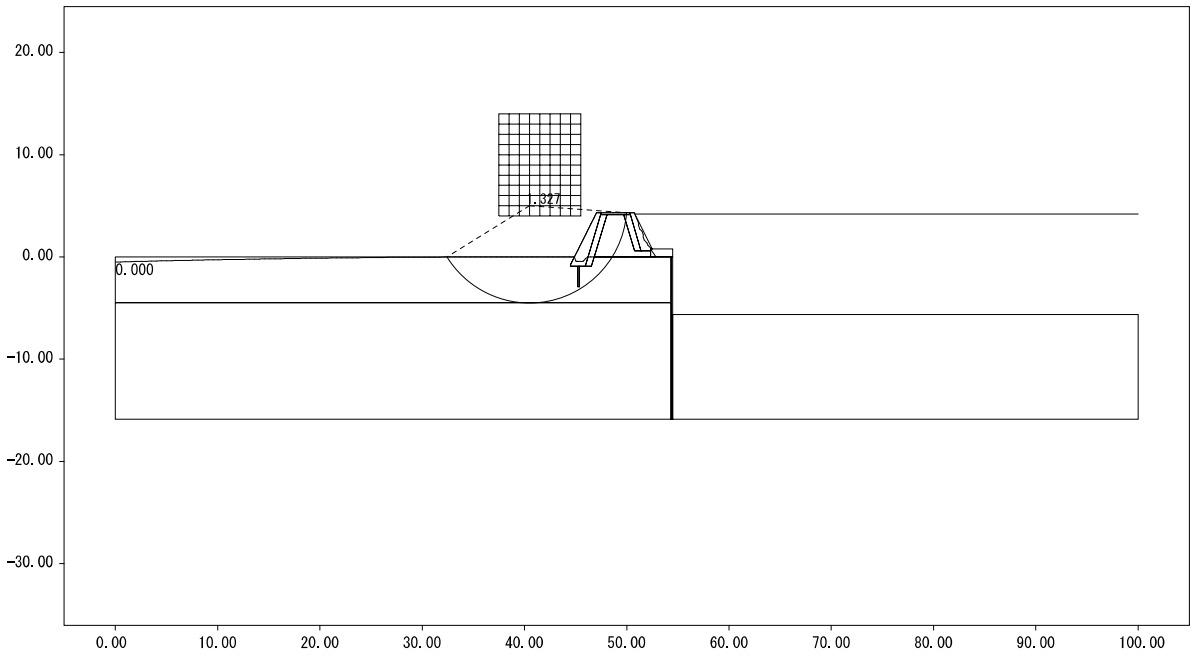
Water unit weight = 10.00 (kN/m³)

Safety Factor (Seismic Condition)

1.2.1 SLOPE STABILITY　ANALYSIS

1.2.1.2　Flood Conditions (Seepage)

(1)　L7+820



(Calculation Result)

Title	L7+820				
Note					
Calculation Method	Slope Stability Calculation+ Seepage Analysis	Output Time	226.000 (hr)	Safety Factor	1.327
Output Items	Soil Layer Diagram, Water Level, Slip Surface				

Slope Stability Analysis considering Seepage

Input Data Sheet

◆ Basic Calculation Conditions

○Title : L7+820

○Note :

○Calculation Type : Seepage Analysis + Slope Stability
○Seepage Type Calculation : Nonstationary Seepage
○ Time Unit : hour
○ Stress Type : Total Stress
○ Safety Factor Formula : Modified Fellenius' Method
○Unit : SI Unit
○Unsaturated Permeability : θ-Kr, θ-ψ

◆ Node

○No. of Nodes : 40

○Node axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	0.000	2	44.889	0.000
3	44.514	-0.752	4	44.514	-0.902
5	45.932	-0.902	6	46.558	-0.902
7	48.063	4.115	8	47.437	4.115
9	47.047	4.315	10	47.497	4.315
11	50.279	4.315	12	50.732	4.315
13	49.716	4.115	14	50.342	4.115
15	50.770	0.600	16	51.396	0.600
17	52.339	0.600	18	52.339	0.800
19	52.489	0.800	20	54.489	0.800
21	54.489	0.000	22	54.339	0.000
23	52.339	0.000	24	54.327	-4.496
25	54.489	-5.616	26	100.000	-5.616
27	100.000	-15.860	28	54.489	-15.860
29	54.339	-15.860	30	0.000	-15.860
31	0.000	-4.496	32	46.829	0.000
33	45.223	-0.902	34	45.223	-2.902
35	45.373	-2.902	36	45.373	-0.902
37	44.400	0.000	38	44.400	-0.500
39	43.900	-0.500	40	43.900	0.000

◆ Soil Layer

○No. of Soil Layers : 12

○Layer No. : 1
○Layer Name : Co
○Nodes : 9, 10, 8, 5, 36, 33, 4, 3, 2

○Layer No. : 2
○Layer Name : Co
○Nodes : 11, 12, 19, 18, 17, 16, 14

○Layer No. : 3
○Layer Name : Co
○Nodes : 17, 18, 19, 20, 21, 22, 23

○Layer No. : 4
○Layer Name : SSP
○Nodes : 25, 28, 29, 24, 22, 21

○Layer No. : 5
○Layer Name : Gr
○Nodes : 8, 7, 32, 6, 5

○Layer No. : 6
○Layer Name : Gr
○Nodes : 13, 14, 16, 15

○Layer No. : 7
○Layer Name : PCCP
○Nodes : 10, 11, 14, 13, 7, 8

○Layer No. : 8
○Layer Name : B
○Nodes : 32, 7, 13, 15, 16, 17, 23

○Layer No. : 9
○Layer Name : As
○Nodes : 1, 2, 3, 4, 33, 34, 35, 36, 5, 6,
: 32, 23, 22, 24, 31

○Layer No. : 10
○Layer Name : Dc
○Nodes : 24, 29, 30, 31

○Layer No. : 11
○Layer Name : Dc
○Nodes : 25, 26, 27, 28

○Layer No. : 12
○Layer Name : SSP
○Nodes : 36, 35, 34, 33

◆ Hole

○No of Holes : 0

◆ Soil Constants

○Layer No. : 1
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c (kN/m2) : 1000.000
○Friction Angle φ (°) : 0.000
○Wet Weight (kN/m3) : 24.000
○Sat. Unit Weight (kN/m3) : 24.000
○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 2
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c (kN/m2) : 1000.000
○Friction Angle φ (°) : 0.000
○Wet Weight (kN/m3) : 24.000
○Sat. Unit Weight (kN/m3) : 24.000
○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 3
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)

1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c (kN/m2) : 1000.000
○Friction Angle φ (°) : 0.000
○Wet Weight (kN/m3) : 24.000
○Sat. Unit Weight (kN/m3) : 24.000
○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 4
○Layer Name : SSP
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 2.000E-006
○Saturated h.c. ky (cm/s) : 2.000E-006
○Specific Storage Coef. Ss (1/m) : 2.000E-008

○Cohesion c (kN/m2) : 1000.000
○Friction Angle φ (°) : 0.000
○Wet Weight (kN/m3) : 77.000
○Sat. Unit Weight (kN/m3) : 77.000
○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 5
○Layer Name : Gr
○Unsaturated Permeability : gravel/sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.049	-12.000
3	0.020	0.020	3	0.050	-1.900
4	0.030	0.030	4	0.056	-1.500
5	0.040	0.040	5	0.068	-1.000
6	0.050	0.050	6	0.078	-0.800
7	0.060	0.060	7	0.084	-0.700
8	0.070	0.080	8	0.090	-0.600
9	0.080	0.090	9	0.100	-0.500
10	0.090	0.110	10	0.112	-0.400
11	0.100	0.130	11	0.126	-0.300
12	0.110	0.160	12	0.136	-0.250
13	0.120	0.190	13	0.150	-0.200
14	0.130	0.230	14	0.164	-0.150
15	0.140	0.290	15	0.178	-0.100

16	0.150	0.360	16	0.190	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-001
○Saturated h.c. ky (cm/s) : 1.000E-001
○Specific Storage Coef. Ss (1/m) : 1.000E-003

○Cohesion c(kN/m2) : 0.000
○Friction Angle φ(°) : 35.000
○Wet Weight(kN/m3) : 19.000
○Sat. Unit Weight(kN/m3) : 20.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 6
○Layer Name : Gr
○Unsaturated Permeability : gravel/sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.049	-12.000
3	0.020	0.020	3	0.050	-1.900
4	0.030	0.030	4	0.056	-1.500
5	0.040	0.040	5	0.068	-1.000
6	0.050	0.050	6	0.078	-0.800
7	0.060	0.060	7	0.084	-0.700
8	0.070	0.080	8	0.090	-0.600
9	0.080	0.090	9	0.100	-0.500
10	0.090	0.110	10	0.112	-0.400
11	0.100	0.130	11	0.126	-0.300
12	0.110	0.160	12	0.136	-0.250
13	0.120	0.190	13	0.150	-0.200
14	0.130	0.230	14	0.164	-0.150
15	0.140	0.290	15	0.178	-0.100
16	0.150	0.360	16	0.190	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-001
○Saturated h.c. ky (cm/s) : 1.000E-001
○Specific Storage Coef. Ss (1/m) : 1.000E-003

○Cohesion c(kN/m2) : 0.000
○Friction Angle φ(°) : 35.000
○Wet Weight(kN/m3) : 19.000
○Sat. Unit Weight(kN/m3) : 20.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 7
○Layer Name : PCCP
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1.000
○Friction Angle φ(°) : 30.000
○Wet Weight(kN/m3) : 24.000
○Sat. Unit Weight(kN/m3) : 24.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 8
○Layer Name : B
○Unsaturated Permeability : gravel/sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)

1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.049	-12.000
3	0.020	0.020	3	0.050	-1.900
4	0.030	0.030	4	0.056	-1.500
5	0.040	0.040	5	0.068	-1.000
6	0.050	0.050	6	0.078	-0.800
7	0.060	0.060	7	0.084	-0.700
8	0.070	0.080	8	0.090	-0.600
9	0.080	0.090	9	0.100	-0.500
10	0.090	0.110	10	0.112	-0.400
11	0.100	0.130	11	0.126	-0.300
12	0.110	0.160	12	0.136	-0.250
13	0.120	0.190	13	0.150	-0.200
14	0.130	0.230	14	0.164	-0.150
15	0.140	0.290	15	0.178	-0.100
16	0.150	0.360	16	0.190	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-003
○Saturated h.c. ky (cm/s) : 1.000E-003
○Specific Storage Coef. Ss (1/m) : 1.000E-005

○Cohesion c(kN/m2) : 1.000
○Friction Angle φ(°) : 30.000
○Wet Weight(kN/m3) : 18.000
○Sat. Unit Weight(kN/m3) : 19.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 9
○Layer Name : As
○Unsaturated Permeability : silty sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.119	-12.000
3	0.020	0.020	3	0.120	-1.900
4	0.030	0.030	4	0.123	-1.500
5	0.040	0.040	5	0.129	-1.000
6	0.050	0.050	6	0.135	-0.800
7	0.060	0.060	7	0.138	-0.700
8	0.070	0.080	8	0.141	-0.600
9	0.080	0.090	9	0.146	-0.500
10	0.090	0.110	10	0.153	-0.400
11	0.100	0.130	11	0.160	-0.300
12	0.110	0.160	12	0.166	-0.250
13	0.120	0.190	13	0.173	-0.200
14	0.130	0.230	14	0.181	-0.150
15	0.140	0.290	15	0.188	-0.100
16	0.150	0.360	16	0.195	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-001
○Saturated h.c. ky (cm/s) : 1.000E-001
○Specific Storage Coef.Ss (1/m) : 1.000E-003

○Cohesion c(kN/m2) : 0.000
○Friction Angle φ(°) : 27.000
○Wet Weight(kN/m3) : 17.500
○Sat. Unit Weight(kN/m3) : 18.500
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 10
○Layer Name : Dc
○Unsaturated Permeability : diluvial clay
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.135	0.000	1	0.135	-900.000
2	0.153	0.000	2	0.153	-300.000
3	0.177	0.000	3	0.177	-100.000
4	0.226	0.000	4	0.226	-20.000
5	0.285	0.000	5	0.285	-5.000
6	0.313	0.000	6	0.313	-3.000
7	0.336	0.000	7	0.336	-2.000
8	0.354	0.000	8	0.354	-1.500
9	0.380	0.001	9	0.380	-1.000
10	0.404	0.001	10	0.404	-0.700
11	0.426	0.003	11	0.426	-0.500
12	0.440	0.004	12	0.440	-0.400
13	0.448	0.006	13	0.448	-0.350
14	0.457	0.008	14	0.457	-0.300
15	0.465	0.011	15	0.465	-0.260
16	0.472	0.013	16	0.472	-0.230
17	0.479	0.017	17	0.479	-0.200
18	0.484	0.020	18	0.484	-0.180
19	0.489	0.024	19	0.489	-0.160
20	0.494	0.030	20	0.494	-0.140
21	0.500	0.037	21	0.500	-0.120
22	0.506	0.047	22	0.506	-0.100
23	0.512	0.062	23	0.512	-0.080
24	0.518	0.085	24	0.518	-0.060
25	0.524	0.123	25	0.524	-0.040
26	0.530	0.199	26	0.530	-0.020
27	0.533	0.283	27	0.533	-0.010
28	0.535	1.000	28	0.535	0.000

○Saturated h.c. kx (cm/s) : 1.000E-006
○Saturated h.c. ky (cm/s) : 1.000E-006
○Specific Storage Coef. Ss (1/m) : 1.000E-008

○Cohesion c (kN/m2) : 100.000
○Friction Angle φ (°) : 0.000
○Wet Weight (kN/m3) : 18.000
○Sat. Unit Weight (kN/m3) : 19.000
○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 11
○Layer Name : Dc
○Unsaturated Permeability : diluvial clay
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.135	0.000	1	0.135	-900.000
2	0.153	0.000	2	0.153	-300.000
3	0.177	0.000	3	0.177	-100.000
4	0.226	0.000	4	0.226	-20.000
5	0.285	0.000	5	0.285	-5.000
6	0.313	0.000	6	0.313	-3.000
7	0.336	0.000	7	0.336	-2.000
8	0.354	0.000	8	0.354	-1.500
9	0.380	0.001	9	0.380	-1.000
10	0.404	0.001	10	0.404	-0.700
11	0.426	0.003	11	0.426	-0.500
12	0.440	0.004	12	0.440	-0.400
13	0.448	0.006	13	0.448	-0.350
14	0.457	0.008	14	0.457	-0.300
15	0.465	0.011	15	0.465	-0.260
16	0.472	0.013	16	0.472	-0.230
17	0.479	0.017	17	0.479	-0.200
18	0.484	0.020	18	0.484	-0.180
19	0.489	0.024	19	0.489	-0.160
20	0.494	0.030	20	0.494	-0.140
21	0.500	0.037	21	0.500	-0.120
22	0.506	0.047	22	0.506	-0.100
23	0.512	0.062	23	0.512	-0.080
24	0.518	0.085	24	0.518	-0.060
25	0.524	0.123	25	0.524	-0.040
26	0.530	0.199	26	0.530	-0.020
27	0.533	0.283	27	0.533	-0.010
28	0.535	1.000	28	0.535	0.000

○Saturated h.c. kx (cm/s) : 1.000E-006
○Saturated h.c. ky (cm/s) : 1.000E-006
○Specific Storage Coef. Ss (1/m) : 1.000E-008

○Cohesion c (kN/m2) : 100.000
○Friction Angle φ (°) : 0.000
○Wet Weight (kN/m3) : 18.000
○Sat. Unit Weight (kN/m3) : 19.000

○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 12
○Layer Name : SSP
○Unsaturated Permeability mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 2.000E-006
○Saturated h.c. ky (cm/s) : 2.000E-006
○Specific Storage Coef. Ss (1/m) : 2.000E-008

○Cohesion c (kN/m2) : 1000.000
○Friction Angle φ (°) : 0.000
○Wet Weight (kN/m3) : 77.000
○Sat. Unit Weight (kN/m3) : 77.000
○Water Unit Weight (kN/m3) : 9.807

◆ FEM Elements

○Soil Layer
Elements Size

Layer No.	xDirection (m)	yDirection (m)
1	0.500	0.500
2	0.500	0.500
3	0.500	0.500
4	0.500	0.500
5	0.500	0.500
6	0.500	0.500
7	0.500	0.500
8	0.500	0.500
9	0.500	0.500
10	1.000	1.000
11	1.000	1.000
12	0.500	0.500

○Element Shape : Triangle + Square

○Partial Area

No	Min. x axis (m)	Min. y axis (m)	Max. x axis (m)	Max. y axis (m)	Element Size xDirection (m)	Element Size yDirection (m)
1	44.000	-0.500	44.500	0.000	0.500	0.500

○Internal Node : 37, 38, 39, 40

◆ Initial Water Level

○ Water Level : 4

No.	x axis (m)	y axis (m)
1	0.000	-0.500
2	54.339	-0.500
3	54.339	-2.300
4	100.000	-2.300

◆ Seepage Surface

○SNo. of eepage Surface : 1

○Seepage Surface No : 1
○Nodes : 1, 2, 9, 10, 11, 12, 19, 20, 21, 25,
: 26

◆ Water Level Fix

○ Water Level Fixed : 1

○ Water Level Fix No : 1
○ Water Level (m) : -0.500
○Nodes : 1, 31, 30

◆ Water Level Changing Point

○ No. of Water Level Changing Points

○ Water Level Changing Point :
○Nodes : 11, 12, 19, 20, 21, 25, 26

○temporal variation

No	Time (hr)	Water Level (m)
1	0.000	-2.300
2	210.000	-2.000
3	225.000	4.190
4	226.000	4.190
5	253.000	-2.300
6	270.000	-2.300

◆ Rain Penetration Line

○No. of Rain Penetration Line 1

○Rain Penetration Line No. : 1
○Nodes : 1, 2, 9, 10, 11, 12, 19, 20, 21, 25,
: 26

○temporal variation

No	Time(hr)	Rainfall (mm)
1	200.000	1.000
2	226.000	10.000
3	270.000	0.000

◆ Repeat Calculation

○Timestep
- Min. : 0.010
- Max. : 10.000
- Allowable Error (m) : 0.100
- Max. Repeat : 10

◆ Slip Surface Conditions

○Merginal Slip Surface (Center・Dianeter)

○No. of Search Area : 1

No	x axis Min.(m)	x axis Max.(m)	x axis Variation(m)	y axis Min.(m)	y axis Max.(m)	y axis Variation(m)
1	37.500	45.500	1.000	4.000	14.000	1.000

No	Dianeter Min.(m)	Dianeter Max.(m)	Dianeter Variation(m)
1	5.000	25.000	1.000

○Slip Surface Limit

	x axis(m)	y axis(m)
must cut line [ON]		
1	47.497	4.315
2	50.279	4.315
must not cut line [ON]		
1	45.223	-0.902
2	45.223	-2.902

○Max. Depth(m) : 0.000
○Search Time : 1
○Slice Width(m) : 1.000

◆ Load

○No. of Loads : 1

No	Left end(m)	Right end(m)	Load(kN/m2)
1	48.000	50.000	5.000

◆ Tension Crack

○No. of Tension Cracks : 0

◆ Seismic Force

○Horizontal Seismic Coef. : 0.000
○Vertical Seismic Coef. : 0.000

◆ Output Time

: 7

○Output Time

No	Seepage Cal.	Stability Cal.
1	10.000	◎
2	100.000	◎
3	210.000	◎
4	225.000	◎
5	226.000	◎
6	253.000	◎
7	270.000	◎

Slope Stability Analysis considering Seepage

Slope Stability Calculation

○ 1. Input Data

◆ Title

L7+820

◆ Calculation Type

Seepage Analysis + Slope Stability Calculation

◆ Safety Factor Formula

Modified Fellenius' Method

◆ Unit

SI Unit

◆ Node

○No. of Nodes : 40

○Node axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	0.000	0.000	2	44.889	0.000
3	44.514	-0.752	4	44.514	-0.902
5	45.932	-0.902	6	46.558	-0.902
7	48.063	4.115	8	47.437	4.115
9	47.047	4.315	10	47.497	4.315
11	50.279	4.315	12	50.732	4.315
13	49.716	4.115	14	50.342	4.115
15	50.770	0.600	16	51.396	0.600
17	52.339	0.600	18	52.339	0.800
19	52.489	0.800	20	54.489	0.800
21	54.489	0.000	22	54.339	0.000
23	52.339	0.000	24	54.327	-4.496
25	54.489	-5.616	26	100.000	-5.616
27	100.000	-15.860	28	54.489	-15.860
29	54.339	-15.860	30	0.000	-15.860
31	0.000	-4.496	32	46.829	0.000
33	45.223	-0.902	34	45.223	-2.902
35	45.373	-2.902	36	45.373	-0.902
37	44.400	0.000	38	44.400	-0.500
39	43.900	-0.500	40	43.900	0.000

◆ Soil Layer

○No. of Soil Layers : 12

○Layer No. : 1
○Layer Name : Co
○Nodes : 9, 10, 8, 5, 36, 33, 4, 3, 2

○Layer No. : 2
○Layer Name : Co
○Nodes : 11, 12, 19, 18, 17, 16, 14

○Layer No. : 3
○Layer Name : Co
○Nodes : 17, 18, 19, 20, 21, 22, 23

: 4
: SSP
: 25, 28, 29, 24, 22, 21

○Layer No. Layer
○Name : 5
: Gr
○Nodes : 8, 7, 32, 6, 5

○Layer No. Layer : 6
○Name : Gr
: 13, 14, 16, 15
○Nodes
: 7
○Layer No. Layer : PCCP
○Name : 10, 11, 14, 13, 7, 8

○Nodes : 8
: B
○Layer No. : 32, 7, 13, 15, 16, 17, 23
○Layer Name
○Nodes : 9

○Layer Name : As
○Nodes : 1, 2, 3, 4, 33, 34, 35, 36, 5, 6,
: 32, 23, 22, 24, 31

○Layer No. : 10
○Layer Name : Dc
○Nodes : 24, 29, 30, 31

○Layer No. : 11
○Layer Name : Dc
○Nodes : 25, 26, 27, 28

○Layer No. : 12
○Layer Name : SSP
○Nodes : 36, 35, 34, 33

◆ Hole

○No. of Holes : 0

◆ Soil Constants

○Soil Layer :Layer 1
Cohesion (kN/m2) : Co
: 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer :Layer 2
: Co
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer :Layer 3
Cohesion (kN/m2) : Co
Friction Angle (°) : 1000.00
: 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer :Layer 4
: SSP
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 77.00
Sat. Unit Weight (kN/m3) : 77.00

○Soil Layer :Layer 5
Cohesion (kN/m2) : Gr
Friction Angle (°) : 0.00
: 35.00
Wet Weight (kN/m3) : 19.00
Sat. Unit Weight (kN/m3) : 20.00

○Soil Layer :Layer 6
Cohesion (kN/m2) : Gr
Friction Angle (°) : 0.00
: 35.00
Wet Weight (kN/m3) : 19.00
Sat. Unit Weight (kN/m3) : 20.00

○Soil Layer :Layer 7
Cohesion (kN/m2) : PCCP
: 1.00
Friction Angle (°) : 30.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer :Layer 8
Cohesion (kN/m2) : B
Friction Angle (°) : 1.00
: 30.00
Wet Weight (kN/m3) : 18.00
Sat. Unit Weight (kN/m3) : 19.00

○Soil Layer :Layer 9
Cohesion (kN/m2) : As
Friction Angle (°) : 0.00
: 27.00
Wet Weight (kN/m3) : 17.50
Sat. Unit Weight (kN/m3) : 18.50

○Soil Layer :Layer 10
Cohesion (kN/m2) : Dc
: 100.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 18.00
Sat. Unit Weight (kN/m3) : 19.00

○Soil Layer :Layer 11
Cohesion (kN/m2) : Dc
Friction Angle (°) : 100.00
: 0.00
Wet Weight (kN/m3) : 18.00
Sat. Unit Weight (kN/m3) : 19.00

○Soil Layer :Layer 12
Cohesion (kN/m2) : SSP
Friction Angle (°) : 1000.00
Wet Weight (kN/m3) : 77.00 : 0.00

Sat. Unit Weight (kN/m3) : 77.00

◆ Slip SurfaceConditions

○Merginal Slip Surface (Center・Dianeter)

○Search Area : 1

No	x axis Min. (m)	x axis Max. (m)	x axis Variation (m)	y axis Min. (m)	y axis Max. (m)	y axis Variation (m)
1	37.500	45.500	1.000	4.000	14.000	1.000

No	Dianeter Min. (m)	Dianeter Max. (m)	Dianeter Variation (m)
1	5.000	25.000	1.000

○Slip Surface
Limit x axis (m) y axis (m) Search Area 1
must cut line [ON]
1 47.497 4.315
2 50.279 4.315
must not cut line [ON]
1 45.223 -0.902
2 45.223 -2.902

◆ Calculation Time

○Time to conduct Stability Cal. : 7

no	Time (hour)	no	Time (hour)	no	Time (hour)	no	Time (hour)	no	Time (hour)
1	10.000	2	100.000	3	210.000	4	225.000	5	226.000

◆ Load

○No. of Loads : 1

No	Left end (m)	Right end (m)	Load (kN/m2)
1	48.000	50.000	5.000

◆ Tension Crack

○No. of Tension Crack : 0

◆ Seismic Force

○Horizontal Seismic Coef. : 0.000
○Vertical Seismic Coef. : 0.000

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○2. Calculation Result

◆ Min.Safety Factor and Slip Surface

◆ At 10.000 (hr) Calculation Result

○Safety Factor and Slip Surface
・Safety Factor : 1.609
・Resistance Force (kN) : 395.403
・Sliding : 245.682 (= 236.858 + 83.827 / 9.500)
○ Slip Surface axis
axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	32.422	0.000	2	32.644	-0.341	3	32.720	-0.451
4	33.138	-1.004	5	33.633	-1.564	6	34.127	-2.046
7	34.622	-2.463	8	35.117	-2.827	9	35.611	-3.146
10	36.106	-3.423	11	36.600	-3.663	12	37.095	-3.869
13	37.590	-4.043	14	38.084	-4.188	15	38.579	-4.304
16	39.073	-4.392	17	39.568	-4.454	18	40.063	-4.490
19	40.224	-4.496	20	40.557	-4.500	21	40.776	-4.496
22	41.052	-4.484	23	41.546	-4.442	24	42.041	-4.374
25	42.536	-4.279	26	43.030	-4.157	27	43.525	-4.006
28	44.019	-3.824	29	44.514	-3.610	30	44.659	-3.541
31	44.889	-3.425	32	45.223	-3.243	33	45.373	-3.155
34	45.653	-2.981	35	45.932	-2.794	36	46.064	-2.700
37	46.245	-2.566	38	46.558	-2.318	39	46.693	-2.204
40	46.829	-2.085	41	47.047	-1.884	42	47.437	-1.491

43	47.497	-1.426	44	47.780	-1.103	45	48.000	-0.831
46	48.063	-0.749	47	48.279	-0.453	48	48.476	-0.160
49	48.578	0.000	50	48.890	0.543	51	49.303	1.428
52	49.716	2.694	53	49.888	3.543	54	49.959	4.115
55	49.975	4.315						

○Arc Center(m) : (40.500, 5.000)
○Arc Diameter(m) : 9.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle(°)	Slice Bottom Pressure(kN/m2)	Slice Bottom Water Length(m)
0.221	0.661	-57.017	0.000	0.407
0.076	0.527	-55.387	0.000	0.134
0.419	5.448	-52.891	2.714	0.694
0.495	11.530	-48.545	8.175	0.747
0.495	16.293	-44.210	13.282	0.690
0.495	20.405	-40.176	17.691	0.647
0.495	23.982	-36.371	21.526	0.614
0.495	27.104	-32.745	24.874	0.588
0.495	29.827	-29.262	27.793	0.567
0.495	32.193	-25.893	30.331	0.550
0.495	34.235	-22.619	32.519	0.536
0.495	35.975	-19.422	34.386	0.524
0.495	37.434	-16.286	35.950	0.515
0.495	38.626	-13.200	37.228	0.508
0.495	39.562	-10.152	38.232	0.502
0.495	40.251	-7.133	38.970	0.498
0.495	40.697	-4.135	39.449	0.496
0.162	13.372	-2.151	39.654	0.162
0.333	27.548	-0.659	39.702	0.333
0.218	18.080	1.004	39.702	0.218
0.276	22.814	2.496	39.624	0.276
0.495	40.615	4.827	39.360	0.496
0.495	40.113	7.830	38.822	0.499
0.495	39.368	10.854	38.023	0.504
0.495	38.374	13.910	36.956	0.510
0.495	37.121	17.006	35.613	0.517
0.495	35.598	20.155	33.981	0.527
0.495	33.790	23.369	32.043	0.539
0.145	9.788	25.480	30.603	0.161
0.230	15.591	26.741	29.562	0.257
0.334	24.935	28.664	27.955	0.381
0.150	30.115	30.336	26.566	0.174
0.280	25.618	31.853	25.284	0.329
0.279	28.433	33.860	23.617	0.337
0.132	14.269	35.363	22.375	0.162
0.181	20.119	36.531	21.337	0.225
0.313	36.103	38.415	19.508	0.399
0.135	16.016	40.152	17.732	0.177
0.136	16.336	41.230	16.589	0.181
0.218	26.588	42.669	15.019	0.296
0.390	45.091	45.234	12.105	0.554
0.060	6.443	47.170	9.860	0.088
0.283	29.214	48.730	7.961	0.429
0.220	21.315	51.080	5.043	0.350
0.063	5.868	52.448	3.305	0.103
0.216	19.350	53.865	1.452	0.366
0.197	16.607	56.034	0.000	0.353
0.101	8.148	57.671	0.000	0.190
0.312	23.065	60.131	0.000	0.626
0.413	25.264	64.965	0.000	0.977
0.413	17.262	71.933	0.000	1.333
0.172	3.950	78.566	0.000	0.865
0.071	0.728	82.916	0.000	0.577
0.017	0.040	85.260	0.000	0.201

○ Water Level axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	0.000	-0.500	2	0.495	-0.499	3	0.989	-0.497
4	1.484	-0.496	5	1.978	-0.495	6	2.473	-0.494
7	2.968	-0.492	8	3.462	-0.491	9	3.957	-0.490
10	4.451	-0.489	11	4.946	-0.488	12	5.441	-0.487
13	5.935	-0.486	14	6.430	-0.485	15	6.924	-0.484
16	7.419	-0.483	17	7.914	-0.482	18	8.408	-0.481
19	8.903	-0.480	20	9.397	-0.479	21	9.892	-0.478
22	10.387	-0.477	23	10.881	-0.476	24	11.376	-0.475
25	11.870	-0.474	26	12.365	-0.473	27	12.860	-0.472
28	13.354	-0.472	29	13.849	-0.471	30	14.343	-0.470
31	14.838	-0.469	32	15.333	-0.468	33	15.827	-0.468
34	16.322	-0.467	35	16.816	-0.466	36	17.311	-0.466
37	17.806	-0.465	38	18.300	-0.464	39	18.795	-0.463
40	19.289	-0.463	41	19.784	-0.462	42	20.279	-0.462
43	20.773	-0.461	44	21.268	-0.460	45	21.762	-0.460
46	22.257	-0.459	47	22.752	-0.459	48	23.246	-0.458
49	23.741	-0.458	50	24.235	-0.457	51	24.730	-0.457
52	25.225	-0.456	53	25.719	-0.456	54	26.214	-0.455
55	26.708	-0.455	56	27.203	-0.455	57	27.698	-0.454
58	28.192	-0.454	59	28.687	-0.453	60	29.181	-0.453
61	29.676	-0.453	62	30.171	-0.452	63	30.665	-0.452
64	31.160	-0.452	65	31.654	-0.452	66	32.149	-0.451
67	32.644	-0.451	68	33.138	-0.451	69	33.633	-0.451
70	34.127	-0.451	71	34.622	-0.450	72	35.117	-0.450
73	35.611	-0.450	74	36.106	-0.450	75	36.600	-0.450
76	37.095	-0.450	77	37.590	-0.450	78	38.084	-0.450
79	38.579	-0.450	80	39.073	-0.450	81	39.568	-0.450
82	40.063	-0.450	83	40.557	-0.450	84	41.052	-0.450
85	41.546	-0.450	86	42.041	-0.450	87	42.536	-0.450
88	43.030	-0.450	89	43.525	-0.450	90	44.019	-0.450
91	44.514	-0.450	92	44.889	-0.477	93	45.223	-0.490
94	45.373	-0.490	95	45.653	-0.490	96	45.932	-0.469
97	46.245	-0.453	98	46.558	-0.453	99	46.829	-0.453
100	47.047	-0.453	101	47.437	-0.453	102	47.497	-0.453
103	47.780	-0.453	104	48.063	-0.453	105	48.476	-0.453

106	48.890	-0.453	107	49.303	-0.453	108	49.716	-0.453
109	49.998	-0.453	110	50.279	-0.453	111	50.342	-0.453
112	50.732	-0.454	113	50.770	-0.454	114	51.083	-0.454
115	51.396	-0.454	116	51.868	-0.454	117	52.339	-0.454
118	52.489	-0.454	119	52.949	-0.454	120	53.408	-0.454
121	53.868	-0.454	122	54.327	-0.454	123	54.339	-0.466
124	54.489	-2.286	125	100.000	-2.286			

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◆ At 100.000(hr) Calculation Result

○Safety Factor and Slip Surface
- Safety Factor : 1.608
- Resistance Force(kN) : 394.989
- Sliding Force(kN) : 245.683 (= 236.859 + 83.827 / 9.500)

○Slip Surface axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	32.422	0.000	2	32.644	-0.341	3	32.715	-0.445
4	33.138	-1.004	5	33.633	-1.564	6	34.127	-2.046
7	34.622	-2.463	8	35.117	-2.827	9	35.611	-3.146
10	36.106	-3.423	11	36.600	-3.663	12	37.095	-3.869
13	37.590	-4.043	14	38.084	-4.188	15	38.579	-4.304
16	39.073	-4.392	17	39.568	-4.454	18	40.063	-4.490
19	40.224	-4.496	20	40.557	-4.500	21	40.776	-4.496
22	41.052	-4.484	23	41.546	-4.442	24	42.041	-4.374
25	42.536	-4.279	26	43.030	-4.157	27	43.525	-4.006
28	44.019	-3.824	29	44.514	-3.610	30	44.662	-3.540
31	44.889	-3.425	32	45.223	-3.243	33	45.373	-3.155
34	45.653	-2.981	35	45.932	-2.794	36	46.066	-2.699
37	46.245	-2.566	38	46.558	-2.318	39	46.696	-2.202
40	46.829	-2.085	41	47.047	-1.884	42	47.437	-1.491
43	47.497	-1.426	44	47.780	-1.103	45	48.000	-0.831
46	48.063	-0.749	47	48.285	-0.444	48	48.476	-0.160
49	48.578	0.000	50	48.890	0.543	51	49.303	1.428
52	49.716	2.694	53	49.888	3.543	54	49.959	4.115
55	49.975	4.315						

○Arc Center(m) : (40.500, 5.000)
○Arc Diameter(m) : 9.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle(°)	Slice Bottom Pressure(kN/m2)	Slice Bottom Water Length(m)
0.221	0.661	-57.017	0.000	0.407
0.072	0.493	-55.410	0.000	0.126
0.423	5.483	-52.914	2.745	0.701
0.495	11.533	-48.545	8.237	0.747
0.495	16.296	-44.210	13.344	0.690
0.495	20.408	-40.176	17.754	0.647
0.495	23.985	-36.371	21.590	0.614
0.495	27.107	-32.745	24.939	0.588
0.495	29.830	-29.262	27.859	0.567
0.495	32.197	-25.893	30.397	0.550
0.495	34.238	-22.619	32.587	0.536
0.495	35.979	-19.422	34.454	0.524
0.495	37.438	-16.286	36.019	0.515
0.495	38.630	-13.200	37.298	0.508
0.495	39.566	-10.152	38.302	0.502
0.495	40.254	-7.133	39.041	0.498
0.495	40.701	-4.135	39.521	0.496
0.162	13.373	-2.151	39.726	0.162
0.333	27.550	-0.659	39.775	0.333
0.218	18.081	1.004	39.776	0.218
0.276	22.816	2.496	39.698	0.276
0.495	40.619	4.827	39.435	0.496
0.495	40.117	7.830	38.897	0.499
0.495	39.372	10.854	38.098	0.504
0.495	38.378	13.910	37.033	0.510
0.495	37.125	17.006	35.691	0.517
0.495	35.602	20.155	34.059	0.527
0.495	33.794	23.369	32.121	0.539
0.148	9.991	25.490	30.665	0.164
0.227	15.389	26.751	29.602	0.254
0.334	24.935	28.664	27.981	0.381
0.150	30.115	30.336	26.583	0.174
0.280	25.618	31.853	25.301	0.329
0.279	28.433	33.860	23.654	0.337
0.134	14.509	35.371	22.431	0.165
0.179	19.880	36.539	21.410	0.223
0.313	36.105	38.415	19.597	0.399
0.138	16.344	40.163	17.810	0.180
0.133	16.011	41.241	16.667	0.177
0.218	26.590	42.669	15.108	0.296
0.390	45.095	45.234	12.195	0.554
0.060	6.443	47.170	9.949	0.088
0.283	29.216	48.730	8.050	0.429
0.220	21.317	51.080	5.132	0.350
0.063	5.868	52.448	3.394	0.103
0.222	19.905	53.899	1.496	0.378
0.191	16.053	56.068	0.000	0.342
0.101	8.148	57.671	0.000	0.190
0.312	23.065	60.131	0.000	0.626
0.413	25.264	64.965	0.000	0.977
0.413	17.262	71.933	0.000	1.333
0.172	3.950	78.566	0.000	0.865
0.071	0.728	82.916	0.000	0.577
0.017	0.040	85.260	0.000	0.201

○ Water Level axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	0.000	-0.500	2	0.495	-0.499	3	0.989	-0.497
4	1.484	-0.496	5	1.978	-0.494	6	2.473	-0.493
7	2.968	-0.492	8	3.462	-0.491	9	3.957	-0.489
10	4.451	-0.488	11	4.946	-0.487	12	5.441	-0.486
13	5.935	-0.485	14	6.430	-0.483	15	6.924	-0.482
16	7.419	-0.481	17	7.914	-0.480	18	8.408	-0.479
19	8.903	-0.478	20	9.397	-0.477	21	9.892	-0.476
22	10.387	-0.475	23	10.881	-0.474	24	11.376	-0.473
25	11.870	-0.472	26	12.365	-0.471	27	12.860	-0.470
28	13.354	-0.469	29	13.849	-0.468	30	14.343	-0.467
31	14.838	-0.466	32	15.333	-0.465	33	15.827	-0.465
34	16.322	-0.464	35	16.816	-0.463	36	17.311	-0.462
37	17.806	0.461	38	18.300	-0.461	39	18.795	-0.460
40	19.289	-0.459	41	19.784	-0.458	42	20.279	-0.458
43	20.773	-0.457	44	21.268	-0.456	45	21.762	-0.456
46	22.257	-0.455	47	22.752	-0.454	48	23.246	-0.454
49	20.741	-0.453	50	24.235	-0.453	51	24.730	-0.452
52	25.225	-0.451	53	25.719	-0.451	54	26.214	-0.450
55	26.708	-0.450	56	27.203	-0.449	57	27.698	-0.449
58	28.192	-0.448	59	28.687	-0.448	60	29.181	-0.448
61	29.676	-0.447	62	30.171	-0.447	63	30.665	-0.446
64	31.160	-0.446	65	31.654	-0.446	66	32.149	-0.445
67	32.644	-0.445	68	33.138	-0.445	69	33.633	-0.444
70	34.127	-0.444	71	34.622	-0.444	72	35.117	-0.444
73	35.611	-0.443	74	36.106	-0.443	75	36.600	-0.443
76	37.095	-0.443	77	37.590	-0.443	78	38.084	-0.443
79	38.579	-0.442	80	39.073	-0.442	81	39.568	-0.442
82	40.063	-0.442	83	40.557	-0.442	84	41.052	-0.442
85	41.546	-0.442	86	42.041	-0.442	87	42.536	-0.442
88	43.030	-0.442	89	43.525	-0.442	90	44.019	-0.442
91	44.514	-0.442	92	44.889	-0.474	93	45.223	-0.488
94	45.373	-0.488	95	45.653	-0.488	96	45.932	-0.463
97	46.245	-0.444	98	46.558	-0.444	99	46.829	-0.444
100	47.047	-0.444	101	47.437	-0.444	102	47.497	-0.444
103	47.780	-0.444	104	48.063	-0.444	105	48.476	-0.444
106	48.890	-0.444	107	49.303	-0.444	108	49.716	-0.444
109	49.998	-0.444	110	50.279	-0.444	111	50.342	-0.444
112	50.732	-0.444	113	50.770	-0.444	114	51.083	-0.444
115	51.396	-0.444	116	51.868	-0.444	117	52.339	-0.445
118	52.489	-0.445	119	52.949	-0.445	120	53.408	-0.445
121	53.868	-0.445	122	54.327	-0.445	123	54.339	-0.448
124	54.489	-2.157	125	100.000	-2.157			

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◆ At 210.000(hr) Calculation Result

○Safety Factor and Slip Surface

- Safety Factor : 1.525
- Resistance Force(kN) : 374.164
- Sliding Force(kN) : 245.359 (= 236.535 + 83.827 / 9.500)

○Slip Surface axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	32.422	0.000	2	32.470	-0.076	3	32.644	-0.341
4	33.138	-1.004	5	33.633	-1.564	6	34.127	-2.046
7	34.622	-2.463	8	35.117	-2.827	9	35.611	-3.146
10	36.106	-3.423	11	36.600	-3.663	12	37.095	-3.869
13	37.590	-4.043	14	38.084	-4.188	15	38.579	-4.304
16	39.073	-4.392	17	39.568	-4.454	18	40.063	-4.490
19	40.224	-4.496	20	40.557	-4.500	21	40.776	-4.496
22	41.052	-4.484	23	41.546	-4.442	24	42.041	-4.374
25	42.536	-4.279	26	43.030	-4.157	27	43.525	-4.006
28	44.019	-3.824	29	44.514	-3.610	30	44.823	-3.460
31	44.889	-3.425	32	45.223	-3.243	33	45.373	-3.155
34	45.653	-2.981	35	45.932	-2.794	36	46.159	-2.631
37	46.245	-2.566	38	46.558	-2.318	39	46.798	-2.112
40	46.829	-2.085	41	47.047	-1.884	42	47.437	-1.491
43	47.497	-1.426	44	47.780	-1.103	45	48.000	-0.831
46	48.063	-0.749	47	48.476	-0.160	48	48.513	-0.104
49	48.578	0.000	50	48.890	0.543	51	49.303	1.428
52	49.716	2.694	53	49.888	3.543	54	49.959	4.115
55	49.975	4.315						

○Arc Center(m) : (40.500, 5.000)
○Arc Diameter(m) : 9.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle(°)	Slice Bottom Pressure(kN/m2)	Slice Bottom Water Length(m)
0.048	0.032	-57.972	0.000	0.090
0.174	0.657	-56.746	1.302	0.317
0.495	6.119	-53.295	5.865	0.828
0.495	11.717	-48.545	11.879	0.747
0.495	16.480	-44.210	16.997	0.690
0.495	20.593	-40.176	21.417	0.647
0.495	24.171	-36.371	25.262	0.614
0.495	27.293	-32.745	28.618	0.588
0.495	30.016	-29.262	31.545	0.567
0.495	32.383	-25.893	34.088	0.550
0.495	34.425	-22.619	36.282	0.536
0.495	36.165	-19.422	38.152	0.524
0.495	37.625	-16.286	39.719	0.515
0.495	38.816	-13.200	40.999	0.508
0.495	39.752	-10.152	42.003	0.502
0.495	40.441	-7.133	42.740	0.498
0.495	40.887	-4.135	43.218	0.496
0.162	13.434	-2.151	43.421	0.162
0.333	27.676	-0.659	43.468	0.333
0.218	18.164	1.004	43.466	0.218
0.276	22.920	2.496	43.386	0.276
0.495	40.805	4.827	43.118	0.496
0.495	40.302	7.830	42.575	0.499
0.495	39.557	10.854	41.770	0.504
0.495	38.562	13.910	40.698	0.510
0.495	37.310	17.006	39.349	0.517
0.495	35.787	20.155	37.711	0.527
0.495	33.978	23.369	35.769	0.539
0.309	20.939	26.030	33.672	0.344
0.066	4.521	27.291	32.391	0.075
0.334	24.935	28.664	29.784	0.381
0.150	30.115	30.336	26.981	0.174
0.280	25.618	31.853	25.699	0.329
0.279	28.433	33.860	24.827	0.337
0.227	24.732	35.717	24.586	0.279
0.086	9.698	36.884	24.267	0.108
0.313	36.212	38.415	22.951	0.399
0.240	28.749	40.574	20.724	0.317
0.031	3.695	41.652	19.581	0.041
0.218	26.665	42.669	18.462	0.296
0.390	45.228	45.234	15.547	0.554
0.060	6.464	47.170	13.300	0.088
0.283	29.313	48.730	11.399	0.429
0.220	21.392	51.080	8.479	0.350
0.063	5.890	52.448	6.739	0.103
0.413	36.027	54.929	3.447	0.719
0.036	2.963	57.302	0.279	0.068
0.065	5.186	57.874	0.000	0.122
0.312	23.065	60.131	0.000	0.626
0.413	25.264	64.965	0.000	0.977
0.413	17.262	71.933	0.000	1.333
0.172	3.950	78.566	0.000	0.865
0.071	0.728	82.916	0.000	0.577
0.017	0.040	85.260	0.000	0.201

46	22.257	-0.140	47	22.752	-0.136	48	23.246	-0.132
49	23.741	-0.127	50	24.235	-0.123	51	24.730	-0.119
52	25.225	-0.116	53	25.719	-0.112	54	26.214	-0.108
55	26.708	-0.105	56	27.203	-0.102	57	27.698	-0.099
58	28.192	-0.096	59	28.687	-0.093	60	29.181	-0.090
61	29.676	-0.088	62	30.171	-0.086	63	30.665	-0.083
64	31.160	-0.081	65	31.654	-0.079	66	32.149	-0.077
67	32.644	-0.076	68	33.138	-0.074	69	33.633	-0.072
70	34.127	-0.071	71	34.622	-0.070	72	35.117	-0.069
73	35.611	-0.068	74	36.106	-0.067	75	36.600	-0.066
76	37.095	-0.066	77	37.590	-0.065	78	38.084	-0.065
79	38.579	-0.065	80	39.073	-0.065	81	39.568	-0.065
82	40.063	-0.065	83	40.557	-0.066	84	41.052	-0.066
85	41.546	-0.067	86	42.041	-0.067	87	42.536	-0.068
88	43.030	-0.069	89	43.525	-0.069	90	44.019	-0.070
91	44.514	-0.070	92	44.889	-0.146	93	45.223	-0.448
94	45.653	-0.448	95	45.932	-0.264	96	46.245	-0.102
97	46.558	-0.102	98	46.829	-0.102	99	47.047	-0.102
100	47.437	-0.102	101	47.780	-0.102	102	48.063	-0.103
103	48.476	-0.103	104	48.890	-0.104	105	49.303	-0.105
106	49.716	-0.106	107	49.998	-0.106	108	50.279	-0.106
109	50.342	-0.106	110	50.732	-0.107	111	50.770	-0.107
112	51.083	-0.108	113	51.396	-0.108	114	51.868	-0.109
115	52.339	-0.109	116	52.489	-0.109	117	52.949	-0.110
118	53.408	-0.110	119	53.868	-0.111	120	54.327	-0.111
121	54.339	-0.112	122	54.489	-2.000	123	100.000	-2.000

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◆ At 225.000(hr) Calculation Result

○Safety Factor and Slip Surface

- Safety Factor : 1.327
- Resistance Force(kN) : 325.707
- Sliding Force(kN) : 245.432 (= 236.608 + 83.827 / 9.500)

○Slip Surface axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	32.422	0.000	2	32.431	-0.014	3	32.644	-0.341
4	33.138	-1.004	5	33.633	-1.564	6	34.127	-2.046
7	34.622	-2.463	8	35.117	-2.827	9	35.611	-3.146
10	36.106	-3.423	11	36.600	-3.663	12	37.095	-3.869
13	37.590	-4.043	14	38.084	-4.188	15	38.798	-4.346
16	39.511	-4.448	17	40.224	-4.496	18	40.776	-4.496
19	41.710	-4.423	20	42.645	-4.255	21	43.579	-3.987
22	44.514	-3.610	23	44.889	-3.425	24	45.223	-3.243
25	45.373	-3.155	26	45.653	-2.981	27	45.932	-2.794
28	46.192	-2.606	29	46.245	-2.566	30	46.558	-2.318
31	46.829	-2.085	32	46.829	-2.085	33	47.047	-1.884
34	47.437	-1.491	35	47.497	-1.426	36	47.780	-1.103

○ Water Level axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	0.000	-0.500	2	0.495	-0.488	3	0.989	-0.476
4	1.484	-0.464	5	1.978	-0.453	6	2.473	-0.442
7	2.968	-0.431	8	3.462	-0.421	9	3.957	-0.411
10	4.451	-0.401	11	4.946	-0.391	12	5.441	-0.381
13	5.935	-0.371	14	6.430	-0.362	15	6.924	-0.352
16	7.419	-0.343	17	7.914	-0.334	18	8.408	-0.326
19	8.903	-0.317	20	9.397	-0.308	21	9.892	-0.300
22	10.387	-0.292	23	10.881	-0.284	24	11.376	-0.276
25	11.870	-0.268	26	12.365	-0.260	27	12.860	-0.253
28	13.354	-0.246	29	13.849	-0.239	30	14.343	-0.232
31	14.838	-0.225	32	15.333	-0.218	33	15.827	-0.212
34	16.322	-0.205	35	16.816	-0.199	36	17.311	-0.193
37	17.806	-0.187	38	18.300	-0.181	39	18.795	-0.176
40	19.289	-0.170	41	19.784	-0.165	42	20.279	-0.160
43	20.773	-0.155	44	21.268	-0.150	45	21.762	-0.145

37	48.000	−0.831	38	48.063	−0.749	39	48.476	−0.160
40	48.578	0.000	41	48.579	0.001	42	48.890	0.543
43	49.303	1.428	44	49.716	2.694	45	49.888	3.543
46	49.959	4.115	47	49.975	4.315			

○Arc Center(m) : (40.500, 5.000)
○Arc Diameter(m) : 9.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle(°)	Slice Bottom Water Pressure (kN/m2)	Slice Bottom Length (m)
0.009	0.001	−58.194	0.000	0.016
0.213	0.696	−56.968	1.609	0.390
0.495	6.150	−53.295	6.481	0.828
0.495	11.748	−48.545	12.499	0.747
0.495	16.512	−44.210	17.622	0.690
0.495	20.625	−40.176	22.045	0.647
0.495	24.202	−36.371	25.894	0.614
0.495	27.325	−32.745	29.253	0.588
0.495	30.049	−29.262	32.183	0.567
0.495	32.415	−25.893	34.728	0.550
0.495	34.457	−22.619	36.924	0.536
0.495	36.198	−19.422	38.794	0.524
0.495	37.657	−16.286	40.360	0.515
0.713	56.314	−12.528	41.846	0.731
0.713	58.034	−8.150	43.124	0.721
0.713	59.022	−3.819	43.859	0.715
0.551	45.855	0.000	44.092	0.551
0.935	77.101	4.491	43.732	0.937
0.935	75.015	10.184	42.549	0.950
0.935	71.250	15.981	40.414	0.972
0.935	65.679	21.954	37.254	1.008
0.375	25.490	26.255	34.500	0.418
0.334	24.935	28.664	30.534	0.381
0.150	30.115	30.336	27.046	0.174
0.280	25.618	31.853	25.764	0.329
0.279	28.433	33.860	25.153	0.337
0.260	28.517	35.844	25.309	0.321
0.053	5.918	37.012	25.198	0.066
0.313	36.245	38.415	23.956	0.399
0.271	32.470	40.697	21.596	0.357
0.000	0.032	41.776	20.453	0.000
0.218	26.655	42.670	19.468	0.296
0.390	45.268	45.234	16.556	0.554
0.060	6.470	47.170	14.311	0.088
0.283	29.342	48.730	12.413	0.429
0.220	21.415	51.080	9.496	0.350
0.063	5.896	52.448	7.758	0.103
0.413	36.070	54.929	4.471	0.719
0.101	8.156	57.671	0.798	0.190
0.001	0.060	58.247	0.006	0.001
0.311	23.005	60.136	0.000	0.625
0.413	25.264	64.965	0.000	0.977
0.413	17.262	71.933	0.000	1.333
0.172	3.950	78.566	0.000	0.865
0.071	0.728	82.916	0.000	0.577
0.017	0.040	85.260	0.000	0.201

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	−0.500	2	0.495	−0.486	3	0.989	−0.473
4	1.484	−0.460	5	1.978	−0.448	6	2.473	−0.436
7	2.968	−0.424	8	3.462	−0.412	9	3.957	−0.401
10	4.451	−0.389	11	4.946	−0.378	12	5.441	−0.367
13	5.935	−0.356	14	6.430	−0.346	15	6.924	−0.335
16	7.419	−0.325	17	7.914	−0.315	18	8.408	−0.305
19	8.903	−0.295	20	9.397	−0.285	21	9.892	−0.276
22	10.387	−0.267	23	10.881	−0.257	24	11.376	−0.248
25	11.870	−0.240	26	12.365	−0.231	27	12.860	−0.222
28	13.354	−0.214	29	13.849	−0.206	30	14.343	−0.198
31	14.838	−0.190	32	15.333	−0.182	33	15.827	−0.175
34	16.322	−0.167	35	16.816	−0.160	36	17.311	−0.153
37	17.806	−0.146	38	18.300	−0.140	39	18.795	−0.133
40	19.289	−0.127	41	19.784	−0.120	42	20.279	−0.114
43	20.773	−0.108	44	21.268	−0.103	45	21.762	−0.097
46	22.257	−0.092	47	22.752	−0.086	48	23.246	−0.081
49	23.741	−0.076	50	24.235	−0.071	51	24.730	−0.067
52	25.225	−0.062	53	25.719	−0.058	54	26.214	−0.054
55	26.708	−0.050	56	27.203	−0.046	57	27.698	−0.042
58	28.192	−0.038	59	28.687	−0.035	60	29.181	−0.032
61	29.676	−0.028	62	30.171	−0.026	63	30.665	−0.023
64	31.160	−0.020	65	31.654	−0.018	66	32.149	−0.015
67	32.644	−0.013	68	33.138	−0.011	69	33.633	−0.009
70	34.127	−0.007	71	34.622	−0.006	72	35.117	−0.004
73	35.611	−0.003	74	36.106	−0.002	75	36.600	−0.001
76	37.095	0.000	77	37.590	0.000	78	38.084	0.000
79	44.889	0.000	80	45.223	−0.441	81	45.653	−0.441
82	45.932	−0.204	83	46.245	0.001	84	46.558	0.001
85	46.829	0.001	86	47.047	0.001	87	47.437	0.001
88	47.780	0.001	89	48.063	0.001	90	48.476	0.001
91	48.890	0.001	92	49.303	0.001	93	49.716	0.002
94	49.998	0.002	95	50.279	0.002	96	50.342	0.002
97	50.770	0.002	98	50.794	4.190	99	100.000	4.190

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◆ At 226.000(hr) Calculation Result

○Safety Factor and Slip Surface
- Safety Factor : 1.327
- Resistance Force(kN) : 325.688
- Sliding Force(kN) : 245.436 (= 236.612 + 83.827 / 9.500)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	32.422	0.000	2	32.431	−0.014	3	32.644	−0.341
4	33.138	−1.004	5	33.633	−1.564	6	34.127	−2.046
7	34.622	−2.463	8	35.117	−2.827	9	35.611	−3.146
10	36.106	−3.423	11	36.600	−3.663	12	37.095	−3.869
13	37.590	−4.043	14	38.084	−4.188	15	38.798	−4.346
16	39.511	−4.448	17	40.224	−4.496	18	40.776	−4.496
19	41.710	−4.423	20	42.645	−4.255	21	43.579	−3.987
22	44.514	−3.610	23	44.889	−3.425	24	45.223	−3.243
25	45.373	−3.155	26	45.653	−2.981	27	45.932	−2.794
28	46.193	−2.605	29	46.245	−2.566	30	46.558	−2.318
31	46.829	−2.085	32	46.830	−2.084	33	47.047	−1.884
34	47.437	−1.491	35	47.497	−1.426	36	47.780	−1.103
37	48.000	−0.831	38	48.063	−0.749	39	48.476	−0.160
40	48.578	0.000	41	48.580	0.003	42	48.890	0.543
43	49.303	1.428	44	49.716	2.694	45	49.888	3.543
46	49.959	4.115	47	49.975	4.315			

○Arc Center(m) : (40.500, 5.000)
○Arc Diameter(m) : 9.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle(°)	Slice Bottom Water Pressure (kN/m2)	Slice Bottom Length (m)
0.009	0.001	−58.194	0.000	0.016
0.213	0.696	−56.968	1.609	0.390
0.495	6.150	−53.295	6.482	0.828
0.495	11.748	−48.545	12.500	0.747
0.495	16.512	−44.210	17.623	0.690
0.495	20.625	−40.176	22.046	0.647
0.495	24.203	−36.371	25.895	0.614
0.495	27.325	−32.745	29.253	0.588
0.495	30.049	−29.262	32.183	0.567
0.495	32.415	−25.893	34.729	0.550
0.495	34.457	−22.619	36.924	0.536
0.495	36.198	−19.422	38.794	0.524
0.495	37.657	−16.286	40.360	0.515
0.713	56.314	−12.528	41.846	0.731
0.713	58.034	−8.150	43.124	0.721
0.713	59.022	−3.819	43.859	0.715
0.551	45.855	0.000	44.092	0.551
0.935	77.101	4.491	43.732	0.937
0.935	75.015	10.184	42.549	0.950
0.935	71.250	15.981	40.414	0.972
0.935	65.679	21.954	37.254	1.008
0.375	25.490	26.255	34.500	0.418
0.334	24.935	28.664	30.535	0.381
0.150	30.115	30.336	27.047	0.174
0.280	25.618	31.853	25.765	0.329
0.279	28.433	33.860	25.159	0.337
0.261	28.595	35.847	25.323	0.322
0.052	5.840	37.014	25.217	0.065
0.313	36.245	38.415	23.976	0.399
0.271	32.470	40.697	21.616	0.357
0.001	0.106	41.779	20.470	0.001
0.217	26.582	42.673	19.485	0.295
0.390	45.269	45.234	16.576	0.554
0.060	6.470	47.170	14.331	0.088
0.283	29.343	48.730	12.433	0.429
0.220	21.415	51.080	9.517	0.350
0.063	5.896	52.448	7.779	0.103
0.413	36.071	54.929	4.492	0.719
0.101	8.156	57.671	0.820	0.190
0.002	0.168	58.255	0.017	0.004
0.310	22.898	60.143	0.000	0.622
0.413	25.264	64.965	0.000	0.977
0.413	17.262	71.933	0.000	1.333
0.172	3.950	78.566	0.000	0.865
0.071	0.728	82.916	0.000	0.577
0.017	0.040	85.260	0.000	0.201

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	−0.500	2	0.495	−0.486	3	0.989	−0.473
4	1.484	−0.460	5	1.978	−0.448	6	2.473	−0.436
7	2.968	−0.424	8	3.462	−0.412	9	3.957	−0.401
10	4.451	−0.389	11	4.946	−0.378	12	5.441	−0.367
13	5.935	−0.356	14	6.430	−0.346	15	6.924	−0.335
16	7.419	−0.325	17	7.914	−0.315	18	8.408	−0.305
19	8.903	−0.295	20	9.397	−0.285	21	9.892	−0.276
22	10.387	−0.267	23	10.881	−0.257	24	11.376	−0.248
25	11.870	−0.240	26	12.365	−0.231	27	12.860	−0.222
28	13.354	−0.214	29	13.849	−0.206	30	14.343	−0.198
31	14.838	−0.190	32	15.333	−0.182	33	15.827	−0.175
34	16.322	−0.167	35	16.816	−0.160	36	17.311	−0.153
37	17.806	−0.146	38	18.300	−0.139	39	18.795	−0.133
40	19.289	−0.126	41	19.784	−0.120	42	20.279	−0.114
43	20.773	−0.108	44	21.268	−0.102	45	21.762	−0.097
46	22.257	−0.091	47	22.752	−0.086	48	23.246	−0.081
49	23.741	−0.076	50	24.235	−0.071	51	24.730	−0.066
52	25.225	−0.062	53	25.719	−0.058	54	26.214	−0.053
55	26.708	−0.049	56	27.203	−0.046	57	27.698	−0.042
58	28.192	−0.038	59	28.687	−0.035	60	29.181	−0.031
61	29.676	−0.028	62	30.171	−0.025	63	30.665	−0.023
64	31.160	−0.020	65	31.654	−0.017	66	32.149	−0.015
67	32.644	−0.013	68	33.138	−0.011	69	33.633	−0.009
70	34.127	−0.007	71	34.622	−0.006	72	35.117	−0.004
73	35.611	−0.003	74	36.106	−0.002	75	36.600	−0.001
76	37.095	0.000	77	37.590	0.000	78	38.084	0.000
79	44.889	0.000	80	45.223	−0.441	81	45.653	−0.441

82	45.932	-0.203	83	46.245	0.003	84	46.558	0.003
85	46.829	0.003	86	47.047	0.003	87	47.437	0.003
88	47.780	0.003	89	48.063	0.003	90	48.476	0.003
91	48.890	0.004	92	49.303	0.004	93	49.716	0.004
94	49.998	0.004	95	50.279	0.004	96	50.342	0.004
97	50.770	0.004	98	50.794	4.190	99	100.000	4.190

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◆ At 253.000 (hr) Calculation Result

○Safety Factor and Slip Surface

- Safety Factor : 1.616
- Resistance Force (kN) : 397.031
- Sliding Force (kN) : 245.718 (= 236.894 + 83.827 / 9.500)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	32.422	0.000	2	32.644	-0.341	3	32.742	-0.483
4	33.138	-1.004	5	33.633	-1.564	6	34.127	-2.046
7	34.622	-2.463	8	35.117	-2.827	9	35.611	-3.146
10	36.106	-3.423	11	36.600	-3.663	12	37.095	-3.869
13	37.590	-4.043	14	38.084	-4.188	15	38.579	-4.304
16	39.073	-4.392	17	39.568	-4.454	18	40.063	-4.490
19	40.224	-4.496	20	40.557	-4.500	21	40.776	-4.496
22	41.052	-4.484	23	41.546	-4.442	24	42.041	-4.374
25	42.536	-4.279	26	43.030	-4.157	27	43.525	-4.006
28	44.019	-3.824	29	44.514	-3.610	30	44.648	-3.546
31	44.889	-3.425	32	45.223	-3.243	33	45.373	-3.155
34	45.653	-2.981	35	45.932	-2.794	36	46.059	-2.704
37	46.245	-2.566	38	46.558	-2.318	39	46.686	-2.210
40	46.829	-2.085	41	47.047	-1.884	42	47.437	-1.491
43	47.497	-1.426	44	47.780	-1.103	45	48.000	-0.831
46	48.063	-0.749	47	48.263	-0.476	48	48.476	-0.160
49	48.578	0.000	50	48.890	0.543	51	49.303	1.428
52	49.716	2.694	53	49.888	3.543	54	49.959	4.115
55	49.975	4.315						

○Arc Center (m) : (40.500, 5.000)
○Arc Diameter (m) : 9.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Pressure (kN/m2)	Slice Bottom Water Length (m)
0.221	0.661	-57.017	0.000	0.407
0.099	0.711	-55.269	0.000	0.173
0.396	5.258	-52.773	2.556	0.655
0.495	11.514	-48.545	7.860	0.747
0.495	16.277	-44.210	12.967	0.690
0.495	20.389	-40.176	17.376	0.647
0.495	23.966	-36.371	21.212	0.614
0.495	27.088	-32.745	24.560	0.588
0.495	29.811	-29.262	27.481	0.567
0.495	32.178	-25.893	30.019	0.550
0.495	34.219	-22.619	32.209	0.536
0.495	35.960	-19.422	34.077	0.524
0.495	37.419	-16.286	35.643	0.515
0.495	38.611	-13.200	36.922	0.508
0.495	39.547	-10.152	37.927	0.502
0.495	40.235	-7.133	38.667	0.498
0.495	40.682	-4.135	39.148	0.496
0.162	13.367	-2.151	39.355	0.162
0.333	27.538	-0.659	39.404	0.333
0.218	18.073	1.004	39.405	0.218
0.276	22.806	2.496	39.328	0.276
0.495	40.600	4.827	39.066	0.496
0.495	40.098	7.830	38.530	0.499
0.495	39.353	10.854	37.733	0.504
0.495	38.359	13.910	36.669	0.510
0.495	37.107	17.006	35.328	0.517
0.495	35.584	20.155	33.698	0.527
0.495	33.776	23.369	31.761	0.539
0.134	9.043	25.443	30.381	0.149
0.241	16.333	26.704	29.419	0.269
0.334	24.935	28.664	27.873	0.381
0.150	30.115	30.336	26.525	0.174
0.280	25.618	31.853	25.243	0.329
0.279	28.433	33.860	23.526	0.337
0.127	13.676	35.343	22.235	0.155
0.186	20.708	36.510	21.156	0.232
0.313	36.095	38.415	19.285	0.399
0.128	15.200	40.125	17.539	0.168
0.143	17.146	41.203	16.396	0.190
0.218	26.583	42.669	14.797	0.296
0.390	45.082	45.234	11.883	0.554
0.060	6.442	47.170	9.637	0.088
0.283	29.207	48.730	7.738	0.429
0.220	21.310	51.080	4.821	0.350
0.063	5.866	52.448	3.083	0.103
0.200	17.968	53.782	1.341	0.339
0.213	17.984	55.951	0.000	0.380
0.101	8.148	57.671	0.000	0.190
0.312	23.065	60.131	0.000	0.626
0.413	25.264	64.965	0.000	0.977
0.413	17.262	71.933	0.000	1.333
0.172	3.950	78.566	0.000	0.865
0.071	0.728	82.916	0.000	0.577
0.017	0.040	85.260	0.000	0.201

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)

1	0.000	-0.500	2	0.495	-0.500	3	0.989	-0.499
4	1.484	-0.499	5	1.978	-0.499	6	2.473	-0.499
7	2.968	-0.498	8	3.462	-0.498	9	3.957	-0.498
10	4.451	-0.498	11	4.946	-0.497	12	5.441	-0.497
13	5.935	-0.497	14	6.430	-0.497	15	6.924	-0.496
16	7.419	-0.496	17	7.914	-0.496	18	8.408	-0.496
19	8.903	-0.495	20	9.397	-0.495	21	9.892	-0.495
22	10.387	-0.494	23	10.881	-0.494	24	11.376	-0.494
25	11.870	-0.494	26	12.365	-0.493	27	12.860	-0.493
28	13.354	-0.493	29	13.849	-0.493	30	14.343	-0.492
31	14.838	-0.492	32	15.333	-0.492	33	15.827	-0.492
34	16.322	-0.491	35	16.816	-0.491	36	17.311	-0.491
37	17.806	-0.491	38	18.300	-0.490	39	18.795	-0.490
40	19.289	-0.490	41	19.784	-0.490	42	20.279	-0.489
43	20.773	-0.489	44	21.268	-0.489	45	21.762	-0.489
46	22.257	-0.488	47	22.752	-0.488	48	23.246	-0.488
49	23.741	-0.488	50	24.235	-0.487	51	24.730	-0.487
52	25.225	-0.487	53	25.719	-0.487	54	26.214	-0.486
55	26.708	-0.486	56	27.203	-0.486	57	27.698	-0.486
58	28.192	-0.485	59	28.687	-0.485	60	29.181	-0.485
61	29.676	-0.485	62	30.171	-0.485	63	30.665	-0.484
64	31.160	-0.484	65	31.654	-0.484	66	32.149	-0.484
67	32.644	-0.483	68	33.138	-0.483	69	33.633	-0.483
70	34.127	-0.483	71	34.622	-0.482	72	35.117	-0.482
73	35.611	-0.482	74	36.106	-0.482	75	36.600	-0.482
76	37.095	-0.481	77	37.590	-0.481	78	38.084	-0.481
79	38.579	-0.481	80	39.073	-0.481	81	39.568	-0.480
82	40.063	-0.480	83	40.557	-0.480	84	41.052	-0.480
85	41.546	-0.479	86	42.041	-0.479	87	42.536	-0.479
88	43.030	-0.479	89	43.525	-0.479	90	44.019	-0.479
91	44.514	-0.479	92	44.889	-0.490	93	45.223	-0.494
94	45.373	-0.494	95	45.653	-0.494	96	45.932	-0.483
97	46.245	-0.475	98	46.558	-0.475	99	46.829	-0.475
100	47.047	-0.476	101	47.437	-0.476	102	47.497	-0.476
103	47.780	-0.476	104	48.063	-0.476	105	48.476	-0.476
106	48.890	-0.476	107	49.303	-0.475	108	49.716	-0.475
109	49.998	-0.475	110	50.279	-0.475	111	50.342	-0.475
112	50.732	-0.475	113	50.770	-0.475	114	51.083	-0.475
115	51.396	-0.475	116	51.868	-0.475	117	52.339	-0.475
118	52.489	-0.475	119	52.949	-0.475	120	53.408	-0.476
121	53.868	-0.476	122	54.327	-0.476	123	54.339	-0.476
124	54.489	-2.300	125	100.000	-2.300			

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◆ At 270.000 (hr) Calculation Result

○Safety Factor and Slip Surface

- Safety Factor : 1.620
- Resistance Force (kN) : 398.172
- Sliding Force (kN) : 245.716 (= 236.892 + 83.827 / 9.500)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	32.422	0.000	2	32.644	-0.341	3	32.754	-0.500
4	33.138	-1.004	5	33.633	-1.564	6	34.127	-2.046
7	34.622	-2.463	8	35.117	-2.827	9	35.611	-3.146
10	36.106	-3.423	11	36.600	-3.663	12	37.095	-3.869
13	37.590	-4.043	14	38.084	-4.188	15	38.579	-4.304
16	39.073	-4.392	17	39.568	-4.454	18	40.063	-4.490
19	40.224	-4.496	20	40.557	-4.500	21	40.776	-4.496
22	41.052	-4.484	23	41.546	-4.442	24	42.041	-4.374
25	42.536	-4.279	26	43.030	-4.157	27	43.525	-4.006
28	44.019	-3.824	29	44.514	-3.610	30	44.640	-3.551
31	44.889	-3.425	32	45.223	-3.243	33	45.373	-3.155
34	45.653	-2.981	35	45.932	-2.794	36	46.052	-2.708
37	46.245	-2.566	38	46.558	-2.318	39	46.679	-2.216
40	46.829	-2.085	41	47.047	-1.884	42	47.437	-1.491
43	47.497	-1.426	44	47.780	-1.103	45	48.000	-0.831
46	48.063	-0.749	47	48.245	-0.501	48	48.476	-0.160
49	48.578	0.000	50	48.890	0.543	51	49.303	1.428
52	49.716	2.694	53	49.888	3.543	54	49.959	4.115
55	49.975	4.315						

○Arc Center (m) : (40.500, 5.000)
○Arc Diameter (m) : 9.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Pressure (kN/m2)	Slice Bottom Water Length (m)
0.221	0.661	-57.017	0.000	0.407
0.111	0.815	-55.206	0.000	0.194
0.384	5.152	-52.710	2.472	0.634
0.495	11.505	-48.545	7.690	0.747
0.495	16.268	-44.210	12.795	0.690
0.495	20.380	-40.176	17.202	0.647
0.495	23.957	-36.371	21.036	0.614
0.495	27.079	-32.745	24.382	0.588
0.495	29.802	-29.262	27.300	0.567
0.495	32.169	-25.893	29.836	0.550
0.495	34.210	-22.619	32.024	0.536
0.495	35.950	-19.422	33.889	0.524
0.495	37.409	-16.286	35.453	0.515
0.495	38.601	-13.200	36.730	0.508
0.495	39.537	-10.152	37.733	0.502
0.495	40.225	-7.133	38.471	0.498
0.495	40.672	-4.135	38.950	0.496
0.162	13.364	-2.151	39.155	0.162
0.333	27.531	-0.659	39.203	0.333
0.218	18.069	1.004	39.203	0.218
0.276	22.800	2.496	39.125	0.276

0.495	40.590	4.827	38.861	0.496
0.495	40.088	7.830	38.323	0.499
0.495	39.343	10.854	37.524	0.504
0.495	38.349	13.910	36.459	0.510
0.495	37.096	17.006	35.116	0.517
0.495	35.573	20.155	33.484	0.527
0.495	33.765	23.369	31.546	0.539
0.126	8.442	25.413	30.207	0.139
0.249	16.930	26.674	29.303	0.279
0.334	24.935	28.664	27.796	0.381
0.150	30.115	30.336	26.472	0.174
0.280	25.618	31.853	25.190	0.329
0.279	28.433	33.860	23.416	0.337
0.120	13.013	35.320	22.074	0.148
0.193	21.367	36.488	20.955	0.239
0.313	36.088	38.415	19.039	0.399
0.121	14.296	40.095	17.324	0.158
0.150	18.043	41.173	16.181	0.200
0.218	26.578	42.669	14.550	0.296
0.390	45.073	45.234	11.636	0.554
0.060	6.440	47.170	9.391	0.088
0.283	29.200	48.730	7.492	0.429
0.220	21.305	51.080	4.574	0.350
0.063	5.865	52.448	2.836	0.103
0.182	16.404	53.689	1.217	0.308
0.231	19.542	55.858	0.000	0.411
0.101	8.148	57.671	0.000	0.190
0.312	23.065	60.131	0.000	0.626
0.413	25.264	64.965	0.000	0.977
0.413	17.262	71.933	0.000	1.333
0.172	3.950	78.566	0.000	0.865
0.071	0.728	82.916	0.000	0.577
0.017	0.040	85.260	0.000	0.201

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	-0.500	2	0.495	-0.500	3	0.989	-0.500
4	1.484	-0.500	5	1.978	-0.500	6	2.473	-0.500
7	2.968	-0.500	8	3.462	-0.500	9	3.957	-0.500
10	4.451	-0.500	11	4.946	-0.500	12	5.441	-0.500
13	5.935	-0.500	14	6.430	-0.500	15	6.924	-0.500
16	7.419	-0.500	17	7.914	-0.500	18	8.408	-0.500
19	8.903	-0.500	20	9.397	-0.500	21	9.892	-0.500
22	10.387	-0.500	23	10.881	-0.500	24	11.376	-0.500
25	11.870	-0.500	26	12.365	-0.500	27	12.860	-0.500
28	13.354	-0.500	29	13.849	-0.500	30	14.343	-0.500
31	14.838	-0.500	32	15.333	-0.500	33	15.827	-0.500
34	16.322	-0.500	35	16.816	-0.500	36	17.311	-0.500
37	17.806	-0.500	38	18.300	-0.500	39	18.795	-0.500
40	19.289	-0.500	41	19.784	-0.500	42	20.279	-0.500
43	20.773	-0.500	44	21.268	-0.500	45	21.762	-0.500
46	22.257	-0.500	47	22.752	-0.500	48	23.246	-0.500
49	23.741	-0.500	50	24.235	-0.500	51	24.730	-0.500
52	25.225	-0.500	53	25.719	-0.500	54	26.214	-0.500
55	26.708	-0.500	56	27.203	-0.500	57	27.698	-0.500
58	28.192	-0.500	59	28.687	-0.500	60	29.181	-0.500
61	29.676	-0.500	62	30.171	-0.500	63	30.665	-0.500
64	31.160	-0.500	65	31.654	-0.500	66	32.149	-0.500
67	32.644	-0.500	68	33.138	-0.500	69	33.633	-0.500
70	34.127	-0.500	71	34.622	-0.500	72	35.117	-0.500
73	35.611	-0.500	74	36.106	-0.500	75	36.600	-0.500
76	37.095	-0.500	77	37.590	-0.500	78	38.084	-0.500
79	38.579	-0.500	80	39.073	-0.500	81	39.568	-0.500
82	40.063	-0.500	83	40.557	-0.500	84	41.052	-0.500
85	41.546	-0.500	86	42.041	-0.500	87	42.536	-0.500
88	43.030	-0.500	89	43.525	-0.501	90	44.019	-0.500
91	44.514	-0.500	92	44.889	-0.500	93	45.223	-0.500
94	45.373	-0.500	95	45.653	-0.500	96	45.932	-0.500
97	46.245	-0.501	98	46.558	-0.501	99	46.829	-0.501
100	47.047	-0.501	101	47.437	-0.501	102	47.497	-0.501
103	47.780	-0.501	104	48.063	-0.501	105	48.476	-0.501
106	48.890	-0.501	107	49.303	-0.501	108	49.716	-0.501
109	49.998	-0.501	110	50.279	-0.501	111	50.342	-0.501
112	50.732	-0.501	113	50.770	-0.501	114	51.083	-0.501
115	51.396	-0.501	116	51.868	-0.501	117	52.339	-0.501
118	52.489	-0.501	119	52.949	-0.501	120	53.408	-0.501
121	53.868	-0.501	122	54.327	-0.501	123	54.339	-0.502
124	54.489	-2.300	125	100.000	-2.300			

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○3. Slip Surface with the minimum Safety Factor

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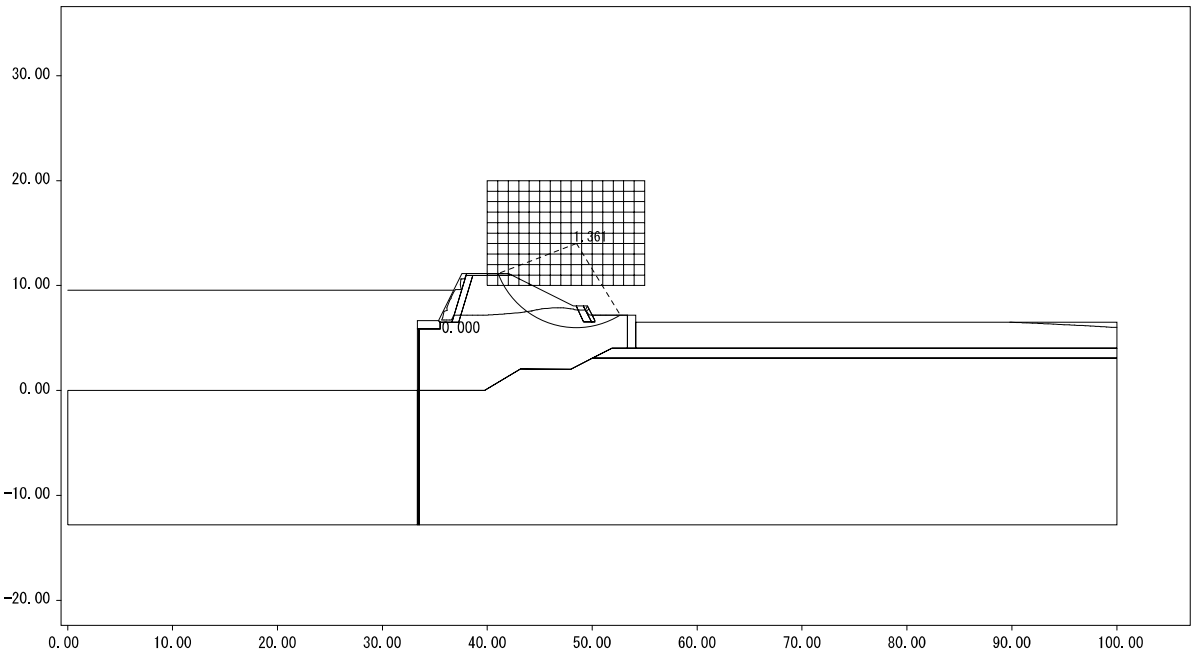
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○ Time(hr) : 226.000
○Safety Factor : 1.327
○Search Area : 1
○Center (m) : (40.500, 5.000)
○Dianeter (m) : 9.5

1.2.1 SLOPE STABILITY　ANALYSIS

1.2.1.2　Flood Conditions (Seepage)

(2)　R6+060



(Calculation Result)

Title	R6+060				
Note					
Calculation Method	Slope Stability Calculation+ Seepage Analysis	Output Time	226.000 (hr)	Safety Factor	1.361
Output Items	Diagram of Soil Layer, Water Level and Slip Surface				

Slip (Flood)

Slope Stability Analysis considering Seepage

Input Data Sheet

◆ Basic Calculation Conditions

○Title : R6+060

○Note :

○Calculation Type : Seepage Analysis + Slope Stability Calculation
○Seepage Type : Non stationary Seepage
○Time Unit : hr
○Stress Type : Total Stress
○Safety Factor Formula : Modified Fellenius' Method
○Unit : SI Unit
○Unsaturated Permeability : θ-Kr, θ-ψ

◆ Node

○Node : 47

○Node axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	0.000	2	33.342	0.000
3	33.342	5.849	4	33.342	6.649
5	33.492	5.849	6	35.342	6.649
7	35.492	6.502	8	37.592	11.149
9	38.042	11.149	10	37.982	10.949
11	38.608	10.949	12	42.042	11.149
13	42.042	10.949	14	35.492	5.849
15	36.647	6.502	16	37.274	6.502
17	50.000	7.170	18	53.356	7.170
19	54.152	7.170	20	100.000	6.502
21	100.000	4.035	22	54.152	4.035
23	53.356	4.035	24	51.877	4.035
25	50.042	3.085	26	47.968	2.011
27	43.173	2.039	28	39.744	-0.001
29	33.492	-0.001	30	100.000	3.085
31	100.000	-12.830	32	33.492	-12.830
33	33.342	-12.830	34	0.000	-12.830
35	54.152	6.502	36	48.200	8.070
37	48.486	8.070	38	49.159	8.070
39	49.550	8.070	40	50.250	6.669
41	50.250	6.520	42	49.934	6.520
43	49.175	6.520	44	50.300	7.170
45	50.300	6.670	46	50.800	6.670
47	50.800	7.170			

◆ Soil Layer

○No. of Soil Layers : 13

○Layer No. : 1
○Layer Name : GFf
○Nodes : 1, 2, 33, 34

○Layer No. : 2
○Layer Name : SSP
○Nodes : 2, 3, 5, 29, 32, 33

○Layer No. : 3
○Layer Name : Co
○Nodes : 3, 4, 6, 7, 14, 5

○Layer No. : 4
○Layer Name : Co
○Nodes : 6, 8, 9, 10, 15, 7

○Layer No. : 5
○Layer Name : Gr
○Nodes : 10, 11, 16, 15

○Layer No. : 6
○Layer Name : PCCP
○Nodes : 12, 13, 11, 10, 9

○Layer No. : 7
○Layer Name : B
○Nodes : 5, 14, 7, 15, 16, 11, 13, 12, 36, 37,
: 43, 42, 41, 40, 17, 18, 23, 24, 25, 26,
: 27, 28, 29

○Layer No. : 8
○Layer Name : Co
○Nodes : 18, 19, 35, 22, 23

○Layer No. : 9
○Layer Name : As
○Nodes : 35, 20, 21, 22

○Layer No. : 10
○Layer Name : Dc
○Nodes : 30, 25, 24, 23, 22, 21

○Layer No. : 11
○Layer Name : GFf
○Nodes : 30, 31, 32, 29, 28, 27, 26, 25

○Layer No. : 12
○Layer Name : Co
○Nodes : 38, 39, 17, 40, 41, 42

○Layer No. : 13
○Layer Name : Gr
○Nodes : 37, 38, 42, 43

◆ Hole

○No of Holes : 0

◆ Soil Constants

○Layer No. : 1
○Layer Name : GFf
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-005
○Saturated h.c. ky (cm/s) : 1.000E-005
○Specific Storage Coef. Ss (1/m) : 1.000E-007

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 30.000
○Wet Weight(kN/m3) : 17.000
○Sat. Unit Weight(kN/m3) : 18.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 2
○Layer Name : SSP
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 2.000E-006
○Saturated h.c. ky (cm/s) : 2.000E-006
○Specific Storage Coef. Ss (1/m) : 2.000E-008

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 77.000

Slip(Flood)

○Sat. Unit Weight(kN/m3) : 77.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 3
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 24.000
○Sat. Unit Weight(kN/m3) : 24.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 4
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

Slip(Flood)

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 24.000
○Sat. Unit Weight(kN/m3) : 24.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 5
○Layer Name : Gr
○Unsaturated Permeability : gravel/sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.049	-12.000
3	0.020	0.020	3	0.050	-1.900
4	0.030	0.030	4	0.056	-1.500
5	0.040	0.040	5	0.068	-1.000
6	0.050	0.050	6	0.078	-0.800

7	0.060	0.060	7	0.084	-0.700
8	0.070	0.080	8	0.090	-0.600
9	0.080	0.090	9	0.100	-0.500
10	0.090	0.110	10	0.112	-0.400
11	0.100	0.130	11	0.126	-0.300
12	0.110	0.160	12	0.136	-0.250
13	0.120	0.190	13	0.150	-0.200
14	0.130	0.230	14	0.164	-0.150
15	0.140	0.290	15	0.178	-0.100
16	0.150	0.360	16	0.190	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-001
○Saturated h.c. ky (cm/s) : 1.000E-001
○Specific Storage Coef. Ss (1/m) : 1.000E-003

○Cohesion c(kN/m2) : 0.000
○Friction Angle ϕ (°) : 35.000
○Wet Weight (kN/m3) : 19.000
○Sat. Unit Weight (kN/m3) : 20.000
○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 6
○Layer Name : PCCP
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1.000
○Friction Angle ϕ (°) : 30.000
○Wet Weight (kN/m3) : 24.000
○Sat. Unit Weight (kN/m3) : 24.000
○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 7
○Layer Name : B
○Unsaturated Permeability : gravel/sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.049	-12.000
3	0.020	0.020	3	0.050	-1.900
4	0.030	0.030	4	0.056	-1.500
5	0.040	0.040	5	0.068	-1.000
6	0.050	0.050	6	0.078	-0.800
7	0.060	0.060	7	0.084	-0.700
8	0.070	0.080	8	0.090	-0.600
9	0.080	0.090	9	0.100	-0.500
10	0.090	0.110	10	0.112	-0.400
11	0.100	0.130	11	0.126	-0.300
12	0.110	0.160	12	0.136	-0.250
13	0.120	0.190	13	0.150	-0.200
14	0.130	0.230	14	0.164	-0.150
15	0.140	0.290	15	0.178	-0.100
16	0.150	0.360	16	0.190	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-003
○Saturated h.c. ky (cm/s) : 1.000E-003
○Specific Storage Coef. Ss (1/m) : 1.000E-005

○Cohesion c(kN/m2) : 1.000
○Friction Angle ϕ (°) : 30.000
○Wet Weight (kN/m3) : 18.000

○Sat. Unit Weight(kN/m3) : 19.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 8
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1000.000
○Friction Angle ϕ (°) : 0.000
○Wet Weight (kN/m3) : 24.000
○Sat. Unit Weight (kN/m3) : 24.000
○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 9
○Layer Name : As
○Unsaturated Permeability : silty sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.119	-12.000
3	0.020	0.020	3	0.120	-1.900
4	0.030	0.030	4	0.123	-1.500
5	0.040	0.040	5	0.129	-1.000
6	0.050	0.050	6	0.135	-0.800
7	0.060	0.060	7	0.138	-0.700
8	0.070	0.080	8	0.141	-0.600
9	0.080	0.090	9	0.146	-0.500
10	0.090	0.110	10	0.153	-0.400
11	0.100	0.130	11	0.160	-0.300
12	0.110	0.160	12	0.166	-0.250
13	0.120	0.190	13	0.173	-0.200
14	0.130	0.230	14	0.181	-0.150
15	0.140	0.290	15	0.188	-0.100
16	0.150	0.360	16	0.195	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-001
○Saturated h.c. ky (cm/s) : 1.000E-001
○Specific Storage Coef. Ss (1/m) : 1.000E-003

○Cohesion c(kN/m2) : 0.000
○Friction Angle ϕ (°) : 27.000
○Wet Weight (kN/m3) : 17.500
○Sat. Unit Weight (kN/m3) : 18.500
○Water Unit Weight (kN/m3) : 9.807

○Layer No. : 10
○Layer Name : Dc
○Unsaturated Permeability : diluvial clay
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ (m)
1	0.135	0.000	1	0.135	-900.000
2	0.153	0.000	2	0.153	-300.000
3	0.177	0.000	3	0.177	-100.000
4	0.226	0.000	4	0.226	-20.000
5	0.285	0.000	5	0.285	-5.000
6	0.313	0.000	6	0.313	-3.000
7	0.336	0.000	7	0.336	-2.000
8	0.354	0.000	8	0.354	-1.500
9	0.380	0.001	9	0.380	-1.000
10	0.404	0.001	10	0.404	-0.700
11	0.426	0.003	11	0.426	-0.500
12	0.440	0.004	12	0.440	-0.400
13	0.448	0.006	13	0.448	-0.350

14	0.457	0.008	14	0.457	-0.300
15	0.465	0.011	15	0.465	-0.260
16	0.472	0.013	16	0.472	-0.230
17	0.479	0.017	17	0.479	-0.200
18	0.484	0.020	18	0.484	-0.180
19	0.489	0.024	19	0.489	-0.160
20	0.494	0.030	20	0.494	-0.140
21	0.500	0.037	21	0.500	-0.120
22	0.506	0.047	22	0.506	-0.100
23	0.512	0.062	23	0.512	-0.080
24	0.518	0.085	24	0.518	-0.060
25	0.524	0.123	25	0.524	-0.040
26	0.530	0.199	26	0.530	-0.020
27	0.533	0.283	27	0.533	-0.010
28	0.535	1.000	28	0.535	0.000

○Saturated h.c. kx (cm/s) : 1.000E-006
○Saturated h.c. ky (cm/s) : 1.000E-006
○Specific Storage Coef. Ss (1/m) : 1.000E-008

○Cohesion c(kN/m2) : 100.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 18.000
○Sat. Unit Weight(kN/m3) : 19.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 11
○Layer Name : GFf
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-005
○Saturated h.c. ky (cm/s) : 1.000E-005
○Specific Storage Coef. Ss (1/m) : 1.000E-007

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 30.000
○Wet Weight(kN/m3) : 17.000
○Sat. Unit Weight(kN/m3) : 18.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 12
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 24.000
○Sat. Unit Weight(kN/m3) : 24.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 13
○Layer Name : Gr
○Unsaturated Permeability : gravel/sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.049	-12.000
3	0.020	0.020	3	0.050	-1.900
4	0.030	0.030	4	0.056	-1.500
5	0.040	0.040	5	0.068	-1.000
6	0.050	0.050	6	0.078	-0.800
7	0.060	0.060	7	0.084	-0.700
8	0.070	0.080	8	0.090	-0.600
9	0.080	0.090	9	0.100	-0.500
10	0.090	0.110	10	0.112	-0.400
11	0.100	0.130	11	0.126	-0.300
12	0.110	0.160	12	0.136	-0.250
13	0.120	0.190	13	0.150	-0.200
14	0.130	0.230	14	0.164	-0.150
15	0.140	0.290	15	0.178	-0.100
16	0.150	0.360	16	0.190	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-001
○Saturated h.c. ky (cm/s) : 1.000E-001
○Specific Storage Coef. Ss (1/m) : 1.000E-003

○Cohesion c(kN/m2) : 0.000
○Friction Angle φ(°) : 35.000
○Wet Weight(kN/m3) : 19.000
○Sat. Unit Weight(kN/m3) : 20.000
○Water Unit Weight(kN/m3) : 9.807

◆ FEM Elements

○Soil Layer
Elements Size

Layer No.	x Direction(m)	yDirection(m)
1	1.000	1.000
2	0.500	0.500
3	0.500	0.500
4	0.500	0.500
5	0.500	0.500
6	0.500	0.500
7	0.500	0.500
8	0.500	0.500
9	0.500	0.500
10	0.500	0.500
11	1.000	1.000
12	0.500	0.500
13	0.500	0.500

○Element Shape : Triangle + Square

○Partial Area

No	Min. x axis(m)	Min. y axis(m)	Max. x axis(m)	Max. y axis(m)	Element Size xDirection(m)	Element Size yDirection(m)

○Internal Node : 44, 46, 45, 47

◆ Initial Water Level

○ Water Level : 4

No	x axis(m)	y axis(m)
1	0.000	4.035
2	33.492	4.035
3	33.492	6.002
4	100.000	6.002

◆ Seepage Surface

○No. of Seepage Surface : 2

○Seepage Surface No. : 1
○Nodes : 9, 12, 17, 18

○Seepage Surface No. : 2
○Nodes : 1, 2

◆ Water Level Fixed Point

○ No. of Water Level Fixed Point : 1

○ Water Level Fixed No. : 1
○ Water Level (m) : 6.002
○ Nodes : 20, 21, 30, 31

◆ Water Level Changing Point

○ No. of Water LevelChanging Point : 1

○ Water LevelChanging Point No. : 1
○ Nodes : 1, 2, 3, 4, 6, 8

○ temporal variation

No	Time (hr)	Water Level (m)
1	0.000	5.920
2	213.000	5.920
3	224.000	9.550
4	226.000	9.550
5	238.000	5.920
6	270.000	5.920

◆ Rain Penetration Line

○ No. of Rain Penetration Line : 1

○ Rain Penetration Line No : 1
○ Nodes : 4, 6, 8, 9, 12, 36, 37, 38, 39, 17,
: 18, 19, 35, 20

○ temporal variation

No	Time (hr)	Rainfall (mm)
1	200.000	1.000
2	226.000	10.000
3	270.000	0.000

◆ Repeat Calculation

○ Time step
- Min. : 0.010
- Max. : 10.000
- Allowable Error (m) : 0.010
- Max. Repeat : 10

◆ Slip Surface Conditions

○ Merginal Slip Surface (Center - Diameter)

○ Search Area : 1

No	x axis Min. (m)	x axis Max. (m)	x axis Variation (m)	y axis Min. (m)	y axis Max. (m)	y axis Variation (m)
1	40.000	55.000	1.000	10.000	20.000	1.000

No	Diameter Min. (m)	Diameter Max. (m)	Diameter Variation (m)
1	5.000	25.000	1.000

○ Slip Surface Limit

	x axis (m)	y axis (m)
must cut line [ON]		
1	38.042	11.149
2	42.042	11.149
must not cut line [ON]		
1	42.042	11.149
2	50.000	7.170

◆ Load

○ Load No : 1

	Left end (m)	Right end (m)	Load (kN/m2)
1	38.500	41.500	5.000

◆ Tension Crack

○ Tension Crack : 0

◆ Seismic Force

Slip(Flood)

○ Horizontal Seismic Coef. : 0.000
○ Vertical Seismic Coef. : 0.000

◆ Output Time

○ Output Time : 7

No	Seepage Cal.	Stability Cal.
1	1.000	
2	10.000	◎
3	200.000	◎
4	224.000	◎
5	226.000	◎
6	238.000	◎
7	270.000	

Slope Stability Analysis considering Seepage

Slope Stability Calculation

==========
○ 1. Input Data
==========

◆ Title

R6+060

◆ Calculation Type

Seepage Analysis + Slope Stability Calculation

◆ Safety Factor Formula

Modified Fellenius' Method

◆ Unit

SI Unit

◆ Node

○Node : 47

○Node axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	0.000	2	33.342	0.000
3	33.342	5.849	4	33.342	6.649
5	33.492	5.849	6	35.342	6.649
7	35.492	6.502	8	37.592	11.149
9	38.042	11.149	10	37.982	10.949
11	38.608	10.949	12	42.042	11.149
13	42.042	10.949	14	35.492	5.849
15	36.647	6.502	16	37.274	6.502
17	50.000	7.170	18	53.356	7.170
19	54.152	7.170	20	100.000	6.502
21	100.000	4.035	22	54.152	4.035
23	53.356	4.035	24	51.877	4.035
25	50.042	3.085	26	47.968	2.011
27	43.173	2.039	28	39.744	-0.001
29	33.492	-0.001	30	100.000	3.085
31	100.000	-12.830	32	33.492	-12.830
33	33.342	-12.830	34	0.000	-12.830
35	54.152	6.502	36	48.200	8.070
37	48.486	8.070	38	49.159	8.070
39	49.550	8.070	40	50.250	6.669
41	50.250	6.520	42	49.934	6.520
43	49.175	6.520	44	50.300	7.170
45	50.300	6.670	46	50.800	6.670
47	50.800	7.170			

◆ Soil Layer

○No. of Soil Layers : 13

○Layer No. : 1
○Layer Name : GFf
○Nodes : 1, 2, 33, 34

○Layer No. : 2
○Layer Name : SSP
○Nodes : 2, 3, 5, 29, 32, 33

○Layer No. : 3
○Layer Name : Co
○Nodes : 3, 4, 6, 7, 14, 5

○Layer No. : 4
○Layer Name : Co
○Nodes : 6, 8, 9, 10, 15, 7

○Layer No. : 5
○Layer Name : Gr
○Nodes : 10, 11, 16, 15

○Layer No. : 6
○Layer Name : PCCP
○Nodes : 12, 13, 11, 10, 9

○Layer No. : 7
○Layer Name : B
○Nodes : 5, 14, 7, 15, 16, 11, 13, 12, 36, 37,
: 43, 42, 41, 40, 17, 18, 23, 24, 25, 26,
: 27, 28, 29

○Layer No. : 8
○Layer Name : Co
○Nodes : 18, 19, 35, 22, 23

○Layer No. : 9
○Layer Name : As
○Nodes : 35, 20, 21, 22

○Layer No. : 10
○Layer Name : Dc
○Nodes : 30, 25, 24, 23, 22, 21

○Layer No. : 11
○Layer Name : GFf
○Nodes : 30, 31, 32, 29, 28, 27, 26, 25

○Layer No. : 12
○Layer Name : Co
○Nodes : 38, 39, 17, 40, 41, 42

○Layer No. : 13
○Layer Name : Gr
○Nodes : 37, 38, 42, 43

◆ Hole

○No. of Holes : 0

◆ Soil Constants

○Soil Layer : 1
Layer Name : GFf
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 30.00
Wet Weight (kN/m3) : 17.00
Sat. Unit Weight (kN/m3) : 18.00

○Soil Layer : 2
Layer Name : SSP
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 77.00
Sat. Unit Weight (kN/m3) : 77.00

○Soil Layer : 3
Layer Name : Co
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer : 4
Layer Name : Co
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer : 5
Layer Name : Gr
Cohesion (kN/m2) : 0.00
Friction Angle (°) : 35.00
Wet Weight (kN/m3) : 19.00
Sat. Unit Weight (kN/m3) : 20.00

○Soil Layer : 6
Layer Name : PCCP
Cohesion (kN/m2) : 1.00
Friction Angle (°) : 30.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer : 7
Layer Name : B
Cohesion (kN/m2) : 1.00
Friction Angle (°) : 30.00
Wet Weight (kN/m3) : 18.00
Sat. Unit Weight (kN/m3) : 19.00

○Soil Layer : 8
Layer Name : Co
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer : 9
Layer Name : As
Cohesion (kN/m2) : 0.00
Friction Angle (°) : 27.00
Wet Weight (kN/m3) : 17.50
Sat. Unit Weight (kN/m3) : 18.50

○Soil Layer : 10
Layer Name : Dc
Cohesion (kN/m2) : 100.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 18.00
Sat. Unit Weight (kN/m3) : 19.00

○Soil Layer : 11
Layer Name : GFf
Cohesion (kN/m2) : 1000.00

Friction Angle (°) : 30.00
Wet Weight (kN/m3) : 17.00
Sat. Unit Weight (kN/m3) : 18.00

○Soil Layer : 12
Layer Name : Co
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer : 13
○Layer Name : Gr
Cohesion (kN/m2) : 0.00
Friction Angle (°) : 35.00
Wet Weight (kN/m3) : 19.00
Sat. Unit Weight (kN/m3) : 20.00

◆ Slip SurfaceConditions

○Merginal Slip Surface (Center・Diameter)

○Search Area : 1

No	x axis Min.(m)	x axis Max.(m)	x axis Variation(m)	y axis Min.(m)	y axis Max.(m)	y axis Variation(m)
1	40.000	55.000	1.000	10.000	20.000	1.000

No	Diameter Min.(m)	Diameter Max.(m)	Diameter Variation(m)
1	5.000	25.000	1.000

○Slip Surface Limit

	x axis(m)	y axis(m)	Search
must cut line [ON]			
1	38.042	11.149	
2	42.042	11.149	
must not cut line [ON]			
1	42.042	11.149	
2	50.000	7.170	

◆ Calculation Time

○ Time to conduct stability Cal. : 5

no	Time (hour)	no	Time (hour)	no	Time (hour)	no	Time (hour)	no	Time (hour)
2	10.000	3	200.000	4	224.000	5	226.000	6	238.000

◆ Load

○Load : 1

No	Left end(m)	Right end(m)	Load(kN/m2)
1	38.500	41.500	5.000

◆ Tension Crack

○Tension Crack : 0

◆ Seismic Force

○Horizontal Seismic Coef. : 0.000
○Vertical Seismic Coef. : 0.000

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○2. Calculation Result
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◆ Min.Safety Factor and Slip Surface

◆ At 10.000 (hr) Calculation Result

○Safety Factor and Slip Surface

- Safety Factor : 1.734
- Resistance Force (kN) : 231.673
- Sliding Force (kN) : 133.608 (= 130.073 + 30.052 / 8.500)

○Slip Surface axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	40.688	11.149	2	40.777	10.949	3	41.123	10.278
4	41.500	9.678	5	41.582	9.561	6	42.042	8.973
7	42.419	8.561	8	42.796	8.198	9	43.173	7.876
10	43.653	7.518	11	44.132	7.208	12	44.612	6.942
13	45.091	6.714	14	45.571	6.521	15	46.050	6.361
16	46.530	6.232	17	47.009	6.132	18	47.489	6.060
19	47.968	6.017	20	47.968	6.017	21	48.200	6.005
22	48.486	6.000	23	48.823	6.006	24	49.159	6.026
25	49.175	6.027	26	49.185	6.028	27	49.550	6.065
28	49.934	6.122	29	50.000	6.133	30	50.042	6.141
31	50.250	6.182	32	50.657	6.278	33	51.064	6.396
34	51.470	6.536	35	51.877	6.700	36	52.370	6.932
37	52.804	7.170						

○Arc Center (m) : (48.500, 14.500)
○Arc Diameter (m) : 8.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Pressure (kN/m2)	Slice Bottom Water Length (m)
0.089	0.213	-66.044	0.000	0.219
0.346	3.746	-62.761	0.000	0.755
0.377	8.403	-57.828	0.000	0.708
0.082	2.368	-54.956	0.000	0.144
0.460	16.121	-51.958	0.000	0.746
0.377	15.524	-47.560	0.000	0.559
0.377	16.875	-43.913	0.000	0.523
0.377	17.919	-40.478	0.000	0.496
0.480	23.878	-36.789	0.000	0.599
0.480	24.692	-32.847	0.000	0.571
0.479	25.110	-29.073	0.000	0.549
0.480	25.175	-25.434	0.000	0.531
0.480	24.922	-21.902	0.000	0.517
0.480	24.375	-18.456	0.000	0.506
0.480	23.554	-15.078	0.000	0.497
0.479	22.473	-11.754	0.000	0.490
0.480	21.142	-8.469	0.000	0.485
0.480	19.569	-5.211	0.000	0.481
0.000	0.010	-3.588	0.000	0.000
0.232	8.832	-2.805	0.061	0.232
0.286	10.647	-1.058	0.159	0.286
0.337	12.653	1.040	0.180	0.337
0.337	12.827	3.310	0.092	0.337
0.016	0.614	4.501	0.013	0.016
0.010	0.404	4.590	0.004	0.011
0.365	14.604	5.861	0.000	0.366
0.384	12.957	8.404	0.000	0.388
0.066	1.600	9.938	0.000	0.067
0.042	0.870	10.308	0.000	0.043
0.208	4.222	11.167	0.000	0.212
0.407	6.881	13.290	0.000	0.418
0.407	6.099	16.126	0.000	0.423
0.407	5.156	19.003	0.000	0.430
0.407	4.043	21.931	0.000	0.438
0.493	3.143	25.246	0.000	0.545
0.434	0.928	28.751	0.000	0.495

○ Water Level axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	0.000	5.920	2	33.342	5.920	3	33.492	5.709
4	33.955	5.755	5	34.417	5.807	6	34.880	5.845
7	35.342	5.885	8	35.492	5.898	9	35.877	5.912
10	36.262	5.926	11	36.647	5.938	12	36.961	5.945
13	37.274	5.950	14	37.592	5.955	15	37.982	5.958
16	38.042	5.959	17	38.325	5.962	18	38.608	5.965
19	38.987	5.969	20	39.365	5.972	21	39.744	5.976
22	40.204	5.980	23	40.663	5.983	24	41.123	5.987
25	41.582	5.990	26	42.042	5.993	27	42.419	5.995
28	42.796	5.997	29	43.173	5.999	30	43.653	6.001
31	44.132	6.004	32	44.612	6.006	33	45.091	6.007
34	45.571	6.009	35	46.050	6.011	36	46.530	6.012
37	47.009	6.013	38	47.489	6.015	39	47.968	6.017
40	48.200	6.018	41	48.486	6.020	42	48.823	6.023
43	49.159	6.027	44	49.175	6.028	45	49.550	6.030
46	49.934	6.031	47	50.250	6.032	48	50.657	6.032
49	51.064	6.033	50	51.470	6.033	51	51.877	6.032
52	52.370	6.030	53	52.863	6.026	54	53.356	6.019
55	53.754	6.070	56	54.152	6.122	57	54.650	6.122
58	55.149	6.122	59	55.647	6.122	60	56.145	6.122
61	56.644	6.122	62	57.142	6.122	63	57.640	6.122
64	58.139	6.122	65	58.637	6.121	66	59.135	6.121
67	59.634	6.121	68	60.132	6.121	69	60.631	6.120
70	61.129	6.120	71	61.627	6.120	72	62.126	6.119
73	62.624	6.119	74	63.122	6.118	75	63.621	6.118
76	64.119	6.117	77	64.617	6.117	78	65.116	6.116
79	65.614	6.115	80	66.112	6.115	81	66.611	6.114
82	67.109	6.113	83	67.607	6.113	84	68.106	6.112
85	68.604	6.111	86	69.102	6.110	87	69.601	6.109
88	70.099	6.109	89	70.597	6.108	90	71.096	6.107
91	71.594	6.106	92	72.093	6.105	93	72.591	6.104
94	73.089	6.103	95	73.588	6.102	96	74.086	6.101
97	74.584	6.099	98	75.083	6.098	99	75.581	6.097
100	76.079	6.096	101	76.578	6.095	102	77.076	6.093
103	77.574	6.092	104	78.073	6.091	105	78.571	6.089
106	79.069	6.088	107	79.568	6.086	108	80.066	6.085
109	80.564	6.084	110	81.063	6.082	111	81.561	6.080
112	82.059	6.079	113	82.558	6.077	114	83.056	6.076
115	83.555	6.074	116	84.053	6.072	117	84.551	6.071
118	85.050	6.069	119	85.548	6.067	120	86.046	6.065
121	86.545	6.063	122	87.043	6.061	123	87.541	6.060
124	88.040	6.058	125	88.538	6.056	126	89.036	6.054
127	89.535	6.052	128	90.033	6.050	129	90.531	6.048

130	91.030	6.045	131	91.528	6.043	132	92.026	6.041
133	92.525	6.039	134	93.023	6.037	135	93.521	6.034
136	94.020	6.032	137	94.518	6.030	138	95.017	6.027
139	95.515	6.025	140	96.013	6.023	141	96.512	6.020
142	97.010	6.018	143	97.508	6.015	144	98.007	6.013
145	98.505	6.010	146	99.003	6.007	147	99.502	6.005
148	100.000	6.002						

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◆ At 200.000 (hr) Calculation Result

○Safety Factor and Slip Surface
- Safety Factor : 1.575
- Resistance Force (kN) : 210.323
- Sliding Force (kN) : 133.571 (= 130.036 + 30.052 / 8.500)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	40.688	11.149	2	40.777	10.949	3	41.123	10.278
4	41.500	9.678	5	41.582	9.561	6	42.042	8.973
7	42.419	8.561	8	42.796	8.198	9	43.173	7.876
10	43.653	7.518	11	44.132	7.208	12	44.612	6.942
13	44.930	6.786	14	45.091	6.714	15	45.571	6.521
16	46.050	6.361	17	46.530	6.232	18	47.009	6.132
19	47.489	6.060	20	47.968	6.017	21	48.200	6.005
22	48.486	6.000	23	48.823	6.006	24	49.023	6.016
25	49.159	6.026	26	49.175	6.027	27	49.550	6.065
28	49.754	6.093	29	49.934	6.122	30	50.000	6.133
31	50.042	6.141	32	50.132	6.158	33	50.250	6.182
34	50.657	6.278	35	51.064	6.396	36	51.470	6.536
37	51.877	6.700	38	52.368	6.931	39	52.370	6.932
40	52.804	7.170						

○Arc Center (m) : (48.500, 14.500)
○Arc Diameter (m) : 8.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Pressure (kN/m2)	Slice Bottom Water Length (m)
0.089	0.213	-66.044	0.000	0.219
0.346	3.746	-62.761	0.000	0.755
0.377	8.403	-57.828	0.000	0.708
0.082	2.368	-54.956	0.000	0.144
0.460	16.121	-51.958	0.000	0.746
0.377	15.524	-47.560	0.000	0.559
0.377	16.875	-43.913	0.000	0.523
0.377	17.919	-40.478	0.000	0.496
0.480	23.878	-36.789	0.000	0.599
0.480	24.692	-32.847	0.000	0.571
0.479	25.110	-29.073	0.000	0.549
0.319	16.760	-26.028	0.000	0.355
0.161	8.439	-24.238	0.372	0.176
0.480	25.007	-21.902	1.737	0.517
0.480	24.549	-18.456	3.561	0.506
0.480	23.802	-15.078	5.067	0.497
0.479	22.779	-11.754	6.268	0.490
0.480	21.493	-8.469	7.182	0.485
0.480	19.952	-5.211	7.821	0.481
0.232	9.033	-2.806	8.142	0.232
0.286	10.884	-1.058	8.267	0.286
0.337	12.933	1.040	8.337	0.337
0.201	7.815	2.852	8.319	0.201
0.136	5.299	3.989	8.249	0.136
0.016	0.628	4.501	8.207	0.016
0.375	15.313	5.825	8.013	0.377
0.204	7.811	7.791	7.767	0.206
0.180	5.422	9.100	7.636	0.182
0.066	1.626	9.938	7.548	0.067
0.042	0.886	10.308	7.507	0.043
0.090	1.951	10.762	7.401	0.092
0.118	2.360	11.477	7.209	0.120
0.407	7.157	13.290	6.645	0.418
0.407	6.333	16.126	5.641	0.423
0.407	5.339	19.003	4.429	0.430
0.407	4.167	21.931	2.988	0.438
0.491	3.188	25.238	1.104	0.543
0.002	0.010	27.075	0.000	0.003
0.434	0.928	28.751	0.000	0.495

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	5.920	2	33.342	5.920	3	35.877	6.575
4	36.262	6.572	5	36.647	6.603	6	36.961	6.655
7	37.274	6.655	8	37.592	6.656	9	37.982	6.658
10	38.042	6.658	11	38.325	6.660	12	38.608	6.662
13	38.987	6.665	14	39.365	6.670	15	39.744	6.675
16	40.204	6.682	17	40.663	6.690	18	41.123	6.699
19	41.582	6.708	20	42.042	6.718	21	42.419	6.727
22	42.796	6.736	23	43.173	6.745	24	43.653	6.757
25	44.132	6.768	26	44.612	6.779	27	45.091	6.789
28	45.571	6.799	29	46.050	6.809	30	46.530	6.817
31	47.009	6.825	32	47.489	6.832	33	47.968	6.840
34	48.200	6.843	35	48.486	6.848	36	48.823	6.858
37	49.159	6.863	38	49.175	6.863	39	49.550	6.863
40	49.934	6.893	41	50.000	6.901	42	50.042	6.904
43	50.250	6.906	44	50.657	6.910	45	51.064	6.915
46	51.470	6.920	47	51.877	6.925	48	52.370	6.931
49	52.863	6.935	50	53.356	6.947	51	53.754	6.526
52	54.152	6.131	53	54.650	6.131	54	55.149	6.131

55	55.647	6.131	56	56.145	6.131	57	56.644	6.131
58	57.142	6.131	59	57.640	6.131	60	58.139	6.130
61	58.637	6.130	62	59.135	6.130	63	59.634	6.129
64	60.132	6.129	65	60.631	6.129	66	61.129	6.128
67	61.627	6.128	68	62.126	6.127	69	62.624	6.127
70	63.122	6.126	71	63.621	6.126	72	64.119	6.125
73	64.617	6.125	74	65.116	6.124	75	65.614	6.123
76	66.112	6.123	77	66.611	6.122	78	67.109	6.121
79	67.607	6.120	80	68.106	6.119	81	68.604	6.118
82	69.102	6.118	83	69.601	6.117	84	70.099	6.116
85	70.597	6.115	86	71.096	6.114	87	71.594	6.113
88	72.093	6.112	89	72.591	6.110	90	73.089	6.109
91	73.588	6.108	92	74.086	6.107	93	74.584	6.106
94	75.083	6.104	95	75.581	6.103	96	76.079	6.102
97	76.578	6.100	98	77.076	6.099	99	77.574	6.098
100	78.073	6.096	101	78.571	6.095	102	79.069	6.093
103	79.568	6.092	104	80.066	6.090	105	80.564	6.088
106	81.063	6.087	107	81.561	6.085	108	82.059	6.084
109	82.558	6.082	110	83.056	6.080	111	83.555	6.078
112	84.053	6.076	113	84.551	6.075	114	85.050	6.073
115	85.548	6.071	116	86.046	6.069	117	86.545	6.067
118	87.043	6.065	119	87.541	6.063	120	88.040	6.061
121	88.538	6.059	122	89.036	6.057	123	89.535	6.054
124	90.033	6.052	125	90.531	6.050	126	91.030	6.048
127	91.528	6.046	128	92.026	6.043	129	92.525	6.041
130	93.023	6.039	131	93.521	6.036	132	94.020	6.034
133	94.518	6.031	134	95.017	6.029	135	95.515	6.026
136	96.013	6.024	137	96.512	6.021	138	97.010	6.018
139	97.508	6.016	140	98.007	6.013	141	98.505	6.010
142	99.003	6.008	143	99.502	6.005	144	100.000	6.002

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◆ At 224.000 (hr) Calculation Result

○Safety Factor and Slip Surface
- Safety Factor : 1.377
- Resistance Force (kN) : 173.965
- Sliding Force (kN) : 126.348 (= 124.204 + 17.153 / 8.000)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	41.025	11.149	2	41.105	10.949	3	41.123	10.905
4	41.500	10.127	5	41.582	9.982	6	42.042	9.278
7	42.419	8.802	8	42.796	8.391	9	43.173	8.031
10	43.653	7.636	11	43.946	7.422	12	44.132	7.298
13	44.612	7.009	14	45.091	6.763	15	45.571	6.556
16	46.050	6.384	17	46.530	6.246	18	47.009	6.140
19	47.489	6.064	20	47.968	6.018	21	48.200	6.006
22	48.486	6.000	23	48.710	6.003	24	48.823	6.007
25	49.159	6.027	26	49.175	6.029	27	49.497	6.062
28	49.550	6.069	29	49.934	6.130	30	50.000	6.142
31	50.042	6.150	32	50.250	6.194	33	51.064	6.422
34	51.877	6.748	35	51.996	6.804	36	52.665	7.170

○Arc Center (m) : (48.500, 14.000)
○Arc Diameter (m) : 8.000

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Pressure (kN/m2)	Slice Bottom Water Length (m)
0.079	0.191	-68.352	0.000	0.215
0.018	0.094	-67.412	0.000	0.047
0.377	4.749	-64.144	0.000	0.865
0.082	1.722	-60.447	0.000	0.167
0.460	13.118	-56.838	0.000	0.840
0.377	13.672	-51.652	0.000	0.608
0.377	15.404	-47.477	0.000	0.558
0.377	16.739	-43.615	0.000	0.521
0.480	22.699	-39.523	0.000	0.622
0.294	14.499	-35.996	0.000	0.363
0.186	9.337	-33.894	0.707	0.224
0.479	24.586	-31.088	3.098	0.560
0.480	24.982	-27.152	6.310	0.539
0.480	25.007	-23.351	9.160	0.522
0.480	24.692	-19.657	11.659	0.509
0.480	24.058	-16.046	13.712	0.499
0.479	23.114	-12.500	15.178	0.491
0.480	21.874	-9.003	16.052	0.485
0.480	20.343	-5.538	16.259	0.482
0.232	9.218	-2.981	16.088	0.232
0.286	11.102	-1.125	15.774	0.286
0.224	8.752	0.702	15.441	0.224
0.112	4.426	1.907	15.263	0.113
0.337	13.336	3.518	15.088	0.337
0.016	0.638	4.783	14.973	0.016
0.322	13.283	6.001	14.008	0.324
0.053	2.235	7.352	12.887	0.053
0.384	13.225	8.934	11.473	0.389
0.066	1.616	10.567	10.152	0.067
0.042	0.846	10.960	10.043	0.043
0.208	4.316	11.874	9.789	0.213
0.814	13.327	15.663	8.456	0.845
0.813	9.046	21.829	5.739	0.876
0.119	0.892	25.442	3.863	0.132
0.669	2.324	28.646	1.793	0.763

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	9.550	2	36.793	9.550	3	36.961	7.100

4	37.274	7.100	5	37.592	7.093	6	37.982	7.076
7	38.042	7.073	8	38.325	7.068	9	38.608	7.064
10	38.987	7.063	11	39.365	7.067	12	39.744	7.073
13	40.204	7.087	14	40.663	7.108	15	41.123	7.138
16	41.582	7.176	17	42.042	7.223	18	42.419	7.261
19	42.796	7.301	20	43.173	7.342	21	43.653	7.392
22	44.132	7.442	23	44.612	7.496	24	45.091	7.562
25	45.571	7.625	26	46.050	7.693	27	46.530	7.734
28	47.009	7.748	29	47.489	7.730	30	47.968	7.667
31	48.200	7.637	32	48.486	7.586	33	48.823	7.556
34	49.175	7.555	35	49.550	7.367	36	49.934	7.172
37	50.000	7.170	38	53.356	7.170	39	90.033	6.492
40	90.531	6.472	41	91.030	6.451	42	91.528	6.430
43	92.026	6.408	44	92.525	6.386	45	93.023	6.363
46	93.521	6.340	47	94.020	6.317	48	94.518	6.293
49	95.017	6.268	50	95.515	6.244	51	96.013	6.218
52	96.512	6.193	53	97.010	6.167	54	97.508	6.141
55	98.007	6.114	56	98.505	6.087	57	99.003	6.059
58	99.502	6.031	59	100.000	6.002			

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◆ At 226.000 (hr) Calculation Result

○Safety Factor and Slip Surface
- Safety Factor : 1.346
- Resistance Force (kN): 170.306
- Sliding Force (kN) : 126.545 (= 124.401 + 17.153 / 8.000)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	41.025	11.149	2	41.105	10.949	3	41.123	10.905
4	41.500	10.127	5	41.582	9.982	6	42.042	9.278
7	42.419	8.802	8	42.796	8.391	9	43.173	8.031
10	43.653	7.636	11	43.811	7.518	12	44.132	7.298
13	44.612	7.009	14	45.091	6.763	15	45.571	6.556
16	46.050	6.384	17	46.530	6.246	18	47.009	6.140
19	47.489	6.064	20	47.968	6.018	21	48.200	6.006
22	48.486	6.000	23	48.665	6.002	24	48.823	6.007
25	49.159	6.027	26	49.175	6.029	27	49.470	6.059
28	49.550	6.069	29	49.934	6.130	30	50.000	6.142
31	50.042	6.150	32	50.250	6.194	33	51.064	6.422
34	51.877	6.748	35	52.336	6.980	36	52.665	7.170

○Arc Center (m) : (48.500, 14.000)
○Arc Diameter (m) : 8.000

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Water Pressure (kN/m2)	Slice Bottom Length (m)
0.079	0.191	-68.352	0.000	0.215
0.018	0.094	-67.412	0.000	0.047
0.377	4.749	-64.144	0.000	0.865
0.082	1.722	-60.447	0.000	0.167
0.460	13.118	-56.838	0.000	0.840
0.377	13.672	-51.652	0.000	0.608
0.377	15.404	-47.477	0.000	0.558
0.377	16.739	-43.615	0.000	0.521
0.480	22.699	-39.523	0.000	0.622
0.159	7.799	-36.588	0.000	0.198
0.321	16.066	-34.486	1.327	0.389
0.479	24.658	-31.088	4.584	0.560
0.480	25.071	-27.152	8.123	0.539
0.480	25.098	-23.351	11.016	0.522
0.480	24.775	-19.657	13.341	0.509
0.480	24.130	-16.046	15.186	0.499
0.479	23.177	-12.500	16.471	0.491
0.480	21.930	-9.003	17.199	0.485
0.480	20.398	-5.538	17.382	0.482
0.232	9.246	-2.981	17.244	0.232
0.286	11.132	-1.125	16.818	0.286
0.179	7.015	0.542	16.399	0.179
0.157	6.197	1.747	16.249	0.157
0.337	13.369	3.518	16.063	0.337
0.016	0.640	4.783	15.950	0.016
0.295	12.151	5.903	14.781	0.297
0.080	3.390	7.254	13.294	0.080
0.384	13.225	8.934	11.617	0.389
0.066	1.616	10.567	10.173	0.067
0.042	0.846	10.960	10.043	0.043
0.208	4.316	11.874	9.789	0.213
0.814	13.327	15.663	8.456	0.845
0.813	9.046	21.829	5.739	0.876
0.459	2.672	26.811	3.004	0.514
0.329	0.596	30.016	0.933	0.380

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	9.550	2	36.793	9.550	3	36.961	7.170
4	37.274	7.170	5	37.592	7.169	6	37.982	7.167
7	38.042	7.165	8	38.325	7.162	9	38.608	7.161
10	38.987	7.166	11	39.365	7.172	12	39.744	7.183
13	40.204	7.201	14	40.663	7.224	15	41.123	7.251
16	41.582	7.284	17	42.042	7.319	18	42.419	7.350
19	42.796	7.386	20	43.173	7.430	21	43.653	7.493
22	44.132	7.568	23	44.612	7.673	24	45.091	7.755
25	45.571	7.810	26	46.050	7.851	27	46.530	7.877
28	47.009	7.869	29	47.489	7.843	30	47.968	7.784
31	48.200	7.756	32	48.486	7.679	33	48.823	7.655
34	49.175	7.654	35	49.550	7.392	36	49.934	7.176

37	50.000	7.170	38	53.356	7.170	39	90.033	6.492
40	90.531	6.472	41	91.030	6.451	42	91.528	6.430
43	92.026	6.408	44	92.525	6.386	45	93.023	6.363
46	93.521	6.340	47	94.020	6.317	48	94.518	6.293
49	95.017	6.268	50	95.515	6.244	51	96.013	6.219
52	96.512	6.193	53	97.010	6.167	54	97.508	6.141
55	98.007	6.114	56	98.505	6.087	57	99.003	6.059
58	99.502	6.031	59	100.000	6.002			

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◆ At 238.000 (hr) Calculation Result

○Safety Factor and Slip Surface
- Safety Factor : 1.361
- Resistance Force (kN): 172.415
- Sliding Force (kN) : 126.645 (= 124.501 + 17.153 / 8.000)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	41.025	11.149	2	41.105	10.949	3	41.123	10.905
4	41.500	10.127	5	41.582	9.982	6	42.042	9.278
7	42.419	8.802	8	42.796	8.391	9	43.173	8.031
10	43.482	7.769	11	43.653	7.636	12	44.132	7.298
13	44.612	7.009	14	45.091	6.763	15	45.571	6.556
16	46.050	6.384	17	46.530	6.246	18	47.009	6.140
19	47.489	6.064	20	47.968	6.018	21	48.200	6.006
22	48.486	6.000	23	48.748	6.004	24	48.823	6.007
25	49.159	6.027	26	49.175	6.029	27	49.514	6.065
28	49.550	6.069	29	49.934	6.130	30	50.000	6.142
31	50.042	6.150	32	50.250	6.194	33	51.064	6.422
34	51.877	6.748	35	52.665	7.170			

○Arc Center (m) : (48.500, 14.000)
○Arc Diameter (m) : 8.000

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Water Pressure (kN/m2)	Slice Bottom Length (m)
0.079	0.191	-68.352	0.000	0.215
0.018	0.094	-67.412	0.000	0.047
0.377	4.749	-64.144	0.000	0.865
0.082	1.722	-60.447	0.000	0.167
0.460	13.118	-56.838	0.000	0.840
0.377	13.672	-51.652	0.000	0.608
0.377	15.404	-47.477	0.000	0.558
0.377	16.739	-43.615	0.000	0.521
0.309	14.497	-40.298	0.000	0.405
0.170	8.245	-38.072	0.729	0.216
0.480	23.956	-35.195	3.267	0.587
0.479	24.754	-31.088	6.537	0.560
0.480	25.122	-27.152	9.162	0.539
0.480	25.109	-23.351	11.240	0.522
0.480	24.750	-19.657	12.831	0.509
0.480	24.070	-16.046	13.958	0.499
0.479	23.089	-12.500	14.669	0.491
0.480	21.826	-9.003	15.059	0.485
0.480	20.290	-5.538	15.170	0.482
0.232	9.195	-2.981	15.091	0.232
0.286	11.076	-1.125	14.881	0.286
0.262	10.209	0.837	14.611	0.262
0.075	2.940	2.042	14.447	0.075
0.337	13.309	3.518	14.300	0.337
0.016	0.637	4.783	14.190	0.016
0.339	13.986	6.063	13.439	0.341
0.036	1.513	7.414	12.613	0.036
0.384	13.225	8.934	11.362	0.389
0.066	1.616	10.567	10.138	0.067
0.042	0.846	10.960	10.043	0.043
0.208	4.316	11.874	9.789	0.213
0.814	13.327	15.663	8.456	0.845
0.813	9.046	21.829	5.739	0.876
0.788	3.163	28.173	2.071	0.894

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	5.920	2	33.342	5.920	3	33.492	6.649
4	35.342	6.649	5	35.492	6.692	6	35.877	6.744
7	36.262	6.740	8	36.647	6.920	9	36.961	7.365
10	37.274	7.365	11	37.592	7.366	12	37.982	7.368
13	38.042	7.368	14	38.325	7.372	15	38.608	7.374
16	38.987	7.383	17	39.365	7.395	18	39.744	7.411
19	40.204	7.437	20	40.663	7.469	21	41.123	7.509
22	41.582	7.557	23	42.042	7.606	24	42.419	7.654
25	42.796	7.702	26	43.173	7.742	27	43.653	7.785
28	44.132	7.815	29	44.612	7.824	30	45.091	7.815
31	45.571	7.795	32	46.050	7.762	33	46.530	7.716
34	47.009	7.662	35	47.489	7.613	36	47.968	7.563
37	48.200	7.538	38	48.486	7.502	39	48.823	7.475
40	49.175	7.475	41	49.550	7.347	42	49.934	7.169
43	50.000	7.170	44	53.356	7.170	45	53.754	6.985
46	54.152	6.049	47	54.650	6.048	48	55.149	6.048
49	55.647	6.048	50	56.145	6.048	51	56.644	6.048
52	57.142	6.048	53	57.640	6.047	54	58.139	6.047
55	58.637	6.047	56	59.135	6.047	57	59.634	6.047
58	60.132	6.046	59	60.631	6.046	60	61.129	6.046
61	61.627	6.046	62	62.126	6.045	63	62.624	6.045
64	63.122	6.045	65	63.621	6.044	66	64.119	6.044
67	64.617	6.044	68	65.116	6.043	69	65.614	6.043
70	66.112	6.043	71	66.611	6.042	72	67.109	6.042

73	67.607	6.042	74	68.106	6.041	75	68.604	6.041
76	69.102	6.040	77	69.601	6.040	78	70.099	6.040
79	70.597	6.039	80	71.096	6.039	81	71.594	6.038
82	72.093	6.038	83	72.591	6.037	84	73.089	6.037
85	73.588	6.036	86	74.086	6.036	87	74.584	6.035
88	75.083	6.035	89	75.581	6.034	90	76.079	6.034
91	76.578	6.033	92	77.076	6.033	93	77.574	6.032
94	78.073	6.032	95	78.571	6.031	96	79.069	6.030
97	79.568	6.030	98	80.066	6.029	99	80.564	6.029
100	81.063	6.028	101	81.561	6.028	102	82.059	6.027
103	82.558	6.026	104	83.056	6.026	105	83.555	6.025
106	84.053	6.024	107	84.551	6.024	108	85.050	6.023
109	85.548	6.022	110	86.046	6.022	111	86.545	6.021
112	87.043	6.020	113	87.541	6.020	114	88.040	6.019
115	88.538	6.018	116	89.036	6.018	117	89.535	6.017
118	90.033	6.016	119	90.531	6.016	120	91.030	6.015
121	91.528	6.014	122	92.026	6.014	123	92.525	6.013
124	93.023	6.012	125	93.521	6.011	126	94.020	6.011
127	94.518	6.010	128	95.017	6.009	129	95.515	6.009
130	96.013	6.008	131	96.512	6.007	132	97.010	6.006
133	97.508	6.006	134	98.007	6.005	135	98.505	6.004
136	99.003	6.003	137	99.502	6.003	138	100.000	6.002

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○3. Slip Surface with the minimum Safety Factor

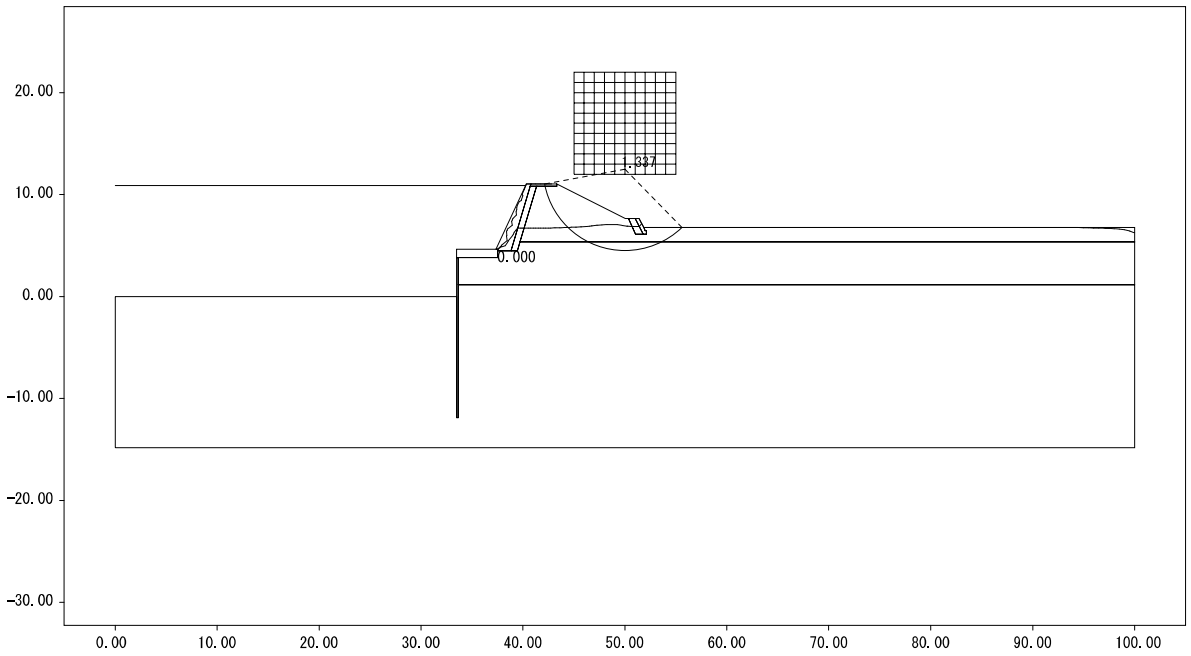
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○ Time (hr) : 226.000
○Safety Factor : 1.346
○Search Area : 1
○Center (m) : (48.500, 14.000)
○ Diameter (m) : 8

1.2.1 SLOPE STABILITY　ANALYSIS

1.2.1.2　Flood Conditions (Seepage)

(3)　R10+960



(Calculation Result)

Title	R10+960				
Note					
Calculation Method	Slope Stability Calculation+ Seepage Analysis	Output Time	226.000 (hr)	Safety Factor	1.337
Output Items	Soil Layer Diagram, Water Level, Slip Surface				

Slope Stability Analysis considering Seepage

Data Sheet

◆ Basic Calculation Conditions

○Title : R10+960

○Note :

○Calculation Type : Seepage Analysis + Slope Stability Calculation
○Seepage Type : Nonstationary Seepage
○Time Unit : hr
○Stress Type : Total Stress
○Safety Factor Formula : Modified Fellenius' Method
○Unit : SI Unit
○Unsaturated Permeability : θ-Kr, θ-ψ

◆ Node

○Node : 40

○Node axis No

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	0.000	2	33.492	0.000
3	33.492	3.831	4	33.492	4.631
5	37.342	4.631	6	37.492	4.631
7	37.492	4.484	8	37.492	3.831
9	33.642	3.831	10	33.642	1.131
11	40.328	11.027	12	40.778	11.027
13	40.718	10.827	14	41.345	10.827
15	43.328	10.827	16	43.328	11.027
17	38.815	4.484	18	39.442	4.484
19	39.705	5.360	20	50.051	7.666
21	50.336	7.666	22	51.025	6.116
23	51.785	6.116	24	51.010	7.666
25	51.401	7.666	26	52.001	6.466
27	52.101	6.466	28	52.101	6.116
29	51.851	6.766	30	100.000	6.766
31	100.000	5.360	32	100.000	1.131
33	100.000	-14.848	34	33.642	-11.869
35	33.492	-11.869	36	0.000	-14.848
37	52.300	6.766	38	52.300	6.266
39	52.800	6.266	40	52.800	6.766

◆ Soil Layer

○No. of Soil Layers : 10

○Layer No. : 1
○Layer Name : Co
○Nodes : 3, 4, 5, 6, 7, 8, 9

○Layer No. : 2
○Layer Name : Co
○Nodes : 11, 12, 13, 17, 7, 6, 5

○Layer No. : 3
○Layer Name : SSP
○Nodes : 2, 3, 9, 10, 34, 35

○Layer No. : 4
○Layer Name : Gr
○Nodes : 13, 14, 19, 18, 17

○Layer No. : 5
○Layer Name : PCCP
○Nodes : 16, 15, 14, 13, 12

○Layer No. : 6
○Layer Name : B
○Nodes : 14, 15, 16, 20, 21, 22, 23, 28, 27, 26,
: 29, 30, 31, 19

○Layer No. : 7
○Layer Name : As
○Nodes : 10, 9, 8, 7, 17, 18, 19, 31, 32

○Layer No. : 8
○Layer Name : Dc
○Nodes : 1, 2, 35, 34, 10, 32, 33, 36

○Layer No. : 9
○Layer Name : Co
○Nodes : 23, 24, 25, 29, 26, 27, 28

○Layer No. : 10
○Layer Name : Gr
○Nodes : 24, 23, 22, 21

◆ Hole

○Hole : 0

◆ Soil Constants

○Layer No. : 1
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 24.000
○Sat. Unit Weight(kN/m3) : 24.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 2
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 24.000
○Sat. Unit Weight(kN/m3) : 24.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 3
○Layer Name : SSP
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000

8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 2.000E-006
○Saturated h.c. ky (cm/s) : 2.000E-006
○Specific Storage Coef. Ss (1/m) : 2.000E-008

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 77.000
○Sat. Unit Weight(kN/m3) : 77.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 4
○Layer Name : Gr
○Unsaturated Permeability : gravel/sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.049	-12.000
3	0.020	0.020	3	0.050	-1.900
4	0.030	0.030	4	0.056	-1.500
5	0.040	0.040	5	0.068	-1.000
6	0.050	0.050	6	0.078	-0.800
7	0.060	0.060	7	0.084	-0.700
8	0.070	0.080	8	0.090	-0.600
9	0.080	0.090	9	0.100	-0.500
10	0.090	0.110	10	0.112	-0.400
11	0.100	0.130	11	0.126	-0.300
12	0.110	0.160	12	0.136	-0.250
13	0.120	0.190	13	0.150	-0.200
14	0.130	0.230	14	0.164	-0.150
15	0.140	0.290	15	0.178	-0.100
16	0.150	0.360	16	0.190	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-001
○Saturated h.c. ky (cm/s) : 1.000E-001
○Specific Storage Coef. Ss (1/m) : 1.000E-003

○Cohesion c(kN/m2) : 0.000
○Friction Angle φ(°) : 35.000
○Wet Weight(kN/m3) : 19.000
○Sat. Unit Weight(kN/m3) : 20.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 5
○Layer Name : PCCP
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007

○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1.000
○Friction Angle φ(°) : 30.000
○Wet Weight(kN/m3) : 24.000
○Sat.Unit Weight(kN/m3) : 24.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 6
○Layer Name : B
○Unsaturated Permeability : gravel/sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.049	-12.000
3	0.020	0.020	3	0.050	-1.900
4	0.030	0.030	4	0.056	-1.500
5	0.040	0.040	5	0.068	-1.000
6	0.050	0.050	6	0.078	-0.800
7	0.060	0.060	7	0.084	-0.700
8	0.070	0.080	8	0.090	-0.600
9	0.080	0.090	9	0.100	-0.500
10	0.090	0.110	10	0.112	-0.400
11	0.100	0.130	11	0.126	-0.300
12	0.110	0.160	12	0.136	-0.250
13	0.120	0.190	13	0.150	-0.200
14	0.130	0.230	14	0.164	-0.150
15	0.140	0.290	15	0.178	-0.100
16	0.150	0.360	16	0.190	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-003
○Saturated h.c. ky (cm/s) : 1.000E-003
○Specific Storage Coef. Ss (1/m) : 1.000E-005

○Cohesion c(kN/m2) : 1.000
○Friction Angle φ(°) : 30.000
○Wet Weight(kN/m3) : 18.000
○Sat. Unit Weight(kN/m3) : 19.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 7
○Layer Name : As
○Unsaturated Permeability : silty sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.119	-12.000
3	0.020	0.020	3	0.120	-1.900
4	0.030	0.030	4	0.123	-1.500
5	0.040	0.040	5	0.129	-1.000
6	0.050	0.050	6	0.135	-0.800
7	0.060	0.060	7	0.138	-0.700
8	0.070	0.080	8	0.141	-0.600
9	0.080	0.090	9	0.146	-0.500
10	0.090	0.110	10	0.153	-0.400
11	0.100	0.130	11	0.160	-0.300
12	0.110	0.160	12	0.166	-0.250
13	0.120	0.190	13	0.173	-0.200
14	0.130	0.230	14	0.181	-0.150
15	0.140	0.290	15	0.188	-0.100
16	0.150	0.360	16	0.195	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-001
○Saturated h.c. ky (cm/s) : 1.000E-001
○Specific Storage Coef. Ss (1/m) : 1.000E-003

○Cohesion c(kN/m2) : 0.000
○Friction Angle φ(°) : 27.000
○Wet Weight(kN/m3) : 17.500
○Sat. Unit Weight(kN/m3) : 18.500
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 8
○Layer Name : Dc
○Unsaturated Permeability : diluvial clay
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.135	0.000	1	0.135	-900.000
2	0.153	0.000	2	0.153	-300.000
3	0.177	0.000	3	0.177	-100.000
4	0.226	0.000	4	0.226	-20.000
5	0.285	0.000	5	0.285	-5.000
6	0.313	0.000	6	0.313	-3.000
7	0.336	0.000	7	0.336	-2.000
8	0.354	0.000	8	0.354	-1.500
9	0.380	0.001	9	0.380	-1.000
10	0.404	0.001	10	0.404	-0.700
11	0.426	0.003	11	0.426	-0.500
12	0.440	0.004	12	0.440	-0.400
13	0.448	0.006	13	0.448	-0.350
14	0.457	0.008	14	0.457	-0.300

15	0.465	0.011	15	0.465	-0.260
16	0.472	0.013	16	0.472	-0.230
17	0.479	0.017	17	0.479	-0.200
18	0.484	0.020	18	0.484	-0.180
19	0.489	0.024	19	0.489	-0.160
20	0.494	0.030	20	0.494	-0.140
21	0.500	0.037	21	0.500	-0.120
22	0.506	0.047	22	0.506	-0.100
23	0.512	0.062	23	0.512	-0.080
24	0.518	0.085	24	0.518	-0.060
25	0.524	0.123	25	0.524	-0.040
26	0.530	0.199	26	0.530	-0.020
27	0.533	0.283	27	0.533	-0.010
28	0.535	1.000	28	0.535	0.000

○Saturated h.c. kx (cm/s) : 1.000E-006
○Saturated h.c. ky (cm/s) : 1.000E-006
○Specific Storage Coef. Ss (1/m) : 1.000E-008

○Cohesion c(kN/m2) : 100.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 18.000
○Sat. Unit Weight(kN/m3) : 19.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 9
○Layer Name : Co
○Unsaturated Permeability : mudstone
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.031	0.000	1	0.031	-900.000
2	0.038	0.000	2	0.038	-300.000
3	0.048	0.000	3	0.048	-100.000
4	0.078	0.000	4	0.078	-20.000
5	0.128	0.000	5	0.128	-5.000
6	0.155	0.000	6	0.155	-3.000
7	0.182	0.000	7	0.182	-2.000
8	0.204	0.000	8	0.204	-1.500
9	0.240	0.000	9	0.240	-1.000
10	0.276	0.000	10	0.276	-0.700
11	0.313	0.001	11	0.313	-0.500
12	0.340	0.002	12	0.340	-0.400
13	0.356	0.003	13	0.356	-0.350
14	0.375	0.005	14	0.375	-0.300
15	0.393	0.007	15	0.393	-0.260
16	0.408	0.010	16	0.408	-0.230
17	0.425	0.014	17	0.425	-0.200
18	0.437	0.018	18	0.437	-0.180
19	0.450	0.023	19	0.450	-0.160
20	0.465	0.030	20	0.465	-0.140
21	0.480	0.041	21	0.480	-0.120
22	0.497	0.057	22	0.497	-0.100
23	0.515	0.082	23	0.515	-0.080
24	0.534	0.123	24	0.534	-0.060
25	0.552	0.195	25	0.552	-0.040
26	0.569	0.338	26	0.569	-0.020
27	0.576	0.478	27	0.576	-0.010
28	0.580	1.000	28	0.580	0.000

○Saturated h.c. kx (cm/s) : 1.000E-007
○Saturated h.c. ky (cm/s) : 1.000E-007
○Specific Storage Coef. Ss (1/m) : 1.000E-009

○Cohesion c(kN/m2) : 1000.000
○Friction Angle φ(°) : 0.000
○Wet Weight(kN/m3) : 24.000
○Sat. Unit Weight(kN/m3) : 24.000
○Water Unit Weight(kN/m3) : 9.807

○Layer No. : 10
○Layer Name : Gr
○Unsaturated Permeability : gravel/sand
○Table of Unsaturated Permeability

No	θ	kr	No	θ	ψ(m)
1	0.000	0.000	1	0.000	-500.000
2	0.010	0.010	2	0.049	-12.000
3	0.020	0.020	3	0.050	-1.900
4	0.030	0.030	4	0.056	-1.500
5	0.040	0.040	5	0.068	-1.000
6	0.050	0.050	6	0.078	-0.800
7	0.060	0.060	7	0.084	-0.700
8	0.070	0.080	8	0.090	-0.600
9	0.080	0.090	9	0.100	-0.500
10	0.090	0.110	10	0.112	-0.400
11	0.100	0.130	11	0.126	-0.300
12	0.110	0.160	12	0.136	-0.250
13	0.120	0.190	13	0.150	-0.200
14	0.130	0.230	14	0.164	-0.150
15	0.140	0.290	15	0.178	-0.100
16	0.150	0.360	16	0.190	-0.050
17	0.160	0.450	17	0.200	0.000
18	0.170	0.550			
19	0.180	0.650			
20	0.190	0.800			
21	0.200	1.000			

○Saturated h.c. kx (cm/s) : 1.000E-001
○Saturated h.c. ky (cm/s) : 1.000E-001
○Specific Storage Coef. Ss (1/m) : 1.000E-003

○Cohesion c(kN/m2) : 0.000
○Friction Angle φ(°) : 35.000
○Wet Weight(kN/m3) : 19.000
○Sat. Unit Weight(kN/m3) : 20.000

○Water Unit Weight (kN/m3) : 9.807

◆ FEM Elements

○Soil Layer Elements Size

Layer No.	xDirection (m)	yDirection (m)
1	0.500	0.500
2	0.500	0.500
3	0.500	0.500
4	0.500	0.500
5	0.500	0.500
6	0.500	0.500
7	0.500	0.500
8	0.500	0.500
9	0.500	0.500
10	0.500	0.500

○Element Shape : Triangle + Square

○Partial Area

No	Min. x axis (m)	Min. y axis (m)	Max. x axis (m)	Max. y axis (m)	Element Size xDirection (m) yDirection (m)

○Internal Node : 37, 38, 39, 40

◆ Initial Water Level

○ Water Level : 6

N	x axis (m)	y axis (m)
1	0.000	2.777
2	33.600	2.770
3	33.600	4.000
4	37.600	4.000
5	39.200	6.266
6	100.000	6.266

◆ Seepage Surface

○Seepage Surface : 1

○Seepage Surface No : 1
○Nodes : 1, 2, 3, 4, 5, 11, 12, 16, 20, 21,
: 24, 25, 29, 30

◆ Water Level Fix

○ Water Level Fixed : 1

○ Water Level Fix No : 1
○ Water Level (m) : 6.265
○ Nodes : 30, 31, 32

◆ Water Level Changing Point

○ No. of Water Level Changing Point : 1

○ Water Level Changing Point No. :
○Nodes : 1, 2, 3, 4, 5, 11

○temporal variation

No	Time (hr)	Water Level (m)
1	0.000	2.771
2	206.000	2.771
3	225.000	10.894
4	226.000	10.894
5	248.000	2.771
6	270.000	2.771

◆ Rain Penetration Line

○No. of Rain Penetration Line : 1

○Rain Penetration Line No : 1
○Nodes : 4, 5, 11, 12, 16, 20, 21, 24, 25, 29,
: 30

○temporal variation

No	Time (hr)	Rainfall (mm)
1	200.000	1.000
2	226.000	10.000
3	270.000	0.000

◆ Repeat Calculation

○Timestep

- Min. : 0.010
- Max. : 10.000
- Allowable Error (m) : 0.100
- Max. Repeat : 10

◆ Slip Surface Conditions

○ Merginal Slip Surface (Center ・ Diameter)

○No. of Search Area : 1

No	x axis Min. (m)	x axis Max. (m)	x axis Variation (m)	y axis Min. (m)	y axis Max. (m)	y axis Variation (m)
1	45.000	55.000	1.000	12.000	22.000	1.000

No	Diameter Min. (m)	Diameter Max. (m)	Diameter Variation (m)
1	5.000	25.000	1.000

○Slip Surface Limit

	x axis (m)	y axis (m)
must cut line [OFF]	—	
must not cut line [ON]		
1	43.328	11.027
2	50.051	7.666

○Max. Depth (m) : 0.000
○Search Time : 1
○Slice Width (m) : 1.000

◆ Load

○No. of Loads : 1

	Left end (m)	Right end (m)	Load (kN/m2)
1	40.800	42.800	5.000

◆ Tension Crack

○Tension Crack : 0

◆ Seismic Force

○Horizontal Seismic Coef. : 0.000
○Vertical Seismic Coef. : 0.000

◆ Output Time

○Output Time : 6

No	Seepage Cal.	Stability Cal.
1	1.000	◎
2	10.000	◎
3	225.000	◎
4	226.000	◎
5	248.000	◎
6	270.000	

Slope Stability Analysis considering Seepage

Slope Stability Calculation

○ 1. Input Data

◆ Title

R10+960

◆ Calculation Type

Seepage Analysis + Slope Stability Calculation

◆ Safety Factor Formula

Modified Fellenius' Method

◆ Unit

SI Unit

◆ Node

○No. of Nodes : 40

○Node axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	0.000	2	33.492	0.000
3	33.492	3.831	4	33.492	4.631
5	37.342	4.631	6	37.492	4.631
7	37.492	4.484	8	37.492	3.831
9	33.642	3.831	10	33.642	1.131
11	40.328	11.027	12	40.778	11.027
13	40.718	10.827	14	41.345	10.827
15	43.328	10.827	16	43.328	11.027
17	38.815	4.484	18	39.442	4.484
19	39.705	5.360	20	50.051	7.666
21	50.336	7.666	22	51.025	6.116
23	51.785	6.116	24	51.010	7.666
25	51.401	7.666	26	52.001	6.466
27	52.101	6.466	28	52.101	6.116
29	51.851	6.766	30	100.000	6.766
31	100.000	5.360	32	100.000	1.131
33	100.000	-14.848	34	33.642	-11.869
35	33.492	-11.869	36	0.000	-14.848
37	52.300	6.766	38	52.300	6.266
39	52.800	6.266	40	52.800	6.766

◆ Soil Layer

○No. of Soil Layers : 10

○Layer No. : 1
○Layer Name : Co
○Nodes : 3, 4, 5, 6, 7, 8, 9

○Layer No. : 2
○Layer Name : Co
○Nodes : 11, 12, 13, 17, 7, 6, 5

○Layer No. : 3
○Layer Name : SSP
○Nodes : 2, 3, 9, 10, 34, 35

○Layer No. : 4
○Layer Name : Gr
○Nodes : 13, 14, 19, 18, 17

○Layer No. : 5
○Layer Name : PCCP
○Nodes : 16, 15, 14, 13, 12

○Layer No. : 6
○Layer Name : B
○Nodes : 14, 15, 16, 20, 21, 22, 23, 28, 27, 26,
: 29, 30, 31, 19

○Layer No. : 7
○Layer Name : As
○Nodes : 10, 9, 8, 7, 17, 18, 19, 31, 32

○Layer No. : 8
○Layer Name : Dc
○Nodes : 1, 2, 35, 34, 10, 32, 33, 36

○Layer No. : 9
○Layer Name : Co
○Nodes : 23, 24, 25, 29, 26, 27, 28

○Layer No. : 10
○Layer Name : Gr
○Nodes : 24, 23, 22, 21

◆ Hole

○Hole : 0

◆ Soil Constants

○Soil Layer : 1
Layer Name : Co
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer : 2
Layer Name : Co
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer : Soil 3
Cohesion (kN/m2) : SSP
: 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 77.00
Sat. Unit Weight (kN/m3) : 77.00

○Soil Layer : 4
Layer Name : Gr
Cohesion (kN/m2) : 0.00
Friction Angle (°) : 35.00
Wet Weight (kN/m3) : 19.00
Sat. Unit Weight (kN/m3) : 20.00

○Soil Layer : 5
Layer Name : PCCP
Cohesion (kN/m2) : 1.00
Friction Angle (°) : 30.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer : 6
Layer Name : B
Cohesion (kN/m2) : 1.00
Friction Angle (°) : 30.00
Wet Weight (kN/m3) : 18.00
Sat. Unit Weight (kN/m3) : 19.00

○Soil Layer : 7
Layer Name : As
Cohesion (kN/m2) : 0.00
Friction Angle (°) : 27.00
Wet Weight (kN/m3) : 17.50
Sat. Unit Weight (kN/m3) : 18.50

○Soil Layer : 8
Layer Name : Dc
Cohesion (kN/m2) : 100.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 18.00
Sat. Unit Weight (kN/m3) : 19.00

○Soil Layer : 9
Layer Name : Co
Cohesion (kN/m2) : 1000.00
Friction Angle (°) : 0.00
Wet Weight (kN/m3) : 24.00
Sat. Unit Weight (kN/m3) : 24.00

○Soil Layer : 10
Layer Name : Gr
Cohesion (kN/m2) : 0.00
Friction Angle (°) : 35.00
Wet Weight (kN/m3) : 19.00
Sat. Unit Weight (kN/m3) : 20.00

◆ Slip Surface Conditions

○Merginal Slip Surface (Center - Diameter)

○ Search Area : 1

No	x axis Min. (m)	x axis Max. (m)	x axis Variation (m)	y axis Min. (m)	y axis Max. (m)	y axis Variation (m)
1	45.000	55.000	1.000	12.000	22.000	1.000

No	Diameter Min. (m)	Diameter Max. (m)	Diameter Variation (m)
1	5.000	25.000	1.000

○Slip Surface Limit
x axis (m) y axis (m)

Search Area1
must cut line
[OFF] —
must not cut line [ON]

1	43.328	11.027
2	50.051	7.666

○Max. Depth (m) : 0.000
○Search Time : 1
○Slice Width (m) : 1.000

◆ Calculation Time

○Tame to conduct Stability Cal. : 5

no	Time (hour)	no	Time (hour)	no	Time (hour)	no	Time (hour)	no	Time (hour)
1	1.000	2	10.000	3	225.000	4	226.000	5	248.000

◆ Load

○No. of Load : 1

	Left end (m)	Right end (m)	Load (kN/m2)
1	40.800	42.800	5.000

◆ Tension Crack

○Tension Crack : 0

◆ Seismic Force

○Horizontal Seismic Coef. : 0.000
○Vertical Seismic Coef. : 0.000

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○2. Calculation Result
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◆ Min.Safety Factor and Slip Surface

◆ At 1.000(hr) Calculation Result

○Safety Factor and Slip Surface
- Safety Factor : 1.508
- Resistance Force (kN) : 291.555
- Sliding Force (kN) : 193.329 (= 188.471 + 41.293 / 8.500)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	41.732	11.027	2	41.782	10.827	3	41.841	10.617
4	42.337	9.323	5	42.800	8.482	6	42.832	8.431
7	43.328	7.734	8	43.808	7.177	9	44.288	6.705
10	44.769	6.301	11	44.914	6.190	12	45.249	5.952
13	45.729	5.651	14	46.209	5.392	15	46.274	5.360
16	46.690	5.171	17	47.170	4.985	18	47.650	4.831
19	48.130	4.708	20	48.610	4.614	21	49.091	4.549
22	49.571	4.511	23	50.051	4.500	24	50.336	4.507
25	50.673	4.527	26	50.981	4.557	27	51.010	4.560
28	51.025	4.562	29	51.401	4.616	30	51.732	4.678
31	51.785	4.690	32	51.851	4.704	33	52.001	4.739
34	52.101	4.764	35	52.600	4.907	36	53.099	5.085
37	53.598	5.299	38	53.726	5.360	39	54.097	5.552
40	54.596	5.850	41	55.095	6.196	42	55.129	6.222
43	55.594	6.600	44	55.778	6.766			

○Arc Center (m) : (50.000, 13.000)
○Arc Diameter (m) : 8.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Pressure (kN/m2)	Slice Bottom Water Length (m)
0.050	0.121	-75.883	0.000	0.206
0.058	0.390	-74.455	0.000	0.218
0.496	10.025	-69.045	0.000	1.386
0.463	18.280	-61.130	0.000	0.960
0.032	1.531	-57.690	0.000	0.060
0.496	26.871	-54.601	0.000	0.856
0.480	29.837	-49.236	0.000	0.735
0.480	32.208	-44.487	0.000	0.673
0.480	33.919	-40.101	0.000	0.628
0.145	10.514	-37.370	0.000	0.183
0.335	24.649	-35.369	1.173	0.411
0.480	36.019	-32.073	3.830	0.567
0.480	36.498	-28.324	6.592	0.546

0.065	4.966	-26.241	8.028	0.073
0.415	31.637	-24.459	9.119	0.456
0.480	36.327	-21.185	10.973	0.515
0.480	35.763	-17.750	12.654	0.504
0.480	34.918	-14.379	14.024	0.496
0.480	33.807	-11.059	15.097	0.489
0.480	32.440	-7.776	15.893	0.485
0.480	30.826	-4.518	16.424	0.482
0.480	28.968	-1.275	16.685	0.480
0.285	16.588	1.305	16.722	0.285
0.337	19.660	3.403	16.588	0.338
0.308	18.027	5.583	16.375	0.309
0.029	1.724	6.724	16.258	0.030
0.015	0.870	6.875	16.236	0.015
0.376	22.637	8.207	15.960	0.380
0.331	18.136	10.624	15.410	0.337
0.053	2.452	11.941	15.078	0.054
0.066	2.892	12.350	14.994	0.068
0.150	6.132	13.097	14.756	0.154
0.100	3.942	13.963	14.388	0.103
0.499	17.894	16.061	13.511	0.519
0.499	16.411	19.596	11.937	0.530
0.499	14.605	23.212	10.040	0.543
0.128	3.416	25.519	8.706	0.142
0.371	9.033	27.405	7.473	0.418
0.499	9.824	30.772	5.086	0.581
0.499	6.774	34.777	1.942	0.607
0.034	0.341	36.968	0.125	0.042
0.465	2.974	39.132	0.000	0.600
0.185	0.276	41.990	0.000	0.248

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	2.771	2	33.492	2.771	3	33.642	4.317
4	34.105	4.461	5	34.567	4.459	6	35.030	4.462
7	35.492	4.460	8	35.955	4.462	9	36.417	4.460
10	36.880	4.461	11	37.342	4.550	12	37.492	4.590
13	37.933	4.861	14	38.374	5.096	15	38.815	5.714
16	39.129	6.073	17	39.442	6.083	18	39.705	6.082
19	40.017	6.089	20	40.328	6.116	21	40.718	6.152
22	40.778	6.154	23	41.062	6.166	24	41.345	6.172
25	41.841	6.175	26	42.337	6.179	27	42.832	6.181
28	43.328	6.183	29	43.808	6.185	30	44.288	6.187
31	44.769	6.189	32	45.249	6.191	33	45.729	6.193
34	46.209	6.195	35	46.690	6.196	36	47.170	6.198
37	47.650	6.199	38	48.130	6.200	39	48.610	6.201
40	49.091	6.203	41	49.571	6.206	42	50.051	6.208
43	50.336	6.209	44	50.673	6.207	45	51.010	6.217
46	51.025	6.217	47	51.401	6.216	48	51.785	6.222
49	51.851	6.229	50	52.001	6.223	51	52.101	6.214
52	52.600	6.212	53	53.099	6.215	54	53.598	6.217
55	54.097	6.219	56	54.596	6.220	57	55.095	6.221
58	55.594	6.223	59	56.093	6.224	60	56.592	6.225
61	57.090	6.226	62	57.589	6.227	63	58.088	6.228
64	58.587	6.229	65	59.086	6.230	66	59.585	6.231
67	60.084	6.232	68	60.583	6.233	69	61.082	6.234
70	61.581	6.235	71	62.080	6.236	72	62.579	6.236
73	63.078	6.237	74	63.577	6.238	75	64.076	6.239
76	64.575	6.240	77	65.074	6.240	78	65.573	6.241
79	66.072	6.242	80	66.570	6.242	81	67.069	6.243
82	67.568	6.244	83	68.067	6.244	84	68.566	6.245
85	69.065	6.246	86	69.564	6.246	87	70.063	6.247
88	70.562	6.248	89	71.061	6.248	90	71.560	6.249
91	72.059	6.249	92	72.558	6.250	93	73.057	6.250
94	73.556	6.251	95	74.055	6.251	96	74.554	6.252
97	75.053	6.252	98	75.552	6.253	99	76.051	6.253
100	76.549	6.254	101	77.048	6.254	102	77.547	6.255
103	78.046	6.255	104	78.545	6.255	105	79.044	6.256
106	79.543	6.256	107	80.042	6.257	108	80.541	6.257
109	81.040	6.257	110	81.539	6.258	111	82.038	6.258
112	82.537	6.258	113	83.036	6.259	114	83.535	6.259
115	84.034	6.260	116	84.533	6.260	117	85.032	6.260
118	85.531	6.261	119	86.029	6.261	120	86.528	6.261
121	87.027	6.261	122	87.526	6.262	123	88.025	6.262
124	88.524	6.262	125	89.023	6.263	126	89.522	6.263
127	90.021	6.263	128	90.520	6.264	129	91.019	6.264
130	91.518	6.264	131	92.017	6.264	132	92.516	6.265
133	93.015	6.265	134	93.514	6.265	135	94.013	6.266
136	94.512	6.266	137	95.011	6.266	138	95.509	6.266
139	96.008	6.267	140	96.507	6.267	141	97.006	6.267
142	97.505	6.267	143	98.004	6.268	144	98.503	6.268
145	99.002	6.268	146	99.501	6.268	147	100.000	6.265

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◆ At 10.000(hr) Calculation Result

○Safety Factor and Slip Surface
- Safety Factor : 1.495
- Resistance Force (kN) : 288.932
- Sliding Force (kN) : 193.330 (= 188.472 + 41.293 / 8.500)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	41.732	11.027	2	41.782	10.827	3	41.841	10.617
4	42.337	9.323	5	42.800	8.482	6	42.832	8.431
7	43.328	7.734	8	43.808	7.177	9	44.288	6.705
10	44.769	6.301	11	44.831	6.253	12	45.249	5.952
13	45.729	5.651	14	46.209	5.392	15	46.274	5.360
16	46.690	5.171	17	47.170	4.985	18	47.650	4.831
19	48.130	4.708	20	48.610	4.614	21	49.091	4.549
22	49.571	4.511	23	50.051	4.500	24	50.336	4.507

25	50.673	4.527	26	50.957	4.554	27	51.010	4.560
28	51.025	4.562	29	51.401	4.616	30	51.707	4.673
31	51.785	4.690	32	51.851	4.704	33	52.001	4.739
34	52.101	4.764	35	52.600	4.907	36	53.099	5.085
37	53.598	5.299	38	53.726	5.360	39	54.097	5.552
40	54.596	5.850	41	55.095	6.196	42	55.204	6.279
43	55.594	6.600	44	55.778	6.766			

○Arc Center (m) : (50.000, 13.000)
○Arc Diameter (m) : 8.500

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Pressure (kN/m2)	Slice Bottom Water Length(m)
0.050	0.121	-75.883	0.000	0.206
0.058	0.390	-74.455	0.000	0.218
0.496	10.025	-69.045	0.000	1.386
0.463	18.280	-61.130	0.000	0.960
0.032	1.531	-57.690	0.000	0.060
0.496	26.871	-54.601	0.000	0.856
0.480	29.837	-49.236	0.000	0.735
0.480	32.208	-44.487	0.000	0.673
0.480	33.919	-40.101	0.000	0.628
0.062	4.475	-37.721	0.000	0.078
0.418	30.700	-35.721	1.479	0.515
0.480	36.049	-32.073	4.438	0.567
0.480	36.528	-28.324	7.191	0.546
0.065	4.970	-26.241	8.621	0.073
0.415	31.662	-24.459	9.708	0.456
0.480	36.356	-21.185	11.554	0.515
0.480	35.791	-17.750	13.228	0.504
0.480	34.946	-14.379	14.593	0.496
0.480	33.835	-11.059	15.665	0.489
0.480	32.468	-7.776	16.453	0.485
0.480	30.853	-4.518	16.962	0.482
0.480	28.994	-1.275	17.205	0.480
0.285	16.603	1.305	17.232	0.285
0.337	19.678	3.403	17.131	0.338
0.284	16.648	5.502	16.940	0.285
0.053	3.123	6.644	16.795	0.054
0.015	0.871	6.875	16.759	0.015
0.376	22.657	8.207	16.484	0.380
0.306	16.903	10.535	15.953	0.311
0.078	3.703	11.852	15.611	0.080
0.066	2.892	12.350	15.477	0.068
0.150	6.132	13.097	15.266	0.154
0.100	3.942	13.963	14.990	0.103
0.499	17.927	16.061	14.170	0.519
0.499	16.445	19.596	12.594	0.530
0.499	14.637	23.212	10.664	0.543
0.128	3.424	25.519	9.310	0.142
0.371	9.056	27.405	8.065	0.418
0.499	9.853	30.772	5.664	0.581
0.499	6.803	34.777	2.510	0.607
0.109	1.041	37.287	0.406	0.137
0.390	2.292	39.451	0.000	0.505
0.185	0.276	41.990	0.000	0.248

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	2.771	2	33.492	2.771	3	33.642	4.373
4	34.105	4.509	5	34.567	4.499	6	35.030	4.518
7	35.492	4.499	8	35.955	4.518	9	36.417	4.499
10	36.880	4.507	11	37.342	4.593	12	37.492	4.593
13	37.933	4.870	14	38.374	5.098	15	38.815	5.731
16	39.129	6.131	17	39.442	6.260	18	39.705	6.260
19	40.017	6.259	20	40.328	6.253	21	40.718	6.248
22	41.062	6.246	23	41.345	6.246	24	41.841	6.246
25	42.337	6.247	26	42.832	6.248	27	43.328	6.249
28	43.808	6.250	29	44.288	6.251	30	44.769	6.253
31	45.249	6.253	32	45.729	6.254	33	46.209	6.255
34	46.690	6.256	35	47.170	6.257	36	47.650	6.257
37	48.130	6.258	38	48.610	6.259	39	49.091	6.259
40	49.571	6.259	41	50.051	6.260	42	50.336	6.261
43	50.673	6.266	44	51.010	6.270	45	51.025	6.270
46	51.401	6.270	47	51.785	6.273	48	51.851	6.276
49	52.001	6.280	50	52.101	6.280	51	52.600	6.281
52	53.099	6.280	53	53.598	6.279	54	54.097	6.278
55	54.596	6.279	56	55.095	6.279	57	55.594	6.279
58	56.093	6.280	59	56.592	6.280	60	57.090	6.280
61	57.589	6.281	62	58.088	6.281	63	58.587	6.282
64	59.086	6.282	65	59.585	6.282	66	60.084	6.283
67	60.583	6.283	68	61.082	6.283	69	61.581	6.284
70	62.080	6.284	71	62.579	6.284	72	63.078	6.285
73	63.577	6.285	74	64.076	6.285	75	64.575	6.286
76	65.074	6.286	77	65.573	6.286	78	66.072	6.287
79	66.570	6.287	80	67.069	6.287	81	67.568	6.287
82	68.067	6.288	83	68.566	6.288	84	69.065	6.288
85	69.564	6.288	86	70.063	6.289	87	70.562	6.289
88	71.061	6.289	89	71.560	6.289	90	72.059	6.290
91	72.558	6.290	92	73.057	6.290	93	73.556	6.290
94	74.055	6.290	95	74.554	6.291	96	75.053	6.291
97	75.552	6.291	98	76.051	6.291	99	76.549	6.291
100	77.048	6.292	101	77.547	6.292	102	78.046	6.292
103	78.545	6.292	104	79.044	6.292	105	79.543	6.292
106	80.042	6.293	107	80.541	6.293	108	81.040	6.293
109	81.539	6.293	110	82.038	6.293	111	82.537	6.293
112	83.036	6.293	113	83.535	6.293	114	84.034	6.293
115	84.533	6.293	116	85.032	6.293	117	85.531	6.293
118	86.029	6.293	119	86.528	6.293	120	87.027	6.293
121	87.526	6.293	122	88.025	6.293	123	88.524	6.293
124	89.023	6.293	125	89.522	6.293	126	90.021	6.293
127	90.520	6.293	128	91.019	6.293	129	91.518	6.293
130	92.017	6.293	131	92.516	6.292	132	93.015	6.292

133	93.514	6.292	134	94.013	6.292	135	94.512	6.292
136	95.011	6.292	137	95.509	6.292	138	96.008	6.291
139	96.507	6.291	140	97.006	6.291	141	97.505	6.290
142	98.004	6.289	143	98.503	6.288	144	99.002	6.284
145	99.501	6.278	146	100.000	6.265			

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◆ At 225.000(hr) Calculation Result

○Safety Factor and Slip Surface
- Safety Factor : 1.342
- Resistance Force (kN) 244.554
- Sliding Force (kN) : 182.224 (= 179.102 + 24.976 / 8.000)

○Slip Surface axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	42.137	11.027	2	42.177	10.827	3	42.337	10.204
4	42.800	9.013	5	42.832	8.947	6	43.328	8.086
7	43.808	7.434	8	44.288	6.898	9	44.429	6.758
10	44.769	6.447	11	45.249	6.064	12	45.729	5.735
13	46.209	5.455	14	46.392	5.360	15	46.690	5.217
16	47.170	5.017	17	47.650	4.853	18	48.130	4.722
19	48.610	4.622	20	49.091	4.552	21	49.571	4.512
22	50.051	4.500	23	50.336	4.507	24	50.673	4.528
25	50.695	4.530	26	51.010	4.564	27	51.025	4.566
28	51.401	4.624	29	51.415	4.626	30	51.785	4.702
31	51.851	4.717	32	52.001	4.754	33	52.101	4.781
34	52.855	5.027	35	53.608	5.360	36	54.594	5.950
37	55.579	6.766						

○Arc Center (m) : (50.000, 12.500)
○Arc Diameter (m) : 8.000

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle (°)	Slice Bottom Pressure (kN/m2)	Slice Bottom Water Length (m)
0.040	0.096	-78.659	0.000	0.204
0.160	1.661	-75.626	0.000	0.643
0.463	12.390	-68.741	0.000	1.278
0.032	1.227	-63.896	0.000	0.073
0.496	22.998	-60.072	0.000	0.994
0.480	27.201	-53.612	0.000	0.809
0.480	30.258	-48.134	0.000	0.720
0.141	9.330	-44.846	0.000	0.198
0.339	23.207	-42.487	1.590	0.460
0.480	34.233	-38.636	5.162	0.615
0.480	35.417	-34.350	8.872	0.582
0.480	36.131	-30.275	12.124	0.556
0.182	13.830	-27.547	14.175	0.206
0.298	22.618	-25.628	15.506	0.330
0.480	36.318	-22.582	17.492	0.520
0.480	35.883	-18.901	19.742	0.508
0.480	35.143	-15.300	21.632	0.498
0.480	34.110	-11.760	23.058	0.491
0.480	32.792	-8.265	23.961	0.485
0.480	31.193	-4.801	24.226	0.482
0.480	29.318	-1.355	23.895	0.480
0.285	16.782	1.386	23.445	0.285
0.337	19.876	3.616	23.073	0.338
0.022	1.288	4.904	22.847	0.022
0.315	18.663	6.118	22.658	0.317
0.015	0.879	7.307	22.469	0.015
0.376	22.838	8.724	22.170	0.380
0.014	0.853	10.136	21.877	0.014
0.370	19.774	11.540	21.706	0.378
0.066	2.877	13.135	20.817	0.068
0.150	6.115	13.931	19.911	0.155
0.100	3.942	14.855	19.599	0.103
0.754	26.496	18.066	18.263	0.793
0.754	22.458	23.858	15.423	0.824
0.985	20.793	30.927	10.895	1.148
0.985	7.635	39.628	4.000	1.279

○ Water Level axis

No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)	No	x axis (m)	y axis (m)
1	0.000	10.894	2	40.266	10.894	3	40.328	6.708
4	40.718	6.701	5	40.778	6.701	6	41.062	6.699
7	41.345	6.699	8	41.841	6.702	9	42.337	6.708
10	42.832	6.717	11	43.328	6.728	12	43.808	6.740
13	44.288	6.753	14	44.769	6.772	15	45.249	6.792
16	45.729	6.816	17	46.209	6.847	18	46.690	6.880
19	47.170	6.922	20	47.650	6.975	21	48.130	7.011
22	48.610	7.034	23	49.091	7.026	24	49.571	6.978
25	50.051	6.907	26	50.336	6.882	27	50.673	6.859
28	51.010	6.856	29	51.025	6.856	30	51.401	6.855
31	51.785	6.898	32	51.851	6.766	33	93.015	6.766
34	93.514	6.766	35	94.013	6.760	36	94.512	6.753
37	95.011	6.744	38	95.509	6.734	39	96.008	6.723
40	96.507	6.710	41	97.006	6.695	42	97.505	6.676
43	98.004	6.649	44	98.503	6.611	45	99.002	6.548
46	99.501	6.434	47	100.000	6.265			

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◆ At 226.000 (hr) Calculation Result

○Safety Factor and Slip Surface

・Safety Factor : 1.337
・Resistance Force(kN) : 243.734
・Sliding Force(kN) : 182.282 (= 179.160 + 24.976 / 8.000)

○Slip Surface axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	42.137	11.027	2	42.177	10.827	3	42.337	10.204
4	42.800	9.013	5	42.832	8.947	6	43.328	8.086
7	43.808	7.434	8	44.288	6.898	9	44.415	6.772
10	44.769	6.447	11	45.249	6.064	12	45.729	5.735
13	46.209	5.455	14	46.392	5.360	15	46.690	5.217
16	47.170	5.017	17	47.650	4.853	18	48.130	4.722
19	48.610	4.622	20	49.091	4.552	21	49.571	4.512
22	50.051	4.500	23	50.336	4.507	24	50.673	4.528
25	50.691	4.530	26	51.010	4.564	27	51.025	4.566
28	51.401	4.624	29	51.411	4.625	30	51.785	4.702
31	51.851	4.717	32	52.001	4.754	33	52.101	4.781
34	52.855	5.027	35	53.608	5.360	36	54.594	5.950
37	55.579	6.766						

○Arc Center(m) : (50.000, 12.500)
○Arc Diameter(m) : 8.000

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle(°)	Slice Bottom Pressure(kN/m2)	Slice Bottom Water Length(m)
0.040	0.096	-78.659	0.000	0.204
0.160	1.661	-75.626	0.000	0.643
0.463	12.390	-68.741	0.000	1.278
0.032	1.227	-63.896	0.000	0.073
0.496	22.998	-60.072	0.000	0.994
0.480	27.201	-53.612	0.000	0.809
0.480	30.258	-48.134	0.000	0.720
0.126	8.377	-44.917	0.000	0.179
0.354	24.163	-42.558	1.672	0.480
0.480	34.242	-38.636	5.347	0.615
0.480	35.429	-34.350	9.103	0.582
0.480	36.145	-30.275	12.406	0.556
0.182	13.836	-27.547	14.502	0.206
0.298	22.629	-25.628	15.880	0.330
0.480	36.341	-22.582	17.975	0.520
0.480	35.909	-18.901	20.273	0.508
0.480	35.164	-15.300	22.068	0.498
0.480	34.126	-11.760	23.386	0.491
0.480	32.805	-8.265	24.217	0.485
0.480	31.204	-4.801	24.451	0.482
0.480	29.328	-1.355	24.084	0.480
0.285	16.786	1.386	23.573	0.285
0.337	19.879	3.616	23.163	0.338
0.018	1.079	4.891	22.927	0.018
0.319	18.875	6.105	22.738	0.321
0.015	0.879	7.307	22.548	0.015
0.376	22.841	8.724	22.249	0.380
0.010	0.627	10.123	21.955	0.010
0.374	20.000	11.526	21.745	0.382
0.066	2.877	13.135	20.817	0.068
0.150	6.115	13.931	19.911	0.155
0.100	3.942	14.855	19.599	0.103
0.754	26.496	18.066	18.263	0.793
0.754	22.458	23.858	15.423	0.824
0.985	20.793	30.927	10.895	1.148
0.985	7.635	39.628	4.000	1.279

○ Water Level axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	0.000	10.894	2	40.266	10.894	3	40.328	6.714
4	40.718	6.707	5	40.778	6.707	6	41.062	6.705
7	41.345	6.706	8	41.841	6.709	9	42.337	6.716
10	42.832	6.727	11	43.328	6.739	12	43.808	6.752
13	44.288	6.767	14	44.769	6.788	15	45.249	6.813
16	45.729	6.842	17	46.209	6.878	18	46.690	6.921
19	47.170	6.979	20	47.650	7.026	21	48.130	7.049
22	48.610	7.063	23	49.091	7.049	24	49.571	7.001
25	50.051	6.922	26	50.336	6.892	27	50.673	6.867
28	51.010	6.864	29	51.025	6.864	30	51.401	6.863
31	51.785	6.898	32	51.851	6.766	33	93.015	6.766
34	93.514	6.766	35	94.013	6.761	36	94.512	6.753
37	95.011	6.744	38	95.509	6.734	39	96.008	6.723
40	96.507	6.710	41	97.006	6.695	42	97.505	6.676
43	98.004	6.650	44	98.503	6.611	45	99.002	6.548
46	99.501	6.434	47	100.000	6.265			

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◆ At 248.000 (hr) Calculation Result

○Safety Factor and Slip Surface
・Safety Factor : 1.429
・Resistance Force(kN) : 260.539
・Sliding Force(kN) : 182.271 (= 179.149 + 24.976 / 8.000)

○Slip Surface axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	42.137	11.027	2	42.177	10.827	3	42.337	10.204
4	42.800	9.013	5	42.832	8.947	6	43.328	8.086
7	43.808	7.434	8	44.288	6.898	9	44.586	6.610
10	44.769	6.447	11	45.249	6.064	12	45.729	5.735
13	46.209	5.455	14	46.392	5.360	15	46.690	5.217

16	47.170	5.017	17	47.650	4.853	18	48.130	4.722
19	48.610	4.622	20	49.091	4.552	21	49.571	4.512
22	50.051	4.500	23	50.336	4.507	24	50.673	4.528
25	50.865	4.547	26	51.010	4.564	27	51.025	4.566
28	51.401	4.624	29	51.606	4.663	30	51.785	4.702
31	51.851	4.717	32	52.000	4.754	33	52.001	4.754
34	52.031	4.762	35	52.101	4.781	36	52.600	4.934
37	53.099	5.125	38	53.598	5.355	39	53.608	5.360
40	54.097	5.629	41	54.596	5.952	42	55.095	6.332
43	55.202	6.422	44	55.579	6.766			

○Arc Center(m) : (50.000, 12.500)
○Arc Diameter(m) : 8.000

○Slice Property

Slice Width (m)	Slice Weight (kN)	Slice Bottom Angle(°)	Slice Bottom Pressure(kN/m2)	Slice Bottom Water Length(m)
0.040	0.096	-78.659	0.000	0.204
0.160	1.661	-75.626	0.000	0.643
0.463	12.390	-68.741	0.000	1.278
0.032	1.227	-63.896	0.000	0.073
0.496	22.998	-60.072	0.000	0.994
0.480	27.201	-53.612	0.000	0.809
0.480	30.258	-48.134	0.000	0.720
0.298	19.923	-44.073	0.000	0.414
0.183	12.578	-41.713	0.829	0.245
0.480	34.157	-38.636	3.599	0.615
0.480	35.334	-34.350	7.182	0.582
0.480	36.037	-30.275	10.197	0.556
0.182	13.790	-27.547	12.026	0.206
0.298	22.546	-25.628	13.164	0.330
0.480	36.185	-22.582	14.772	0.520
0.480	35.721	-18.901	16.432	0.508
0.480	34.951	-15.300	17.712	0.498
0.480	33.893	-11.760	18.634	0.491
0.480	32.562	-8.265	19.252	0.485
0.480	30.965	-4.801	19.572	0.482
0.480	29.108	-1.355	19.603	0.480
0.285	16.667	1.386	19.459	0.285
0.337	19.744	3.616	19.234	0.338
0.192	11.301	5.517	19.010	0.193
0.145	8.525	6.731	18.827	0.146
0.015	0.873	7.307	18.731	0.015
0.376	22.695	8.724	18.437	0.380
0.205	11.803	10.835	17.952	0.209
0.179	8.790	12.239	17.554	0.183
0.066	2.877	13.135	17.277	0.068
0.149	6.051	13.928	17.003	0.153
0.001	0.041	14.481	16.808	0.001
0.030	1.191	14.597	16.758	0.031
0.070	2.721	14.968	16.595	0.072
0.499	17.811	17.096	15.663	0.522
0.499	16.219	20.878	13.866	0.534
0.499	14.275	24.758	11.728	0.549
0.011	0.278	26.769	10.545	0.012
0.488	11.637	28.807	9.182	0.557
0.499	9.082	32.933	6.245	0.594
0.499	5.746	37.309	2.767	0.627
0.107	0.754	40.057	0.444	0.140
0.377	1.167	42.386	0.000	0.510

○ Water Level axis

No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)	No	x axis(m)	y axis(m)
1	0.000	2.771	2	33.492	2.771	3	33.642	4.631
4	37.342	4.631	5	37.492	4.610	6	37.933	4.884
7	38.374	5.148	8	38.815	5.750	9	39.129	6.198
10	39.442	6.443	11	39.705	6.443	12	40.017	6.444
13	40.328	6.454	14	40.718	6.465	15	40.778	6.468
16	41.062	6.476	17	41.345	6.486	18	41.841	6.502
19	42.337	6.521	20	42.832	6.541	21	43.328	6.562
22	43.808	6.582	23	44.288	6.600	24	44.769	6.617
25	45.249	6.629	26	45.729	6.635	27	46.209	6.635
28	46.690	6.629	29	47.170	6.618	30	47.650	6.603
31	48.130	6.583	32	48.610	6.560	33	49.091	6.540
34	49.571	6.515	35	50.051	6.494	36	50.336	6.482
37	50.673	6.476	38	51.010	6.475	39	51.025	6.475
40	51.401	6.475	41	51.785	6.472	42	51.851	6.470
43	52.001	6.468	44	52.101	6.461	45	52.600	6.448
46	53.099	6.438	47	53.598	6.433	48	54.097	6.429
49	54.596	6.425	50	55.095	6.423	51	55.594	6.420
52	56.093	6.418	53	56.592	6.416	54	57.090	6.414
55	57.589	6.413	56	58.088	6.411	57	58.587	6.410
58	59.086	6.408	59	59.585	6.407	60	60.084	6.405
61	60.583	6.403	62	61.082	6.402	63	61.581	6.400
64	62.080	6.399	65	62.579	6.397	66	63.078	6.396
67	63.577	6.394	68	64.076	6.392	69	64.575	6.391
70	65.074	6.389	71	65.573	6.388	72	66.072	6.386
73	66.570	6.384	74	67.069	6.383	75	67.568	6.381
76	68.067	6.380	77	68.566	6.378	78	69.065	6.376
79	69.564	6.375	80	70.063	6.373	81	70.562	6.372
82	71.061	6.370	83	71.560	6.369	84	72.059	6.367
85	72.558	6.367	86	73.057	6.366	87	73.556	6.366
88	74.055	6.367	89	74.554	6.366	90	75.053	6.365
91	75.552	6.364	92	76.051	6.362	93	76.549	6.360
94	77.048	6.359	95	77.547	6.357	96	78.046	6.355
97	78.545	6.353	98	79.044	6.351	99	79.543	6.349
100	80.042	6.347	101	80.541	6.345	102	81.040	6.343
103	81.539	6.342	104	82.038	6.340	105	82.537	6.338
106	83.036	6.336	107	83.535	6.335	108	84.034	6.333
109	84.533	6.332	110	85.032	6.330	111	85.531	6.329
112	86.029	6.327	113	86.528	6.326	114	87.027	6.324
115	87.526	6.323	116	88.025	6.321	117	88.524	6.319
118	89.023	6.317	119	89.522	6.315	120	90.021	6.313
121	90.520	6.311	122	91.019	6.309	123	91.518	6.306

124	92.017	6.304	125	92.516	6.302	126	93.015	6.300
127	93.514	6.298	128	94.013	6.296	129	94.512	6.293
130	95.011	6.291	131	95.509	6.289	132	96.008	6.287
133	96.507	6.285	134	97.006	6.283	135	97.505	6.281
136	98.004	6.278	137	98.503	6.276	138	99.002	6.273
139	99.501	6.269	140	100.000	6.265			

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O3. Slip Surface with the minimum Safety Factor
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O Time(hr) : 226.000
O Safety Factor : 1.337
O Search Area : 1
O Center(m) : (50.000, 12.500)
O Diameter(m) : 8

1.2.2 Gravity Wall

Structural calculations for the following types of gravity wall are shown in the following pages.

-Type I (the retaining wall of the maintenance road) (*the soil property near L5+400 is applied)

-Type II (the retaining wall of the maintenance road) (*the soil property near L6+560 is applied)

-Type A (the retaining wall at the left bank transition near 6+560) (*the soil property near L6+560 is applied)

-Type B (the retaining wall at the left bank transition near 6+560) (*the soil property near L6+560 is applied)

-Type C (the retaining wall at the left bank transition near 6+480) (*the soil property near L6+560 is applied)

1.2.2 GRAVITY　WALL
1.2.2.1 TYPE I , REPRESENTED BY L5+400

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1. Design Conditions

1.1 General

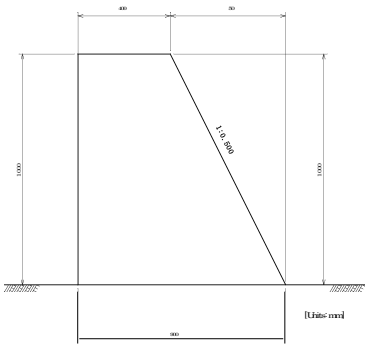
Title: Gravity Wall (TYPE I OF MAINTENANCE ROAD, REPRESENTED BY L5 + 400)

1.2 Applied Criteria

Japan Construction Technology Association, Civil Engineering Structure Standard Design Vol. 2, Manual (Retaining Wall) 2000

1.3 Format

'Gravity (direct foundation) '



Width in the depth direction (block length) B=5000

1.4 Geometry

1.5 Ground Conditions

Seismic scale: Medium
Region: A
Ground Type: TYPE I

Judgment of Ground Classification

$$T_G = 4\Sigma\frac{Hi}{Vsi} = 0.158 \quad (\quad T_G < 0.2)$$

Here,

T_G: Ground property value (s)
Hi: Thickness of the ith stratum (m)

Vsi: Average shear elastic wave velocity of the i-th stratum (m/s)
Case of cohesive soil
Vsi = 100 Ni 1/3 (1 ≦ Ni ≦ 25)
In the case of sandy soil
Vsi = 80 Ni 1/3 (1 ≦ Ni ≦ 50)
Ni: Average N value of the i-th stratum by the standard penetration test
Vsi = 50 m/s when N value is 0, and Vsi = 50 m/s when Vsi < 50 m/s
i: Number of the i-th stratum from the ground surface when the ground is divided into n layers from the ground surface to the seismic design foundation surface

Geological Number	Layer Type	Layer Thickness Hi (m)	Mean N-Value	Vsi (m/s)
1	sandy soil	1.370	5.0	136.798
2	sandy soil	2.140	10.0	172.355
3	cohesive soil	3.700	10.0	215.443
4	cohesive soil	10.000	50.0	292.402

1.6 Materials Used

[Concrete]　Vertical wall (plain concrete) : σck = 18 (N/mm2)

[Soil]　Quality: Backside soil: sandy soil
Backfill soil: sandy soil
Foundation ground: gravel

[Internal friction angle]　Backside Soil: 30.00 (degrees)

[Unit volume weight]

(kN/m3)

Body	Plain Concrete	23.000	
Water	For Calculation of Uplift	10.000	
Soil		Wet Weight	Saturated Weight
Back surface		18.000	19.000
Front surface		18.000	19.000

[Design horizontal seismic coefficient] Body: Kh = 0.20
Soil (Front) : Kh = 0.20 (Back) : Kh = 0.20

1.7 Soil

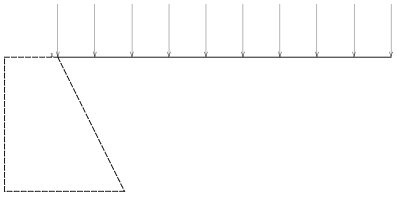
(1) Backside Soil Shape



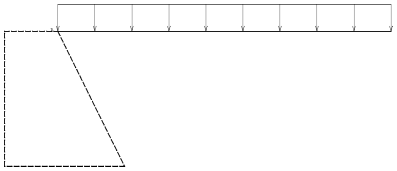
Level difference between retaining wall crown and backside ground	(m)	0.000
Height without considering Earth Pressure Hr	(m)	0.000

1.8 Load

[1] Normal



No.	Loading Position (m)	Loading Width (m)	Load (kN/m2)		Items to Consider		
			Start Point	End Point	Stability	Vertical Wall	Bottom Plate
1	0.000	infinity	10.000	10.000	○	-	-



[2] Seismic

No.	Loading Position (m)	Loading Width (m)	Load (kN/m2)		Items to Consider		
			Start Point	End Point	Stability	Vertical wall	Bottom Plate
1	0.000	infinity	5.000	5.000	○	-	-

1.9 Other Loads

Not considered

1.10 Uplift

- Consider the uplift equivalent as uplift pressure

1.11 Earth Pressure

- Earth Pressure formulas: trial wedges
- Angle of friction of Earth Pressure acting surface (degrees)

Load Condition	Active Earth Pressure		Passive Earth Pressure
	at the Stability Calculation	Cut	
Normal Earth Pressure	20.000		
Seismic Earth Pressure	15.000		

- The imaginary back surface of Earth Pressure for stability calculation is the back of the vertical wall.
- Angle between the surface at which earth pressure acts and the vertical plane at the time of stability calculation: 26.565(degrees)
- The design horizontal seismic intensity is applied to the inertia force at the time of earthquake when calculating the earth pressure below the water Level.
- Cohesion (kN/m2)

Load Condition	For Sliding Surfaces	For Cohesive Height	For Passive Earth Pressure
Normal	1.000	0.000	0.000
Seismic	1.000	0.000	0.000

- Treatment of Earth Pressure different from the direction of Seismic motion

	Consider as	Availability Factor
Stability Calculation	Normal Earth Pressure	0.500
Vertical Wall Design		0.500

1.12 Water Pressure

- Concept of Hydrostatic Pressure Calculation

Load Condition	Back Surface	Front Surface
Normal	Consider	Consider
Seismic	Consider	Consider

- Hydrostatic pressure different from the direction of seismic motion

External Water Level	Stability Calculation	Consider
	Vertical Wall Design	Consider

1.13 Load Combination Case

No	Load Name	Comments
1	Normal	Normal
2	Seismic	Seismic

	Load Name	1	2
Soil	Soil 1	○	
	Soil 2		○
Water Level	Water Level 1	○	
	Water Level 2		○
Load	Load 1	○	
	Load 2		○
Active Earth Pressure	Not considered		
	Normal Earth Pressure	○	
	Seismic Earth Pressure		○
Passive Earth Pressure	Passive Earth Pressure 1		

1.14 Conditions of Foundation

1.14.1 Data for calculating allowable shear resistance

Bottom Plate width used for checking		Effective Loading Width
Cohesive force CB between base bottom surface and ground	(kN/m2)	0.000
Friction coefficient between base and ground tan φB		0.600

1.15 Allowable Values for Stability Calculation and Allowable Stress of Members

1.15.1 Tolerance for Stability Calculation

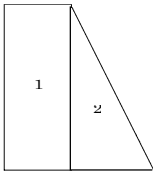
Load Condition	Allowable Eccentricity eB/B(m)	Safety Factor Against Overturning	Safety Factor Against Sliding	Allowable Bearing Capacity
Normal	1/6	1.500	1.500	200.000
Seismic	1/3	1.200	1.200	300.000

2. Stability Calculations

2.1 Block Data Not Considering Water Level

(1) Body weight

1) Block Division



2) Weight and Center of Gravity

Division	Equation Width x height x depth	Volume Vi (m3)	Center of Gravity (m) Xi	Yi	Vi Xi	Vi Yi	Remarks
1	0.400 x 1.000 x 1.000	0.400	0.200	0.500	0.080	0.200	
2	1/2 x 0.500 x1.000 x 1.000	0.250	0.567	0.333	0.142	0.083	
2		0.650			0.222	0.283	

Centroid position XG = 2 (Vi Xi) /2Vi = 0.222/0.650 = 0.341 (m)

YG = 2 (Vi Yi) /2Vi = 0.283/0.650 = 0.436 (m)

2.2 Body Weight, Earth and Sand Weight, Arbitrary Load, Vertical Force due to Uplift (Uplift Pressure) and Horizontal Force

(1) Acting Force Due to Dead Weight

[1] Normal

Location	Vertical Force W = γ ·V (kN)			Acting Position X (m)
Body	23.000 x	0.650 =	14.950	0.341

[2] Seismic

Location	Vertical Force W = γ ·V (kN)			Acting Position X (m)
Body	23.000 x	0.650 =	14.950	0.341

Location	Horizontal Force H = W kh (kN)			Acting Position Y (m)
Body	14.950 x	0.20 =	2.990	0.436

(2) Dead-Weight

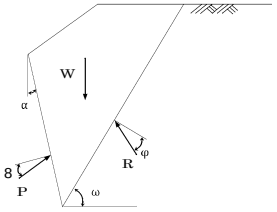
[1] Normal (Water Level 1)

	Weight Ni (kN)	Horizontal Force Hi (kN)	Acting Position Xi	Yi	Moment (kNm) Ni Xi	Hi Yi
Body	14.950	0.000	0.341	0.000	5.099	0.000
Total	14.950	0.000			5.099	0.000

[2] Seismic (Water Level 2)

	Weight Ni (kN)	Horizontal Force Hi (kN)	Acting Position Xi	Yi	Moment (kNm) Ni Xi	Hi Yi
Body	14.950	2.990	0.341	0.436	5.099	1.303
Total	14.950	2.990			5.099	1.303

2.3. Earth Pressure and Water Pressure



[1] Normal (Water Level 1)

The Earth Pressure is determined by the trial wedge method considering the cohesive force.

Imaginary Backside Position (distance from toe) xp = 0.900 m

yp = 0.000 m

Imaginary Backside Height H = 1.000 m

Angle between the Surface at which the Earth Pressure Acts and the Vertical Surface α = 26.565 °

Unit Volume Weight of Backside Soil γs = 18.000 kN/m3

Internal Friction Angle of Backside Soil φ = 30.000 °

Wall Friction Angle δ = 2/3 φ = 20.000 °

Range of Slip Angle ωi = 10.00 ° to 80.00 °

Soil Weight (W) against Slip Angle (ω) , soil pressure (P) , Water Level hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN) Above Water Level	Below Water Level	Surcharge	Total	Earth Pressure P (kN)
64.00	8.890	0.000	9.877	18.767	9.764
65.00	8.697	0.000	9.663	18.360	9.774

Soil weight (W) and soil pressure (P) Water Level with respect to Slip Angle (ω) hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN) Above Water Level	Below Water Level	Surcharge	Total	Earth Pressure P (kN)
66.00	8.507	0.000	9.452	17.959	9.773

The maximum soil pressure is

P = 9.774 kN when ω = 65.00 °

Cohesive force of sliding surface

Co = c · L = 1.000 x 1.103 = 1.103 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega-\varphi) - Co \cdot \cos\varphi}{\cos(\omega-\varphi-\alpha-\delta)}$$

$$= \frac{18.360 \times \sin(65.00° - 30.00°) - 1.103 \times \cos 30.00°}{\cos(65.00° - 30.00° - 26.565 - 20.000°)} = 9.774\ kN$$

The horizontal component, vertical component and working position of the Earth Pressure at this time are as follows.

horizontal component

Ph = P-cos (α + δ) = 9.774 x cos (26.565° + 20.000°) =6.720 kN

vertical component

Pv = P sin (α + δ) = 9.774 x sin (26.565° + 20.000°) =7.097 kN

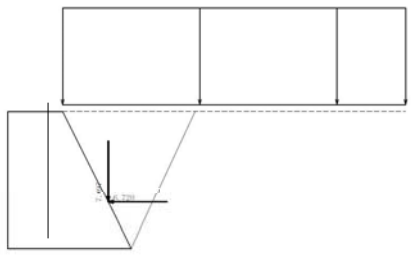
Acting position

$$Ho = \frac{H}{3} = \frac{1.000}{3} = 0.333\ m$$

x = xp-Ho · tan α = 0.900 -0.333 × tan 26.565 ° = 0.733 m

y = yp + Ho = 0.000 + 0.333 = 0.333 m

- Earth Pressure Diagram



[2] Seismic (Water Level 2)

The earth pressure is obtained by the trial wedge method considering inertia force and Cohesion force at the earthquake.

Imaginary Backside Position (distance from toe) xp = 0.900 m

yp = 0.000 m

Imaginary Backside Height H = 1.000 m

Angle between the Surface at which the Earth Pressure Acts and the Vertical Surface α = 26.565 °

Unit volume weight of Backside Soil γs = 18.000 kN/m3

Internal Friction Angle of Backside Soil φ = 30.000 °

Wall Friction Angle 6 = 1/2 φ = 15.000 °

Seismic Composite Angle θ = tan -1 kh = tan -10.20 = 11.310 °

Range of Slip Angle ωi = 10.00 ° to 80.00 °

Soil weight (W) and soil pressure (P) Water Level with respect to Slip Angle (ω) hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN) Above Water Level	Below Water Level	Surcharge	Total	Earth Pressure P (kN)
52.00	11.532	0.000	6.406	17.938	9.495
53.00	11.282	0.000	6.268	17.550	9.498
54.00	11.039	0.000	6.133	17.172	9.494

The maximum soil pressure is

P = 9.498 kN when ω = 53.00 °

Cohesive force of sliding surface

Co = c · L = 1.000 x 1.252 = 1.252 kN

Earth Pressure

$$P = \frac{W/\cos\theta \cdot \sin(\omega-\varphi+\theta) - Co\cos\varphi}{\cos(\omega-\varphi-\alpha-\delta)}$$

$$= \frac{17.550/\cos 11.310° \times \sin(53.00° - 30.00° + 11.310°) - 1.252 \times \cos 30.00°}{\cos(53.00° - 30.00° - 26.565 - 15.000°)}$$

= 9.498 kN

The horizontal component, vertical component and working position of the Earth Pressure at this time are as follows.

horizontal component

Ph = P-cos (α + 6) = 9.498 x cos (26.565° + 15.000°) =7.106 kN vertical component

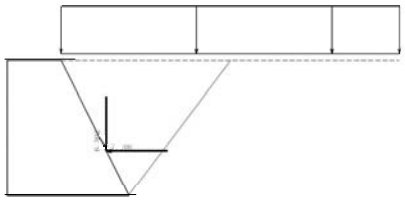
Pv = P sin (α + 6) = 9.498 x sin (26.565° + 15.000°) =6.302 kN working position

$$Ho = \frac{H}{3} = \frac{1.000}{3} = 0.333\ m$$

x = xp-Ho · tan α = 0.900 -0.333 × tan 26.565 ° = 0.733 m

y = yp + Ho = 0.000 + 0.333 = 0.333 m

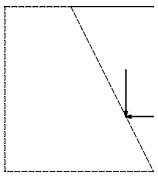
- Earth Pressure Diagram



2.4 Aggregation of Acting Forces

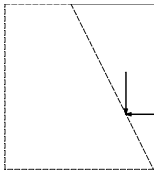
(1) Sum of Force at Front of Body

[1] Normal (Water Level 1)



Item	Vertical Force Ni (kN)	Horizontal Force Hi (kN)	Arm Length		Rotational Moment (kNm)	
			Xi (m)	Yi (m)	Mxi = Ni/Xi	Myi = Hi Yi
Dead Weight	14.950	0.000	0.341	0.000	5.099	0.000
Earth Pressure	7.097	6.720	0.733	0.333	5.202	2.238
Total	22.047	6.720			10.301	2.238

[2] Seismic (Water Level 2)



5	Vertical Force Ni (kN)	Horizontal Force Hi (kN)	Arm Length		Rotational Moment (kNm)	
			Xi (m)	Yi (m)	Mxi = Ni/Xi	Myi = Hi Yi
Dead Weight	14.950	2.990	0.341	0.436	5.099	1.303

Item	Vertical Force Ni (kN)	Horizontal Force Hi (kN)	Arm Length		Rotational Moment (kNm)	
			Xi (m)	Yi (m)	Mxi = Ni/Xi	Myi = Hi Yi
Earth Pressure	6.302	7.106	0.733	0.333	4.619	2.366
Total	21.252	10.096			9.718	3.670

Loading Conditions (Water Level)	No (kN)	Ho (kN)	Mo (kNm)
Normal (Water Level 1)	22.047	6.720	8.063
Seismic (Water Level 2)	21.252	10.096	6.048

(2) Aggregate Force at Body Center

Vertical Force : Nc = No (kN)
Horizontal Force : Hc = Ho (kN)
Rotational Moment: Mc = No Bj/2.0 - Mo (kNm) where:
Body Width in the Direction of Earth Pressure: Bj = 0.900 (m)

■ Per Unit Width

Loading Conditions (Water Level)	Nc (kN)	Hc (kN)	Mc (kNm)
Normal (Water Level 1)	22.04	6.720	1.858
Seismic (Water Level 2)	21.25	10.096	3.515

■ Per Full Width (5.000 m)

Loading Conditions (Water Level)	Nc (kN)	Hc (kN)	Mc (kNm)
Normal (Water Level 1)	110.2	33.600	9.292
Seismic (Water Level 2)	106.2	50.480	17.576

2.5 Stability Calculation Results

2.5.1 Stability against Overturning

(1) Calculation of Resultant Acting Point and Eccentricity

$$d = \frac{\Sigma Mr - \Sigma Mt}{\Sigma V}$$

Here,

d: Distance from toe of base plate to action point of resultant force (m)
ΣMr: Resistance moment around toe of base plate (kNm)
ΣMt: Fall moment around toe of base plate (kNm)
ΣV: Total vertical load at bottom of base plate (kN)

$$e = B/2 - d$$

Here,

e: Eccentric distance (m) from the center of the Base Plate of the point of action of the resultant force
B: Base Plate width (m) , B = 0.900

$$ea = B/n$$

Here,

ea: Allowable eccentric distance (m)
n: Safety factor

Loading conditions (Water Level)	ΣMr (kNm)	ΣMt (kNm)	ΣV (kN)	d (m)	e (m)		Ea (m)
Normal (Water Level 1)	10.301	2.238	22.047	0.366	0.084	<<	0.150
Seismic (Water Level 2)	9.718	3.670	21.252	0.285	0.165	<<	0.300

(2) Calculation of the Safety Factor

$$F = \left| \frac{Mr}{Mo} \right|$$

Here,

Mr: Moment of resistance
Mo: Moment of rotation

Loading Conditions (Water Level)	Mr. (kNm)	Mo (kNm)	Safety Factor		
			F = Mr/Mo		Tolerance
Normal (Water Level 1)	10.301	2.238	4.603	≧	1.500
Seismic (Water Level 2)	9.718	3.670	2.648	≧	1.200

2.5.2 Stability Against Sliding

$$Fs = \frac{\Sigma V \mu + C_B B}{\Sigma H}$$

Here,

ΣV: Total vertical load at Base Plate (kN)
ΣH: Total horizontal load on Base Plate (kN)
μ: Friction coefficient between bottom slab and Bearing capacity of foundation ground, μ = 0.600
C_B: Cohesion between slab and bearing capacity of foundation ground (kN/m2) , CB = 0.000
B: Bottom plate width (m) , B = 0.900

Loading Conditions (Water Level)	Vertical Load ΣV (kN)	Horizontal Load ΣH (kN)	Safety Factor Fs		Required Safety Factor Fsa
Normal (Water Level 1)	22.047	6.720	1.968	≧	1.500
Seismic (Water Level 2)	21.252	10.096	1.263	≧	1.200

2.5.3 Check of Bearing Capacity

1) When the resultant action point lies within the base plate width of 1/3 (middle third) at the center of the bottom plate

$$q_1 = \frac{\Sigma V}{B} \cdot \left(1 + \frac{6e}{B}\right)$$

$$q_2 = \frac{\Sigma V}{B} \cdot \left(1 - \frac{6e}{B}\right)$$

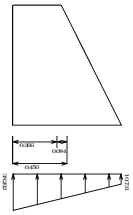
2) When the resultant force acting point is within the Base Plate width of 2/3 at the center of the Base Plate

$$q1 = \frac{2\Sigma V}{3(B/2 - e)}$$

Here,

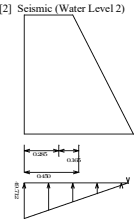
ΣV: Total vertical load acting on bottom of the bottom plate (kN)
B: Bottom plate width (m) , B = 0.900
e: Eccentricity (m)

[1] Normal (Water Level 1)



Width of Subgrade Reaction (m) x and B	Shape of Subgrade Reaction	Subgrade Reaction(kN/m2)			
		qmin	qmax		Tolerance
0.900	Trapezoid	10.731	38.262	≦	200.000

[2] Seismic (Water Level 2)



Width of Subgrade Reaction (m) x and B	Shape of Subgrade Reaction	Subgrade Reaction (kN/m2)		
		qmin	qmax	Tolerance
0.855	Triangle	0.000	49.712 ≦	300.000

1.2.2 GRAVITY　WALL
1.2.2.2 TYPE A, REPRESENTED BY L6+560

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1. Design Conditions

1.1 General

Title: Gravity Wall (TYPE A, REPRESENTED BY R6 + 560)

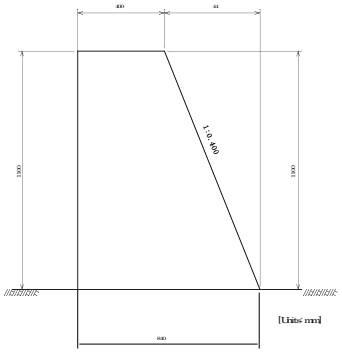
1.2 Applied Criteria

Japan Construction Technology Association, Civil Engineering Structure Standard Design Vol. 2, Manual (Retaining Wall) 2000

1.3 Format

'Gravity (direct foundation) '

1.4 Geometry



Width in the depth direction (block length) B=5000

1.5 Ground Conditions

Seismic scale: Medium scale

Region: A

Ground type: Type II

Judgment of Ground Classification

$\frac{Hi}{Vsi}$ = 0.353 (0.2 ≦ TG < 0.6)

Here,

TG: Ground property value (s)

Hi: Thickness of the ith stratum (m)

Vsi: average shear elastic wave velocity of the i-th stratum (m/s)

case of cohesive soil

Vsi = 100 Ni 1/3 (1 ≦ Ni ≦ 25)

In the case of sandy soil

Vsi = 80 Ni 1/3 (1 ≦ Ni ≦ 50)

Ni: Average N value of the i-th stratum by the standard penetration test

Vsi = 50 m/s when N value is 0, and Vsi = 50 m/s when Vsi < 50 m/s

i: Number of the i-th stratum from the ground surface when the ground is divided into n layers from the ground surface to the seismic design foundation surface

Geological Number	Layer Type	Layer Thickness Hi (m)	Mean N-Value	Vsi (m/s)
1	sandy soil	5.500	12.0	183.154
2	sandy soil	2.370	5.0	136.798
3	cohesive soil	3.630	8.0	200.000
4	sandy soil	2.000	33.0	256.603
5	cohesive soil	4.000	19.0	266.840
6	cohesive soil	10.000	50.0	292.402

1.6 Materials Used

[concrete]　Vertical wall (plain concrete) : σck = 18 (N/mm2)

[soil]　Quality: Backside soil: sandy soil
Backfill soil: sandy soil
Foundation ground: gravel

[internal friction angle]　Backside soil sand: 30.00 (degrees)

[unit volume weight]

(kN/m3)

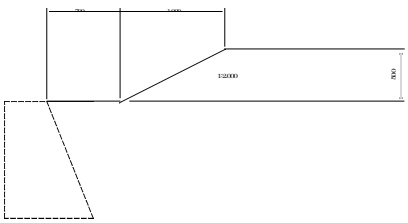
Body	Plain Concrete	23.000	
Water	For Calculation of	10.000	
Soil		Wet Weight	Saturated
Back surface		18.000	19.000
Front surface		18.000	19.000

[Design horizontal seismic coefficient]　Body: Kh = 0.20

Soil (Front) : Kh = 0.20 (Back) : Kh = 0.20

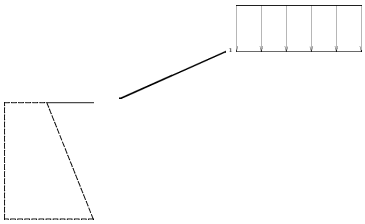
1.7 Soil

(1) Backside Soil Shape



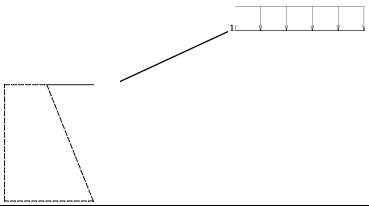
Level difference between retaining wall crown and backside ground (m)		0.000
Slope		2.000
Fill height	(m)	0.500
Horizontal length	(m)	0.700
Height without considering Earth Pressure Hr	(m)	0.000

1.8 Load [1] Normal



No.	Loading Position (m)	Loading Width (m)	Load (kN/m2)		Items to Consider		
			Start Point	End Point	Stability	Vertical wall	Bottom Plate
1	1.800	infinity	10.000	10.000	○	-	-

[2] Seismic



No.	Loading Position (m)	Loading Width (m)	Load (kN/m2)		Items to Consider		
			Start Point	End Point	Stability	Vertical wall	Bottom Plate
1	1.800	infinity	5.000	5.000	○	-	-

1.9 Other Loads

Not considered

1.10 Uplift

- Consider the Uplift equivalent as uplift pressure

1.11 Earth Pressure

Load Condition	Active Earth Pressure		Passive Earth Pressure
	at the Stability Calculation	Cut	
Normal Earth Pressure	20.000		
Seismic Earth Pressure	15.000		

- The imaginary back surface of Earth Pressure for stability calculation is the back of the vertical wall
- Angle between the surface at which earth pressure acts and the vertical plane at the time of stability calculation: 21.801 (deg)
- The design horizontal seismic intensity is applied to the inertia force at the time of earthquake when calculating the earth pressure below the water Level.
- When the height of the fill is up to 15.000 m, the ratio of the height of the raised fill is set to 1.0.

- Cohesion (kN/m2)

Load Condition	For Sliding Surfaces	For Cohesive Height	For Passive Earth Pressure
Normal Earth Pressure	1.000	0.000	0.000
Seismic Earth Pressure	1.000	0.000	0.000

- Treatment of Earth Pressure different from the direction of Seismic motion

	Consider as	Availability Factor
Stability Calculation	Normal Earth Pressure	0.500
Vertical Wall Design		0.500

1.12 Water Pressure

- Concept of Hydrostatic Pressure Calculation

Load Condition	Back Surface	Front Surface
Normal	Consider	Consider
Seismic	Consider	Consider

- Treatment of hydrostatic pressure different from the direction of Seismic motion

	Stability Calculation	Consider
External Water Level	Vertical Wall Design	Consider

1.13 Load Combination Case

No	Load Name	Comments
1	Normal	Normal
2	Seismic	Seismic

	Load Name	1	2
Soil	Soil 1	○	
	Soil 2		○
Water Level	Water Level 1	○	
	Water Level 2		○
Load	Load 1	○	
	Load 2		○
Active Earth Pressure	Not considered		
	Normal Earth Pressure	○	
	Seismic Earth Pressure		○
Passive Earth Pressure	Passive Earth Pressure 1		

1.14 Conditions of Foundation

1.14.1 Calculation Data for Allowable Shear Resistance

Bottom Plate width used for checking	Effective Loading Width
Cohesive force CB between base bottom surface and ground (kN/m2)	0.000
Friction coefficient between base and ground tan φB	0.600

1.15 Allowable values for stability calculations and allowable stresses of members

1.15.1 Tolerance for stability calculation

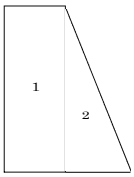
Load Condition	Allowable Eccentricity eB/B(m)	Safety Factor Against Overturning	Safety Factor Against Sliding	Allowable Bearing Capacity
Normal	1/6	1.500	1.500	200.000
Seismic	1/3	1.200	1.200	300.000

2. Stability Calculations

2.1 Block Data Not Considering Water Level

(1) Dead Weight

1) Block Division



2) weight and center of gravity

Division	Equation Width x height x depth	Volume Vi (m3)	Center of gravity (m)		Vi Xi	Vi Yi	Remarks
			Xi	Yi			
1	0.400 x 1.100 x 1.000	0.440	0.200	0.550	0.088	0.242	
2	1/2 x 0.440 x1.100 x 1.000	0.242	0.547	0.367	0.132	0.089	
2		0.682			0.220	0.331	

Centroid position XG=2 (Vi Xi) / 2Vi = 0.220 / 0.682 = 0.323 (m)

YG=2 (Vi Yi) / 2Vi = 0.331 / 0.682 = 0.485 (m)

2.2 Body weight, earth and sand weight, other loads, Vertical Force and Horizontal Force due to Uplift

(1) Acting force due to dead weight

[1] Normal

Location	Vertical Force W = γ ·V (kN)			Acting Position X (m)
Body	23.000 x	0.682 =	15.686	0.323

[2] Seismic

Location	Vertical Force W = γ ·V (kN)			Acting Position X (m)
Body	23.000 x	0.682 =	15.686	0.323

Location	Horizontal Force H = W kh (kN)			Acting Position Y (m)
Body	15.686 x	0.20 =	3.137	0.485

(2) Dead-Weight

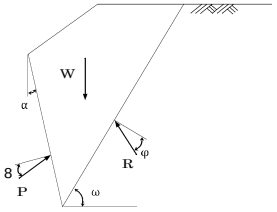
[1] Normal (Water Level 1)

	Weight Ni (kN)	Horizontal Force Hi (kN)	Acting Position		Moment (kNm)	
			Xi	Yi	Ni Xi	Hi Yi
Body	15.686	0.000	0.323	0.000	5.067	0.000
Total	15.686	0.000			5.067	0.000

[2] Seismic (Water Level 2)

	Weight Ni (kN)	Horizontal Force Hi (kN)	Acting Position		Moment (kNm)	
			Xi	Yi	Ni Xi	Hi Yi
Body	15.686	3.137	0.323	0.485	5.067	1.521
Total	15.686	3.137			5.067	1.521

2.3. Earth Pressure and Water Pressure



[1] Normal (Water Level 1)

The Earth Pressure is determined by the trial wedge method considering the cohesive force.

Imaginary Backside Position (distance from toe) xp = 0.840 m

yp = 0.000 m

Imaginary Backside Height H = 1.100 m

Angle between the Surface at which the Earth Pressure Acts and the Vertical Surface α = 21.801 °

Unit Volume Weight of Backside Soil γs = 18.000 kN/m3

Internal Friction Angle of Backside Soil φ = 30.000 °

Wall Friction Angle δ = 2/3 φ = 20.000 °

Range of Slip Angle ωi = 10.00 ° to 80.00 °

Soil Weight (W) against Slip Angle (ω) , soil pressure (P) , Water Level hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Surcharge	Total	
59.00	11.933	0.000	0.000	11.933	4.496
60.00	11.533	0.000	0.000	11.533	4.498

Soil weight (W) and soil pressure (P) Water Level with respect to Slip Angle (ω) hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Surcharge	Total	
61.00	11.154	0.000	0.000	11.154	4.496

The maximum soil pressure is

P = 4.498 kN when ω = 60.00 °

Cohesive force of sliding surface

Co = c · L = 1.000 x 1.575 = 1.575 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \varphi) - Co \cdot \cos\varphi}{\cos(\omega - \varphi - \alpha - \delta)}$$

$$= \frac{11.533 \times \sin(60.00° - 30.00°) - 1.575 \times \cos 30.00°}{\cos(60.00° - 30.00° - 21.801 - 20.000°)} = 4.498\ kN$$

The horizontal component, vertical component and working position of the Earth Pressure at this time are as follows.

horizontal component

Ph = P·cos (α + δ) = 4.498 x cos (21.801° + 20.000°) =3.353 kN

Vertical component

Pv = P sin (α + δ) = 4.498 x sin (21.801° + 20.000°) =2.998 kN

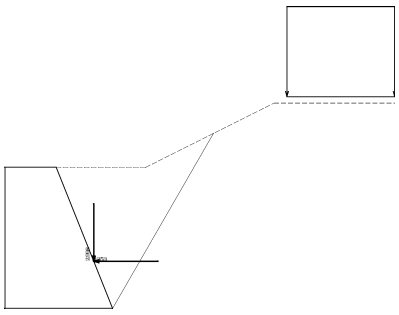
Acting position

$$Ho = \frac{H}{3} = \frac{1.100}{3} = 0.367\ m$$

x = xp-Ho · tan α = 0.840 -0.367 × tan 21.801 ° = 0.693 m

y = yp + Ho = 0.000 + 0.367 = 0.367 m

- Earth Pressure Diagram



[2] Seismic (Water Level 2)

The earth pressure is obtained by the trial wedge method considering inertia force and Cohesion force at the earthquake.

Imaginary Backside Position (distance from toe) xp = 0.840 m

yp = 0.000 m

Imaginary Backside Height H = 1.100 m

Angle between the Surface at which the Earth Pressure Acts and the Vertical Surface α = 21.801 °

Unit volume weight of Backside Soil γs = 18.000 kN/m3

Internal Friction Angle of Backside Soil φ = 30.000 °

Wall Friction Angle δ = 1/2 φ = 15.000 °

Seismic Composite Angle θ = tan -1 kh = tan -10.20 = 11.310 °

Range of Slip Angle ωi = 10.00 ° to 80.00 °

Soil weight (W) and soil pressure (P) Water Level with respect to Slip Angle (ω) hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Surcharge	Total	
37.00	28.091	0.000	3.816	31.907	9.126
38.00	27.006	0.000	3.439	30.445	9.148
39.00	25.968	0.000	3.079	29.047	9.135

The maximum soil pressure is determined by the following equation:

P = 9.148 kN when ω = 38.00 °

Cohesive force of sliding surface

Co = c · L = 1.000 x 2.599 = 2.599 kN

Earth Pressure

$$P = \frac{W/\cos\theta \cdot \sin(\omega-\varphi+\theta) - Co\cos\varphi}{\cos(\omega-\varphi-\alpha-\delta)}$$

$$= \frac{30.445/\cos 11.310° \times \sin(38.00° - 30.00° + 11.310°) - 2.599 \times \cos 30.00°}{\cos(38.00° - 30.00° - 21.801 - 15.000°)}$$

$$= 9.148 \text{ kN}$$

The horizontal component, vertical component and working position of the Earth Pressure at this time are as follows.

Horizontal component

$Ph = P \cdot \cos(\alpha + \delta) = 9.148 \times \cos(21.801° + 15.000°) =$ 7.325 kN

Vertical component

$Pv = P \sin(\alpha + \delta) = 9.148 \times \sin(21.801° + 15.000°) =$ 5.480 kN

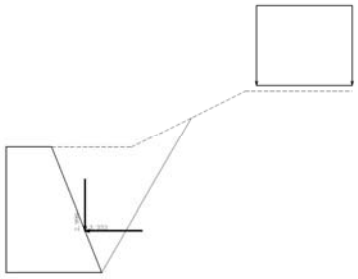
Acting position

$$Ho = \frac{H}{3} = \frac{1.100}{3} = 0.367 \text{ m}$$

$x = xp - Ho \cdot \tan\alpha = 0.840 - 0.367 \times \tan 21.801° = 0.693$ m

$y = yp + Ho = 0.000 + 0.367 = 0.367$ m

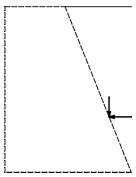
- Earth Pressure Diagram



2.4 Aggregation of Acting Forces

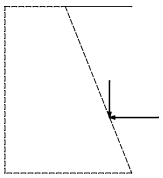
(1) Sum of Force at Front of Body

[1] Normal (Water Level 1)



Item	Vertical Force Ni (kN)	Horizontal Force Hi (kN)	Arm Length Xi (m)	Arm Length Yi (m)	Rotational Moment (kNm) Mxi = Ni/Xi	Rotational Moment (kNm) Myi = Hi Yi
Dead Weight	15.686	0.000	0.323	0.000	5.067	0.000
Earth Pressure	2.998	3.353	0.693	0.367	2.078	1.231
Total	18.684	3.353			7.144	1.231

[2] Seismic (Water Level 2)



Item	Vertical Force Ni (kN)	Horizontal Force Hi (kN)	Arm Length Xi (m)	Arm Length Yi (m)	Rotational Moment (kNm) Mxi = Ni/Xi	Rotational Moment (kNm) Myi = Hi Yi
Dead Weight	15.686	3.137	0.323	0.485	5.067	1.521
Earth Pressure	5.480	7.325	0.693	0.367	3.798	2.688
Total	21.166	10.462			8.864	4.210

Loading Conditions (Water Level)	No (kN)	Ho (kN)	Mo(kNm)
Normal (Water Level 1)	18.684	3.353	5.914
Seismic (Water Level 2)	21.166	10.462	4.655

(2) Aggregate Force at Body Center

Vertical Force : Nc = No (kN)

Horizontal Force : Hc = Ho (kN)

Rotational Moment: Mc = No Bj/2.0 - Mo (kNm) where:

Body Width in the Direction of Earth Pressure: Bj = 0.840 (m)

■ Per Unit Width

Loading Conditions (Water Level)	Nc (kN)	Hc (kN)	Mc (kNm)
Normal (Water Level 1)	18.684	3.353	1.933
Seismic (Water Level 2)	21.166	10.462	4.235

■ Per Full Width (5.000 m)

Loading Conditions (Water Level)	Nc (kN)	Hc (kN)	Mc (kNm)
Normal (Water Level 1)	93.420	16.765	9.667
Seismic (Water Level 2)	105.830	52.311	21.175

2.5 Stability Calculation Results

2.5.1 Stability against Overturning

(1) Calculation of Resultant Acting Point and Eccentricity

$$d = \frac{\Sigma Mr - \Sigma Mt}{\Sigma V}$$

Here,

d: Distance from toe of base plate to action point of resultant force (m)

ΣMr: Resistance moment around toe of base plate (kNm)

ΣMt: Fall moment around toe of base plate (kNm)

ΣV: Total vertical load at bottom of base plate (kN)

$$e = B/2 - d$$

Here,

e: Eccentric distance (m) from the center of the Base Plate of the point of action of the resultant force

B: Base Plate width (m) , B=0.840

$$ea = B/n$$

Here,

ea: Allowable eccentric distance (m)

n: Safety factor

Loading conditions (Water Level)	ΣMr (kNm)	ΣMt (kNm)	ΣV (kN)	d (m)	e (m)		Ea (m)
Normal (Water Level 1)	7.144	1.231	18.684	0.317	0.103	<<	0.140
Seismic (Water Level 2)	8.864	4.210	21.166	0.220	0.200	<<	0.280

(2) Calculation of the Safety Factor

$$F = \left| \frac{Mr}{Mo} \right|$$

Here,

Mr: Moment of resistance

Mo: Moment of rotation

Loading Conditions (Water Level)	Mr: (kNm)	Mo (kNm)	Safety Factor F=Mr/Mo		Tolerance
Normal (Water Level 1)	7.144	1.231	5.806	≧	1.500
Seismic (Water Level 2)	8.864	4.210	2.106	≧	1.200

2.5.2 Stability Against Sliding

$$Fs = \frac{\Sigma V \mu + CB B}{\Sigma H}$$

Here,

ΣV: Total vertical load at Base Plate (kN)

ΣH: Total horizontal load on Base Plate (kN)

μ: Friction coefficient between bottom slab and Bearing capacity of foundation ground,, μ = 0.600

C_B: Cohesion between slab and bearing capacity of foundation ground (kN/m2) , CB = 0.000

B: Bottom plate width (m) , B = 0.900

Loading Conditions (Water Level)	Vertical Load	Horizontal Load ΣH (kN)	Safety Factor Fs		Required Safety Factor Fsa
Normal (Water Level 1)	18.684	3.353	3.343	≧	1.500
Seismic (Water Level 2)	21.166	10.462	1.214	≧	1.200

2.5.3 Check of Bearing Capacity

1) When the resultant action point lies within the base plate width of 1/3 (middle third) at the center of the bottom plate

$$q_1 = \frac{\Sigma V}{B} \cdot \left(1 + \frac{6e}{B}\right)$$

$$q_2 = \frac{\Sigma V}{B} \cdot \left(1 - \frac{6e}{B}\right)$$

2) When the resultant force acting point is within the Base Plate width of 2/3 at the center of the bottom plate

$$q1 = \frac{2\Sigma V}{3(B/2-e)}$$

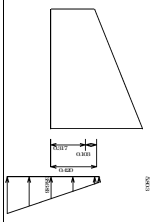
Here,

ΣV: Total vertical load acting on Base Plate bottom surface (kN)

B: Base Plate width (m) , B = 0.840

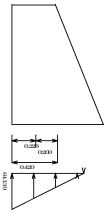
e: Eccentricity (m)

[1] Normal (Water Level 1)



Width of Subgrade Reaction (m) x and B	Shape of Subgrade Reaction	Subgrade Reaction(kN/m2)		
		qmin	qmax	Tolerance
0.840	Trapezoid	5.803	38.683 ≦	200.000

[2] Seismic (Water Level 2)



Width of Subgrade Reaction (m) x and B	Shape of Subgrade Reaction	Subgrade Reaction(kN/m2)		
		qmin	qmax	Tolerance
0.680	Triangle	0.000	64.139 ≦	300.000

1.2.2 GRAVITY　WALL
1.2.2.3 TYPE B, REPRESENTED BY L6+560

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1. Design Conditions

1.1 General

Title: Gravity Wall (TYPE C and TYPE II OF MAINTENANCE ROAD, REPRESENTED BY L 6 + 560)

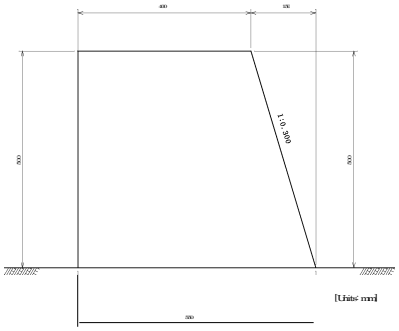
1.2 Applied Criteria

Japan Construction Technology Association, Civil Engineering Structure Standard Design Vol. 2, Manual (Retaining Wall) 2000

1.3 Format

'Gravity (direct foundation) '

1.4 Geometry



Width in the depth direction (block length) B=5000

1.5 Ground Conditions

Seismic scale: Medium scale

Region: A

Ground type: Type II

Judgment of Ground Classification

$$TG = 4\Sigma\frac{Hi}{Vsi} = 0.353 \ (0.2 \leqq TG < 0.6)$$

Here,

TG: Ground property value (s)

Hi: Thickness of the ith stratum (m)

Vsi: average shear elastic wave velocity of the i-th stratum (m/s)

case of cohesive soil

Vsi = 100 Ni 1/3 (1 ≦ Ni ≦ 25)

In the case of sandy soil

Vsi = 80 Ni 1/3 (1 ≦ Ni ≦ 50)

Ni: Average N value of the i-th stratum by the standard penetration test

Vsi = 50 m/s when N value is 0, and Vsi = 50 m/s when Vsi < 50 m/s

i: Number of the i-th stratum from the ground surface when the ground is divided into n layers from the ground surface to the seismic design foundation surface

Geological Number	Layer Type	Layer Thickness Hi (m)	Mean N-Value	Vsi (m/s)
1	sandy soil	5.500	12.0	183.154
2	sandy soil	2.370	5.0	136.798
3	cohesive soil	3.630	8.0	200.000
4	sandy soil	2.000	33.0	256.603
5	cohesive soil	4.000	19.0	266.840
6	cohesive soil	10.000	50.0	292.402

1.6 Materials Used

[concrete]　Vertical wall (plain concrete) : σck =　18 (N/mm2)

[soil]　Quality: Backfill soil:　sandy soil

Recessed soil:　sandy soil

Bearing Capacitying ground plane:　gravel

[internal friction angle]　Backside soil sand:　30.00 (degrees)

[unit volume weight]

(kN/m3)

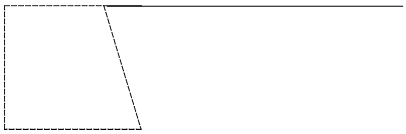
Body	Plain Concrete	23.000	
Water	For Calculation of	10.000	
Soil		Wet Weight	Saturated
Back surface		18.000	19.000
Front surface		18.000	19.000

[Design horizontal seismic coefficient]　Body: Kh = 0.20

Soil (Front) : Kh = 0.20 (Back) : Kh = 0.20

1.7 Soil

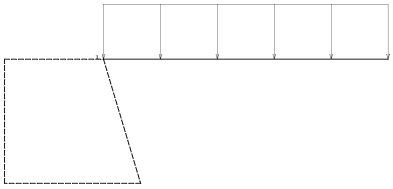
(1) Backside Soil Shape



Level difference between retaining wall crown and	0.000
Height without considering Earth Pressure Hr (m)	0.000

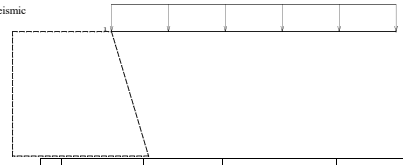
1.8 Load

[1] Normal



No.	Loading Position (m)	Loading Width (m)	Load (kN/m2)		Items to Consider		
			Start Point	End Point	Stability	vertical wall	Base Plate
1	0.000	4.000	10.000	10.000	○	-	-

[2] Seismic



No.	Loading Position (m)	Loading Width (m)	Load (kN/m2)		Items to Consider		
			Start Point	End Point	Stability	vertical wall	Base Plate
1	0.000	4.000	5.000	5.000	○	-	-

1.9 Other Loads

Not considered

1.10 Uplift

- Consider the Uplift equivalent as uplift pressure

1.11 Earth Pressure

- Earth Pressure formulas: trial wedges
- Angle of friction of Earth Pressure acting surface (degrees)

Load Condition	Active Earth Pressure		Passive Earth Pressure
	at the Stability Calculation	Cut	
Normal Earth Pressure	20.000		
Seismic Earth Pressure	15.000		

- The imaginary back surface of Earth Pressure for stability calculation is the back of the vertical wall.
- Angle between the surface at which earth pressure acts and the vertical plane at the time of stability calculation: 16.699(degrees)
- The design horizontal seismic intensity is applied to the inertia force at the time of earthquake when calculating the earth pressure below the water Level.
- Cohesion (kN/m2)

Load Condition	For Sliding Surface	For Cohesive Height	For Passive Earth Pressure
Normal	1.000	0.000	
Seismic	1.000	0.000	

- Treatment of Earth Pressure different from the direction of Seismic motion

	Consider as	Availability Factor
Stability Calculation	Normal Earth Pressure	0.500
Vertical Wall Design		0.500

1.12 Water Pressure

- Concept of Hydrostatic Pressure Calculation

Load Condition	Back Surface	Front Surface
Normal	Consider	Consider
Seismic	Consider	Consider

- Hydrostatic pressure different from the direction of seismic motion

External Water Level	Stability Calculation	Consider
	Vertical Wall Design	Consider

1.13 Load Combination Case

No	Load Name	Comments
1	Normal	Normal
2	Seismic	Seismic

	Load Name	1	2
Soil	Soil 1	○	
	Soil 2		○
Water Level	Water Level 1	○	
	Water Level 2		○
Load	Load 1	○	
	Load 2		○
Active Earth Pressure	Not considered		
	Normal Earth Pressure	○	
	Seismic Earth Pressure		○
Passive Earth Pressure	Passive Earth Pressure 1		

1.14 Conditions of Foundation

1.14.1 Data for calculating allowable shear resistance

Bottom Plate width used for checking	Effective Loading Width
Cohesive force CB between base bottom surface and ground (kN/m2)	0.000
Friction coefficient between base and ground tan φB	0.600

1.15 Allowable Values for Stability Calculation and Allowable Stress of Members

1.15.1 Tolerance for Stability Calculation

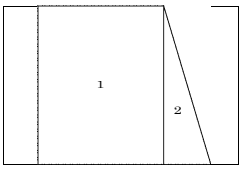
Load Condition	Allowable Eccentricity eB/B(m)	Safety Factor Against Overturning	Safety Factor Against Sliding	Allowable Bearing Capacity
Normal	1/6	1.500	1.500	200.000
Seismic	1/3	1.200	1.200	300.000

2. Stability Calculations

2.1 Block Data Not Considering Water Level

(1) Body weight

1) Block Division



2) Weight and Center of Gravity

Division	Equation Width x height x depth	Volume Vi (m3)	Center of Gravity (m)		Vi Xi	Vi Yi	Remarks
			Xi	Yi			
1	0.400 x 0.500 x 1.000	0.200	0.200	0.250	0.040	0.050	
2	1/2 x 0.150 x 0.500 x 1.000	0.038	0.450	0.167	0.017	0.006	
2		0.238			0.057	0.056	

Centroid position XG = 2 (Vi Xi) /2Vi = 0.057/0.238 = 0.239 (m)

YG = 2 (Vi Yi) /2Vi = 0.056/0.238 = 0.237 (m)

2.2 Body weight, earth and sand weight, other loads, Vertical Force and Horizontal Force due to Uplift

(1) Acting force due to Dead Weight

[1] Normal

Location	Vertical Force W = γ ·V (kN)			Acting Position X (m)
Body	23.000 x	0.238 =	5.463	0.239

[2] Seismic

Location	Vertical Force W = γ ·V (kN)			Acting Position X (m)
Body	23.000 x	0.238 =	5.463	0.239

Location	Horizontal Force H = W kh (kN)			Acting Position Y (m)
Body	5.463 x	0.20 =	1.093	0.237

(2) Dead-Weight

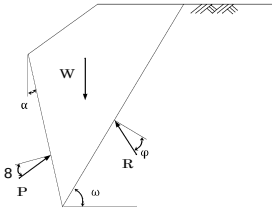
[1] Normal (Water Level 1)

	Weight Ni (kN)	Horizontal Force Hi (kN)	Acting Position		Moment (kNm)	
			Xi	Yi	Ni Xi	Hi Yi
Body	5.463	0.000	0.239	0.000	1.308	0.000
Total	5.463	0.000			1.308	0.000

[2] Seismic (Water Level 2)

	Weight Ni (kN)	Horizontal Force Hi (kN)	Acting Position		Moment (kNm)	
			Xi	Yi	Ni Xi	Hi Yi
Body	5.463	1.093	0.239	0.237	1.308	0.259
Total	5.463	1.093			1.308	0.259

2.3. Earth Pressure and Water Pressure



[1] Normal (Water Level 1)

The Earth Pressure is determined by the trial wedge method considering the cohesive force

Imaginary Backside Position (distance from toe) xp = 0.550 m

yp = 0.000 m

Imaginary Backside Height H = 0.500 m

Angle between the Surface at which the Earth Pressure Acts and the Vertical Surface α = 16.699 °

Unit Volume Weight of Backside Soil γs = 18.000 kN/m3

Internal Friction Angle of Backside Soil φ = 30.000 °

Wall Friction Angle δ = 2/3 φ = 20.000 °

Range of Slip Angle ωi = 10.00 ° to 80.00 °

Soil Weight (W) against Slip Angle (ω) , soil pressure (P) , Water Level hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Surcharge	Total	
62.00	1.871	0.000	4.159	6.030	2.714
63.00	1.821	0.000	4.048	5.869	2.716

Soil Weight (W) against Slip Angle (ω) , soil pressure (P) , Water Level hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Surcharge	Total	
64.00	1.772	0.000	3.939	5.711	2.715

The maximum soil pressure is

P = 2.716 kN when ω = 63.00 °

are used.

adhesive force of sliding surface

Co = c · L = 1.000 x 0.561 = 0.561 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega-\varphi) - Co \cdot \cos\varphi}{\cos(\omega-\varphi-\alpha-\delta)}$$

$$= \frac{5.869 \times \sin(63.00° - 30.00°) - 0.561 \times \cos 30.00°}{\cos(63.00° - 30.00° - 16.699 - 20.000°)} = 2.716 \text{ kN}$$

The horizontal component, vertical component and working position of the Earth Pressure at this time are as follows.

horizontal component

Ph = P·cos (α + δ) = 2.716 x cos (16.699° + 20.000°) =2.178 kN

Vertical component

Pv = P sin (α + δ) = 2.716 x sin (16.699° + 20.000°) =1.623 kN

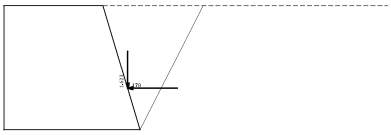
Acting position

$$Ho = \frac{H}{3} = \frac{0.500}{3} = 0.167 \text{ m}$$

x = xp-Ho · tan α = 0.550 -0.167 × tan 16.699 ° = 0.500 m

y = yp + Ho = 0.000 + 0.167 = 0.167 m

- Earth Pressure Diagram



[2] Seismic (Water Level 2)

The earth pressure is obtained by the trial wedge method considering inertia force and Cohesion force at the earthquake.

Imaginary Backside Position (distance from toe) xp = 0.550 m

yp = 0.000 m

Imaginary Backside Height H = 0.500 m

Angle between the Earth Pressure action surface and the vertical surface α = 16.699 °

Unit volume weight of Backside Soil γs = 18.000 kN/m3

Internal Friction Angle of Backside Soil φ = 30.000 °

Wall Friction Angle 6 = 1/2 φ = 15.000 °

Seismic Composite Angle 0 = tan -1 kh = tan -10.20 = 11.310 °

Range of Slip Angle ωi = 10.00 ° to 80.00 °

Soil weight (W) and soil pressure (P) Water Level with respect to Slip Angle (ω) hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Surcharge	Total	
52.00	2.433	0.000	2.703	5.136	2.360
53.00	2.370	0.000	2.634	5.004	2.361
54.00	2.310	0.000	2.566	4.876	2.360

The maximum soil pressure is determined by the following equation:

P = 2.361 kN when ω = 53.00 °

Cohesion of the sliding surface

Co = c · L = 1.000 x 0.626 = 0.626 kN

Earth Pressure

$$P = \frac{W/\cos\theta \cdot \sin(\omega-\varphi+\delta) - Co\cos\varphi}{\cos(\omega-\varphi-\alpha-\delta)}$$

$$= \frac{5.004/\cos 11.310° \times \sin(53.00° - 30.00° + 11.310°) - 0.626 \times \cos 30.00°}{\cos(53.00° - 30.00° - 16.699 - 15.000°)}$$

= 2.361 kN

The horizontal component, vertical component and working position of the Earth Pressure at this time are as follows.

horizontal component

Ph = P·cos (α + δ) = 2.361 x cos (16.699° + 15.000°) =2.009 kN

Vertical component

Pv = P sin (α + δ) = 2.361 x sin (16.699° + 15.000°) =1.241 kN

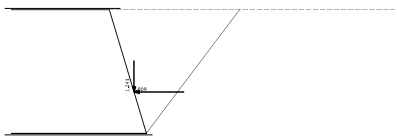
Acting position

$$Ho = \frac{H}{3} = \frac{0.500}{3} = 0.167 \text{ m}$$

x = xp-Ho · tan α = 0.550 -0.167 × tan 16.699 ° = 0.500 m

y = yp + Ho = 0.000 + 0.167 = 0.167 m

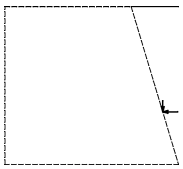
- Earth Pressure Diagram



2.4 Aggregation of Acting Forces

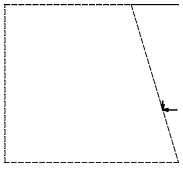
(1) Aggregate Force on front of Body

[1] Normal (Water Level 1)



Item	Vertical Force Ni (kN)	Horizontal Force Hi (kN)	Arm Length		Rotational Moment (kNm)	
			Xi (m)	Yi (m)	Mxi = Ni/Xi	Myi = Hi Yi
Dead Weight	5.463	0.000	0.240	0.000	1.308	0.000
Earth Pressure	1.623	2.178	0.500	0.167	0.812	0.364
Total	7.086	2.178			2.120	0.364

[2] Seismic (Water Level 2)



Item	Vertical Force Ni (kN)	Horizontal Force Hi (kN)	Arm Length		Rotational Moment (kNm)	
			Xi (m)	Yi (m)	Mxi = Ni/Xi	Myi = Hi Yi
Dead Weight	5.463	1.093	0.240	0.237	1.308	0.259
Earth Pressure	1.241	2.009	0.500	0.167	0.621	0.336
Total	6.704	3.102			1.929	0.594

Loading conditions (Water Level)	No (kN)	Ho (kN)	Mo (kNm)
Normal (Water Level 1)	7.086	2.178	1.756
Seismic (Water Level 2)	6.704	3.102	1.334

(2) Aggregate Force at Body center

Vertical Force : Nc = No (kN)
Horizontal Force : Hc = Ho (kN)
Rotational Moment: Mc = No Bj/2.0 - Mo (kNm) where:
Body Width in the Direction of Earth Pressure: Bj = 0.550 (m)

■ Per Unit Width

Loading conditions (Water Level)	Nc (kN)	Hc (kN)	Mc (kNm)
Normal (Water Level 1)	7.086	2.178	0.193
Seismic (Water Level 2)	6.704	3.102	0.509

■ Per Full Width (5.000 m)

Loading conditions (Water Level)	Nc (kN)	Hc (kN)	Mc (kNm)
Normal (Water Level 1)	35.428	10.890	0.963
Seismic (Water Level 2)	33.518	15.508	2.546

2.5 Stability Calculation Results

2.5.1 Stability against Overturning

(1) Calculation of Resultant Acting Point and Eccentricity

$$d = \frac{\Sigma Mr - \Sigma Mt}{\Sigma V}$$

Here,

d: Distance from toe of base plate to action point of resultant force (m)
ΣMr: Resistance moment around toe of base plate (kNm)
ΣMt: Fall moment around toe of base plate (kNm)
ΣV: Total vertical load at bottom of base plate (kN)

$$e = B/2 - d$$

Here,

e: Eccentric distance (m) from the center of the Base Plate of the point of action of the resultant force
B: Base Plate width (m): B = 0.550

$$ea = B/n$$

Here,

ea: Allowable eccentric distance (m)
n: Safety factor

Loading conditions (Water Level)	ΣMr (kNm)	ΣMt (kNm)	ΣV (kN)	d (m)	e (m)		Ea (m)
Normal (Water Level 1)	2.120	0.364	7.086	0.248	0.027	<<	0.092
Seismic (Water Level 2)	1.929	0.594	6.704	0.199	0.076	<<	0.183

(2) Calculation of the Safety Factor

$$F = \left| \frac{Mr}{Mo} \right|$$

Here,

Mr: Moment of resistance
Mo: Moment of rotation

Loading Conditions (Water Level)	Mr. (kNm)	Mo (kNm)	Safety Factor		
			F = Mr/Mo		Tolerance
Normal (Water Level 1)	2.120	0.364	5.827	≧	1.500
Seismic (Water Level 2)	1.929	0.594	3.245	≧	1.200

2.5.2 Stability Against Sliding

$$Fs = \frac{\Sigma V \mu + CB B}{\Sigma H}$$

Here,

ΣV: Total vertical load at Base Plate (kN)
ΣH: Total horizontal load on Base Plate (kN)
μ: Friction coefficient between bottom slab and Bearing capacity of foundation ground,, μ = 0.600
C_B: Cohesion between slab and bearing capacity of foundation ground (kN/m2) , CB = 0.000
B: Bottom slab width (m), B = 0.550

Loading Conditions (Water Level)	Vertical Load ΣV (kN)	Horizontal Load ΣH (kN)	Safety Factor Fs		Required Safety Factor Fsa
Normal (Water Level 1)	7.086	2.178	1.952	≧	1.500
Seismic (Water Level 2)	6.704	3.102	1.297	≧	1.200

2.5.3 Check of Bearing Capacity

1) When the resultant action point lies within the base plate width of 1/3 (middle third) at the center of the bottom plate

$$q_1 = \frac{\Sigma V}{B} \cdot \left(1 + \frac{6e}{B}\right)$$

$$q_2 = \frac{\Sigma V}{B} \cdot \left(1 - \frac{6e}{B}\right)$$

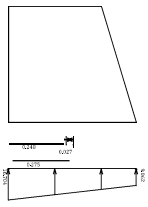
2) When the resultant point of action is within the bottom slab width of 2/3 in the center of the bottom plate.

$$q1 = \frac{2\Sigma V}{3(B/2 - e)}$$

Here,

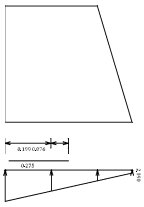
2V: Total vertical load acting on bottom face of slab (kN)
B: Bottom slab width (m) , B = 0.780
e: Eccentricity (m)

[1] Normal (Water Level 1)



Width of Subgrade Reaction (m) x and B	Shape of Subgrade Reaction	Subgrade Reaction(kN/m2)		
		qmin	qmax	Tolerance
0.550	platformtype	9.062	16.704 ≦	200.000

[2] Seismic (Water Level 2)



Width of Subgrade Reaction (m) x and B	Shape of Subgrade Reaction	Subgrade Reaction(kN/m2)		
		qmin	qmax	Tolerance
0.550	platform	2.090	22.287 ≦	300.000

1.2.2 GRAVITY　WALL
1.2.2.4 TYPE C AND TYPE II, REPRESENTED BY L6+560

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1. Design Conditions

1.1 General Information

Title: Gravity Wall (TYPE B REPRESENTED BY L6 + 560)

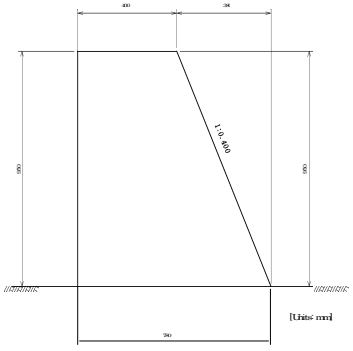
1.2 Applied Criteria

Japan Construction Technology Association, Civil Engineering Structure Standard Design Vol. 2, Manual (Retaining Wall) 2000

1.3 Format

'Gravity (direct foundation) '

1.4 Geometry



Width in the depth direction (block length) B=5000

1.5 Ground conditions

Seismic Scale: Medium

Geography: A

Ground type: Type II

Judgment of Ground Classification

$$TG = 4\Sigma \frac{Hi}{Vsi} = 0.353 \ (0.2 \leqq TG \leqq 0.6)$$

Here,

Here,

T_G: Ground property value (s)

Hi: Thickness of the ith stratum (m)

Vsi: Average shear elastic wave velocity of the i-th stratum (m/s)

Case of cohesive soil

Vsi = 100 Ni 1/3 (1 ≦ Ni ≦ 25)

In the case of sandy soil

Vsi = 80 Ni 1/3 (1 ≦ Ni ≦ 50)

Ni: Average N value of the i-th stratum by the standard penetration test

Vsi = 50 m/s when N value is 0, and Vsi = 50 m/s when Vsi < 50 m/s

i: Number of the i-th stratum from the ground surface when the ground is divided into n layers from the ground surface to the seismic design foundation surface

Geological Number	Layer Type	Layer Thickness Hi (m)	Mean N-Value	Vsi (m/s)
1	sandy soil	5.500	12.0	183.154
2	sandy soil	2.370	5.0	136.798
3	cohesive soil	3.630	8.0	200.000
4	sandy soil	2.000	33.0	256.603
5	cohesive soil	4.000	19.0	266.840
6	cohesive soil	10.000	50.0	292.402

1.6 Materials Used

[concrete]　Vertical Wall (plain concrete) : σck = 18 (N/mm2)

【 Soil 】　Quality] Back Soily soil

Backfill: sandy soil

Zodiac:: gravel

[internal friction angle]　Back Soil: 30.00 (degrees)

[unit weight] (kN/m3)

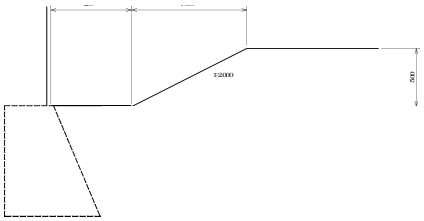
Body	Plain Concrete	23.000	
Water	For Calculation of	10.000	
Soil		Wet Weight	Saturated
Back surface		18.000	19.000
Front surface		18.000	19.000

[Design horizontal seismic coefficient] Body: Kh = 0.20

Soil (Front) : Kh = 0.20 (Back) : Kh = 0.20

1.7. Soil

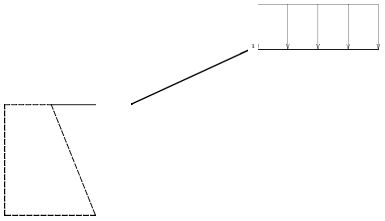
(1) Backside Soil Shape



Level difference between retaining wall crown and backside ground (m)		0.000
Slope		2.000
Embankment height	(m)	0.500
Horizontal length	(m)	0.700
Height without considering Earth Pressure Hr	(m)	0.000

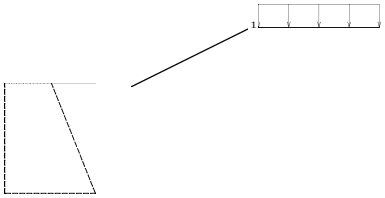
1.8 Load

[1] Normal



No.	Loading Position (m)	Loading Width (m)	Load (kN/m2)		Items to Consider		
			Start Point	End Point	Stability	Vertical Wall	Bottom Plate
1	1.800	4.000	10.000	10.000	○	-	-

[2] Seismic



No.	Loading Position (m)	Loading Width (m)	Load (kN/m2)		Items to Consider		
			Start Point	End Point	Stability	Vertical wall	Bottom Plate
1	1.800	4.000	5.000	5.000	○	-	-

1.9 Other loads

Not considered

1.10 Uplift

- Consider the Uplift equivalent as the uplift pressure

1.11 Earth Pressure

- Earth Pressure formulas: trial wedges
- Angle of wall friction of Earth Pressure acting surface (degrees)

Load Condition	Active Earth Pressure		Passive Earth Pressure
	at the Stability Calculation	Cut	
Normal Earth Pressure	20.000		Normal Earth Pressure
Seismic Earth Pressure	15.000		Seismic Earth Pressure

- The imaginary back surface of Earth Pressure for stability calculation is the back of the vertical wall.
- Angle between the surface at which earth pressure acts and the vertical plane at the time of stability calculation: 21.801 (degrees)
- The design horizontal seismic intensity is applied to the inertia force at the time of earthquake when calculating the earth pressure below the water Level.
- Raised embankment height ratio = 1.0 when the embankment height is 15.000 (m) .

- Cohesion (kN/m2)

Load Condition	For Sliding Surfaces	For Cohesive Height	For Passive Earth Pressure
Normal	1.000	0.000	
Seismic	1.000	0.000	

- Treatment of Earth Pressure different from direction of Seismic motion

	Consider as	Availability Factor
Stability Calculation	Normal Earth Pressure	0.500
Vertical Wall Design		0.500

1.12 Water Pressure

- Concept of Hydrostatic Pressure Calculation

Load Condition	Back Surface	Front Surface
Normal	Consider	Consider
Seismic	Consider	Consider

- Hydrostatic pressure different from the direction of seismic motion

External Water Level	Stability Calculation	Consider
	Vertical Wall Design	Consider

1.13 Load Combination Case

No	Load Name	Comments
1	Normal	Normal
2	Seismic	Seismic

	Load Name	1	2
Soil	Soil 1	○	
	Soil 2		○
Water Level	Water Level 1	○	
	Water Level 2		○
Load	Load 1	○	
	Load 2		○
Active Earth Pressure	Not considered		
	Normal Earth Pressure	○	
	Seismic Earth Pressure		○
Passive Earth Pressure	Passive Earth Pressure 1		

1.14 Conditions of Foundation

1.14.1 Data for calculating allowable shear resistance

Bottom Plate width used for checking	Effective Loading Width
Cohesive force CB between base bottom surface and ground (kN/m2)	0.000
Friction coefficient between base and ground tan φB	0.600

1.15 Allowable Values for Stability Calculation and Allowable Stress of Members

1.15.1Tolerance for the stability calculation

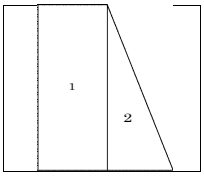
Load Condition	Allowable Eccentricity eB/B(m)	Safety Factor Against Overturning	Safety Factor Against Sliding	Allowable Bearing Capacity
Normal	1/6	1.500	1.500	200.000
Seismic	1/3	1.200	1.200	300.000

2. Stability Calculation

2.1 Block Data Not Considering Water Level

(1) Body weight

1) Block Division



2) Weight and Center of Gravity

Division	Width x Height x Depth Equation	Volume Vi (m3)	Center of Gravity (m) Xi	Yi	Vi Xi	Vi Yi	Remarks
1	0.400 x 0.950 x 1.000	0.380	0.200	0.475	0.076	0.180	
2	1/2 x 0.380 x 0.950 x 1.000	0.181	0.527	0.317	0.095	0.057	
2		0.561			0.171	0.238	

Centroid location XG = 2 (Vi Xi) /2Vi = 0.171/0.561 = 0.305 (m)

YG = 2 (Vi Yi) /2Vi = 0.238/0.561 = 0.424 (m)

2.2 Body weight, earth and sand weight, other loads, Vertical Force and Horizontal Force due to Uplift

(1) Acting force due to dead weight

[1] Normal

Location	W = γ ·V (kN) Vertical Force	Acting Position X (m)
Body	23.000 x 0.561 = 12.892	0.305

[2] Seismic

Location	W = γ ·V (kN) Vertical Force	Acting Position X (m)
Body	23.000 x 0.561 = 12.892	0.305

Location	W = γ ·V (kN) Vertical Force	Acting Position X (m)
Body	12.892 x 0.20 = 2.578	0.424

(2) Dead-Weight

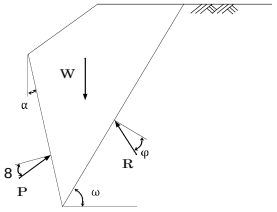
[1] Normal (Water Level 1)

	Weight Ni (kN)	Horizontal Force Hi (kN)	Acting Position Xi	Yi	Moment (kNm) Ni Xi	Hi Yi
Body	12.892	0.000	0.305	0.000	3.935	0.000
Total	12.892	0.000			3.935	0.000

[2] Seismic (Water Level 2)

	Weight Ni (kN)	Horizontal Force Hi (kN)	Acting Position Xi	Yi	Moment (kNm) Ni Xi	Hi Yi
Body	12.892	2.578	0.305	0.424	3.935	1.093
Total	12.892	2.578			3.935	1.093

2.3. Earth Pressure and Water Pressure



[1] Normal (Water Level 1)

The Earth Pressure is determined by the trial wedge method considering the cohesive force.

Imaginary Backside Position (distance from toe) xp = 0.780 m

yp = 0.000 m

Imaginary Backside Height H = 0.950 m

Angle between the Surface at which the Earth Pressure Acts and the Vertical Surface α = 21.801 °

Unit Volume Weight of Backside Soil γs = 18.000 kN/m3

Internal Friction Angle of Backside Soil φ = 30.000 °

Wall Friction Angle δ = 2/3 φ = 20.000 °

Range of Slip Angle ωi = 10.00 ° to 80.00 °

Soil Weight (W) against Slip Angle (ω) , soil pressure (P) , Water Level hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN) Above Water Level	Below Water Level	Surcharge	Total	Earth Pressure P (kN)
65.00	7.125	0.000	0.000	7.125	3.124
66.00	6.927	0.000	0.000	6.927	3.125

Soil Weight (W) against Slip Angle (ω) , soil pressure (P) , Water Level hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN) Above Water Level	Below Water Level	Surcharge	Total	Earth Pressure P (kN)
67.00	6.736	0.000	0.000	6.736	3.122

The maximum soil pressure is determined by the following equation:

P = 3.125 kN at ω = 66.00 °

is true.

Cohesion of the sliding surface

Co = c · L = 1.000 x 1.112 = 1.112 kN

Earth Pressure

$$P = \frac{W \sin(\omega-\varphi) \cdot \text{Co} \cos\varphi}{\cos(\omega-\varphi-\alpha-\delta)}$$

$$= \frac{6.927 \times \sin(66.00° - 30.00°) \cdot 1.112 \times \cos 30.00°}{\cos(66.00° - 30.00° - 21.801° - 20.000°)} = 3.125 \text{ kN}$$

The horizontal component, vertical component, and working location of soil pressure at this time are as follows.

horizontal component

Ph = P · cos (α + δ) = 3.125 × cos (21.801° + 20.000°) =2.330 kN

Vertical component

Pv = P · sin (α + δ) = 3.125 × sin (21.801° + 20.000°) =2.083 kN

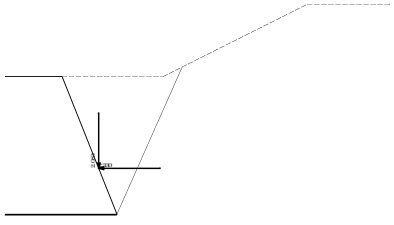
Acting position

$$Hb = \frac{H}{3} = \frac{0.950}{3} = 0.317 \text{ m}$$

x = xp-Ho · tan α = 0.780 -0.317 × tan 21.801 ° = 0.653 m

y = yp + Hb = 0.000 + 0.317 = 0.317 m

- Earth Pressure Diagram



[2] Seismic (Water Level 2)

The earth pressure is obtained by the trial wedge method considering inertia force and Cohesion force at the earthquake.

Imaginary Backside Position (distance from toe) xp = 0.780 m

yp = 0.000 m

Imaginary Backside Height H = 0.950 m

Angle between the Surface at which the Earth Pressure Acts and the Vertical Surface α = 21.801 °

Unit volume weight of Backside Soil γs = 18.000 kN/m3

Internal Friction Angle of Backside Soil φ = 30.000 °

Wall Friction Angle 6 = 1/2 φ = 15.000 °

Seismic Composite Angle θ = tan -1 kh = tan -10.20 = 11.310 °

Range of Slip Angle ωi = 10.00 ° to 80.00 °

Soil weight (W) and soil pressure (P) Water Level with respect to Slip Angle (ω) hw = 0.000 m

Slip Angle ω (°)	Soil Weight W (kN) Above Water Level	Below Water Level	Surcharge	Total	Earth Pressure P (kN)
36.00	21.913	0.000	2.879	24.792	6.271
37.00	20.980	0.000	2.521	23.501	6.272
38.00	20.089	0.000	2.180	22.269	6.242

The maximum soil pressure is determined by the following equation:

P = 6.272 kN at ω = 37.00 °

Cohesion of the sliding surface

Co = c · L = 1.000 x 2.409 = 2.409 kN

Earth Pressure

$$P = \frac{W/\cos\theta \cdot \sin(\omega-\varphi+\theta) - \text{Co} \cos\varphi}{\cos(\omega-\varphi-\alpha-\delta)}$$

$$= \frac{23.501/\cos 11.310° \times \sin(37.00° - 30.00° + 11.310°) - 2.409 \times \cos 30.00°}{\cos(37.00° - 30.00° - 21.801° - 15.000°)}$$

= 6.272 kN

The horizontal component, vertical component, and working location of soil pressure at this time are as follows.

horizontal component

Ph = P · cos (α + δ) = 6.272 × cos (21.801° + 15.000°) =5.022 kN

Vertical component

Pv = P · sin (α + δ) = 6.272 × sin (21.801° + 15.000°) =3.757 kN

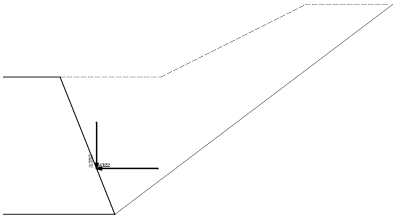
Acting position

$$Ho = \frac{H}{3} = \frac{0.950}{3} = 0.317 \text{ m}$$

x = xp-Ho · tan α = 0.780 -0.317 × tan 21.801 ° = 0.653 m

y = yp + Ho = 0.000 + 0.317 = 0.317 m

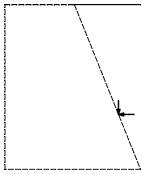
- Earth Pressure Diagram



2.4 Aggregation of Acting Forces

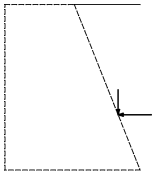
(1) Aggregate Force on front of Body

[1] Normal (Water Level 1)



Item	Vertical Force Ni (kN)	Horizontal Force Hi (kN)	Arm Length Xi (m)	Arm Length Yi (m)	Rotational Moment (kNm) Mxi = Ni,	Rotational Moment (kNm) Myi = Hi Yi
Dead Weight	12.892	0.000	0.305	0.000	3.935	0.000
Earth Pressure	2.083	2.330	0.653	0.317	1.360	0.739
Total	14.975	2.330			5.295	0.739

[2] Seismic (Water Level 2)



Item	Vertical Force Ni (kN)	Horizontal Force Hi (kN)	Arm Length Xi (m)	Arm Length Yi (m)	Rotational Moment (kNm) Mxi = Ni, Xi	Rotational Moment (kNm) Myi = Hi Yi
Dead Weight	12.892	2.578	0.305	0.424	3.935	1.093
Earth Pressure	3.757	5.022	0.653	0.317	2.453	1.592
Total	16.649	7.600			6.388	2.685

Loading Conditions (Water Level)	No (kN)	Ho (kN)	Mo(kN.m.)
Normal (Water Level 1)	14.975	2.330	4.556
Seismic (Water Level 2)	16.649	7.600	3.703

(2) Aggregate Force at Body center

Vertical Force : Nc = No (kN)

Horizontal Force : Hc = Ho (kN)

Rotational Moment: Mc = No · Bj/2.0 - Mo (kN.m.) where:

Body Width in the Direction of Earth Pressure: Bj = 0.780 (m)

■ Per Unit Width

Loading Conditions (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Normal (Water Level 1)	14.975	2.330	1.284
Seismic (Water Level 2)	16.649	7.600	2.790

■ Per Full Width (5.000 m)

Loading Conditions (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Normal (Water Level 1)	74.873	11.650	6.419
Seismic (Water Level 2)	83.243	38.001	13.951

2.5 Stability Calculation Results

2.5.1 Stability against Overturning

(1) Calculation of Resultant Acting Point and Eccentricity

$$d = \frac{\Sigma Mr - \Sigma Mt}{\Sigma V}$$

Here,

d: Distance from toe of base plate to action point of resultant force (m)

ΣMr: Resistance moment around toe of base plate (kNm)

ΣMt: Fall moment around toe of base plate (kNm)

ΣV: Total vertical load at bottom of base plate (kN)

$$e = B/2 - d$$

Here,

e: Eccentric distance (m) from the center of the Base Plate of the point of action of the resultant force

B: Base Plate width (m) , B = 0.780

$$ea = B/n$$

Here,

ea: Allowable eccentric distance (m)

n: Safety factor

Loading conditions (Water Level)	ΣMr (kNm)	ΣMt (kNm)	ΣV (kN)	d (m)	e (m)		Ea (m)
Normal (Water Level 1)	5.295	0.739	14.975	0.304	0.086	≦	0.130
Seismic (Water Level 2)	6.388	2.685	16.649	0.222	0.168	≦	0.260

(2) Calculation of the Safety Factor

$$F = \left| \frac{Mr}{Mo} \right|$$

Here,

Mr: Moment of resistance

Mo: Moment of rotation

Loading Conditions (Water Level)	Mr. (kNm)	Mo (kNm)	Safety Factor F = Mr/Mo		Tolerance
Normal (Water Level 1)	5.295	0.739	7.169	≧	1.500
Seismic (Water Level 2)	6.388	2.685	2.379	≧	1.200

2.5.2 Stability Against Sliding

$$Fs = \frac{\Sigma V \cdot \mu + CB \cdot B}{\Sigma H}$$

Here,

ΣV: Total vertical load at Base Plate (kN)

ΣH: Total horizontal load on Base Plate (kN)

μ: Friction coefficient between bottom slab and Bearing capacity of foundation ground,, μ = 0.600

C_B: Cohesion between slab and bearing capacity of foundation ground (kN/m2) , CB = 0.000

B: Bottom slab width (m) , B = 0.780

Loading Conditions (Water Level)	Vertical Load ΣV (kN)	Horizontal Load ΣH (kN)	Safety Factor Fs		Required Safety Factor Fsa
Normal (Water Level 1)	14.975	2.330	3.856	≧	1.500
Seismic (Water Level 2)	16.649	7.600	1.314	≧	1.200

2.5.3 Check of Bearing Capacity

1) When the resultant action point lies within the base plate width of 1/3 (middle third) at the center of the bottom plate

$$q_1 = \frac{\Sigma V}{B} \cdot \left(1 + \frac{6e}{B}\right)$$

$$q_2 = \frac{\Sigma V}{B} \cdot \left(1 - \frac{6e}{B}\right)$$

2) When the resultant point of action is within the bottom slab width of 2/3 in the center of the bottom plate.

$$q1 = \frac{2\Sigma V}{3\,(B/2 - e)}$$

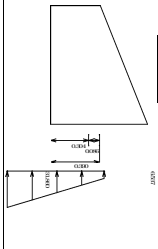
Here,

2V: Total vertical load acting on bottom face of slab (kN)

B: Bottom slab width (m) , B = 0.780

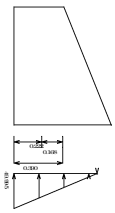
e: Eccentricity (m)

[1] Normal (Water Level 1)



Width of Subgrade Reaction (m) x and B	Shape of Subgrade Reaction	Subgrade Reaction(kN/m2) qmin	qmax		Tolerance
0.780	Trapezoid	6.537	31.860	≦	200.000

[2] Seismic (Water Level 2)



Width of Subgrade Reaction (m) x and B	Shape of Subgrade Reaction	Subgrade Reaction(kN/m2)		
		qmin	qmax	Tolerance
0.666	Triangle	0.000	49.995 ≦	300.000

1.2.3 Inclined Wall

There are two types of shapes as inclined wall in this project. The wall whose heights, Hw is lower than 3.0 m is Type A, and the wall whose heights, Hw, is higher than 3.0 m is Type B.

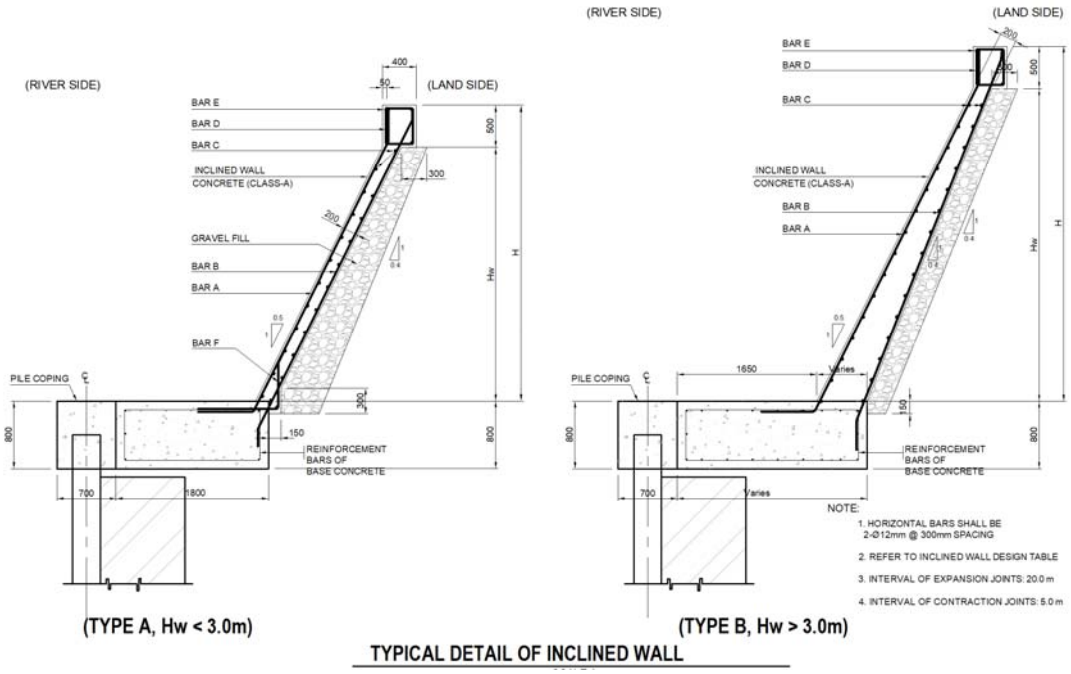


Figure Typical Detail of Inclined Wall

The structural calculation was conducted every 50cm from Hw=3.0 m to Hw=7.0 m.

In this design, inclined walls are installed in the revetment on the river channel side above SSP revetment. The toe portion of the inclined wall and the top coping of the revetment for low water channel are connected by dowel bars.

The stability of the inclined wall is usually evaluated by sliding, overturning, and bearing resistance. However, in this design, since the inclined wall is connected to the SSP revetment, and the vertical force is transmitted to SSP, bearing resistance isn't evaluated.

Also, when the inclined wall does not satisfy with the requirement of sliding and overturning, the shortage of horizontal force and moment is added to the structural calculation of the steel sheet pile.

The summary of the result is shown below.

Table　Summary of the Structure Calculation for Inclined Wall (Stability)

Wall Height (m)	Condition	Over-Turning									Slide					
		Base Length (m)	Resistaince Moment at ToeΣMr (kN・m)	Over-Turning Moment at ToeΣMt (kN・m)	Vertical LoadΣV (kN)	Distance from toe to the working point of resultant force d (m)	Eccentric Distance (m)	Acceptable Eccentric Distance (m)	Judge※	Moment of Acting to SSP (KN*m)	Vertical Load ΣV (kN)	Horozontal Load ΣH (kN)	Safety Factor	Required Safety Factor	Judge※	Forth of Acting to SSP (KN)
3.0m	Steady	1.8	83.383	44.730	52.632	0.734	0.166	0.3	OK	0	52.632	31.214	0.843	1.5	NG	13.7
	Earthquake	1.8	83.383	85.061	52.632	-0.032	0.932	0.6	NG	17.5	52.632	60.613	0.434	1.2	NG	38.7
3.5m	Steady	2.223	142.439	68.150	75.856	0.979	0.133	0.37	OK	0	75.856	42.594	0.890	1.5	NG	17.4
	Earthquake	2.223	142.439	128.329	75.856	0.186	0.926	0.741	NG	14.0	75.856	81.831	0.463	1.2	NG	50.3
4.0m	Steady	2.273	167.356	90.416	83.484	0.922	0.215	0.379	OK	0	83.484	51.169	0.816	1.5	NG	23.4
	Earthquake	2.273	167.356	169.597	83.484	-0.027	1.164	0.758	NG	33.9	83.484	97.546	0.428	1.2	NG	62.8
4.5m	Steady	2.323	195.363	116.991	91.674	0.855	0.307	0.387	OK	0	91.674	60.523	0.757	1.5	NG	30.0
	Earthquake	2.323	195.363	218.298	91.674	-0.250	1.412	0.774	NG	58.5	91.674	114.406	0.401	1.2	NG	76.3
5.0m	Steady	2.373	226.618	148.319	100.426	0.780	0.407	0.395	NG	1.2	100.426	70.628	0.711	1.5	NG	37.2
	Earthquake	2.373	226.618	274.713	100.426	-0.479	1.666	0.791	NG	87.9	100.426	132.189	0.380	1.2	NG	90.4
5.5m	Steady	2.423	261.259	184.470	109.742	0.700	0.512	0.404	NG	11.9	109.742	81.372	0.674	1.5	NG	44.8
	Earthquake	2.423	261.259	339.833	109.742	-0.716	1.928	0.808	NG	122.9	109.742	151.164	0.363	1.2	NG	105.5
6.0m	Steady	2.473	299.511	225.595	119.619	0.618	0.619	0.412	NG	24.8	119.619	92.723	0.645	1.5	NG	52.9
	Earthquake	2.473	299.511	413.655	119.619	-0.954	2.191	0.824	NG	163.5	119.619	171.145	0.349	1.2	NG	121.4
6.5m	Steady	2.523	341.517	271.326	130.059	0.540	0.722	0.421	NG	39.2	130.059	104.356	0.623	1.5	NG	61.1
	Earthquake	2.523	341.517	521.717	130.059	-1.386	2.648	0.841	NG	234.9	130.059	201.654	0.322	1.2	NG	147.5
7.0m	Steady	2.573	387.398	322.795	141.062	0.458	0.829	0.429	NG	56.4	141.062	116.659	0.605	1.5	NG	69.7
	Earthquake	2.573	387.398	625.821	141.062	-1.690	2.977	0.858	NG	298.9	141.062	227.027	0.311	1.2	NG	168.3
6.5m (Long Bottom Concrete)	Steady	4.323	589.905	268.291	158.803	2.025	0.137	0.72	OK	0	158.803	103.189	0.769	1.5	NG	50.3
	Earthquake	4.323	589.905	518.814	158.803	0.448	1.714	1.441	NG	43.4	158.803	206.124	0.385	1.2	NG	140.0
7.0m (Long Bottom Concrete)	Steady	4.423	669.223	322.795	172.235	2.011	0.201	0.737	OK	0	172.235	116.659	0.738	1.5	NG	59.3
	Earthquake	4.423	669.223	627.153	172.235	0.244	1.968	1.474	NG	85.0	172.235	233.262	0.369	1.2	NG	161.5
3.5m (Short Bottom Concrete, Aroud Sta.7+200)	Steady	0.7	37.223	40.470	33.278	-0.098	0.448	0.117	NG	11.1	33.278	28.866	0.576	1.5	NG	17.8
	Earthquake	0.7	37.223	77.646	33.278	-1.215	1.565	0.233	NG	44.4	33.278	53.509	0.311	1.2	NG	39.7

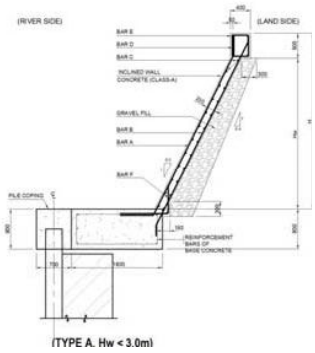
Table　Summary of the Structure Calculation for Inclined Wall (Stress Calculation)

Wall Height (m)	Condition	Stress Calculation																		
		Wall									Base Concrete									
		Compressive Stress			Tensile Stress				Shear Stress Intensity			Compressive Stress			Tensile Stress				Shear Stress Intensity		
		Compressive Stress (N/mm2)	Affordable Compressive Stress (N/mm2)	Judge	Diameter of Rabor	Tensile Stress (N/mm2)	Affordable Tensile Stress (N/mm2)	Judge	Shear Stress Intensity (N/mm2)	Affordable Shear Stress Intensity (N/mm2)	Judge	Compressive Stress (N/mm2)	Affordable Compressive Stress (N/mm2)	Judge	Diameter of Rabor	Tensile Stress (N/mm2)	Affordable Tensile Stress (N/mm2)	Judge	Shear Stress Intensity (N/mm2)	Affordable Shear Stress Intensity (N/mm2)	Judge
3.0m	Steady	0.447	8.200	OK	D20	22.606	140.000	OK	0.029	0.360	OK	0.447	8.200	OK	D16	22.606	140.000	OK	0.029	0.360	OK
	Earthquake	0.460	10.906	OK		23.229	186.200	OK	0.042	0.479	OK	0.460	10.906	OK		23.229	186.200	OK	0.042	0.479	OK
3.5m	Steady	0.327	8.200	OK	D20	10.207	140.000	OK	0.063	0.360	OK	0.569	8.200	OK	D16	28.743	140.000	OK	0.045	0.360	OK
	Earthquake	1.434	10.906	OK		44.747	186.200	OK	0.111	0.479	OK	1.624	10.906	OK		82.077	186.200	OK	0.065	0.479	OK
4.0m	Steady	0.457	8.200	OK	D20	15.117	140.000	OK	0.071	0.360	OK	0.753	8.200	OK	D16	38.044	140.000	OK	0.057	0.360	OK
	Earthquake	1.784	10.906	OK		59.030	186.200	OK	0.126	0.479	OK	0.460	10.906	OK		23.229	186.200	OK	0.042	0.479	OK
4.5m	Steady	0.591	8.200	OK	D20	20.613	140.000	OK	0.079	0.360	OK	0.968	8.200	OK	D16	48.932	140.000	OK	0.071	0.360	OK
	Earthquake	2.147	10.906	OK		74.893	186.200	OK	0.141	0.479	OK	0.460	10.906	OK		23.229	186.200	OK	0.042	0.479	OK
5.0m	Steady	0.731	8.200	OK	D20	26.784	140.000	OK	0.086	0.360	OK	1.224	8.200	OK	D16	62.255	140.000	OK	0.087	0.360	OK
	Earthquake	2.513	10.906	OK		92.039	186.200	OK	0.155	0.479	OK	0.462	10.906	OK		23.503	186.200	OK	0.042	0.479	OK
5.5m	Steady	0.753	8.200	OK	D25	22.140	140.000	OK	0.094	0.360	OK	1.511	8.200	OK	D16	76.355	140.000	OK	0.106	0.360	OK
	Earthquake	2.462	10.906	OK		72.346	186.200	OK	0.169	0.479	OK	0.460	10.906	OK		23.229	186.200	OK	0.042	0.479	OK
6.0m	Steady	0.884	8.200	OK	D25	27.110	140.000	OK	0.102	0.360	OK	1.859	8.200	OK	D16	93.932	140.000	OK	0.125	0.360	OK
	Earthquake	2.776	10.906	OK		85.148	186.200	OK	0.182	0.479	OK	0.460	10.906	OK		23.229	186.200	OK	0.042	0.479	OK
6.5m	Steady	1.014	8.200	OK	D25	32.331	140.000	OK	0.110	0.360	OK	2.249	8.200	OK	D16	113.675	140.000	OK	0.141	0.360	OK
	Earthquake	3.239	10.906	OK		103.333	186.200	OK	0.202	0.479	OK	0.460	10.906	OK		23.229	186.200	OK	0.042	0.479	OK
7.0m	Steady	1.144	8.200	OK	D25	37.864	140.000	OK	0.117	0.360	OK	2.266	8.200	OK	D20	88.725	140.000	OK	0.157	0.360	OK
	Earthquake	3.629	10.906	OK		120.072	186.200	OK	0.218	0.479	OK	0.386	10.906	OK		15.130	186.200	OK	0.042	0.479	OK
6.5m (Long Bottom Concrete)	Steady	1.144	8.200	OK	D25	35.082	140.000	OK	0.116	0.360	OK	1.802	8.200	OK	D25	54.179	140.000	OK	0.099	0.360	OK
	Earthquake	3.608	10.906	OK		110.679	186.200	OK	0.214	0.479	OK	5.024	10.906	OK		151.035	186.200	OK	0.135	0.479	OK
7.0m (Long Bottom Concrete)	Steady	1.242	8.200	OK	D25	40.286	140.000	OK	0.121	0.360	OK	2.161	8.200	OK	D25	64.956	140.000	OK	0.115	0.360	OK
	Earthquake	3.852	10.906	OK		124.952	186.200	OK	0.224	0.479	OK	6.085	10.906	OK		182.931	186.200	OK	0.153	0.479	OK
3.5m (Short Bottom Concrete, Aroud Sta.7+200)	Steady	1.095	8.200	OK	D20	13.495	140.000	OK	0.146	0.360	OK	0.026	8.200	OK	D16	0.026	140.000	OK	0.012	0.360	OK
	Earthquake	8.058	10.906	OK		99.332	186.200	OK	0.260	0.479	OK	0.026	10.906	OK		0.026	186.200	OK	0.012	0.479	OK
Canita H=2.4m	Steady	0.582	8.200	OK		29.167	140.000	OK	0.045	0.360	OK	0.659	8.200	OK		53.613	140.000	OK	0.030	0.360	OK
	Earthquake	1.662	10.906	OK		83.288	186.200	OK	0.066	0.479	OK	0.677	10.906	OK		55.090	186.200	OK	0.042	0.479	OK

The calculation sheets of Hw =3.0, the maximum height of Type A, and Hw =7.0, the maximum height of Type B, are shown in the following pages. The calculation of the other cases was conducted with the same procedures for those cases.

Type A

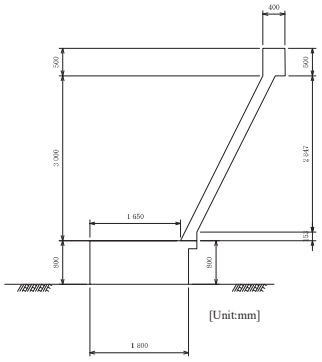
Hw :3.0m



(TYPE A. Hw < 3.0m)

1 Design Conditions

1.1 Geometry



Depth Width (Block Length) B = 5000 (mm)

1.2 Materials

[Concrete] Vertical wall (reinforced concrete) : σck = 20.7 (N/mm2)
Base concrete (reinforced concrete) : σck = 20.7 (N/mm2)

[Iron bar] Type: : Grade 275

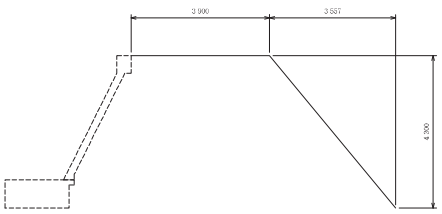
[Soil] Backfill : sand and gravel
Foudation : sandy gravel

[Internal Fdiction] Backfill : 30 degrees

[Unit weight]
(kN/m3)

Body	Base Concrete	22.500	
	Vertical wall	22.500	
Water		9.800	
Soil		Wet weight	Saturated weight
River side		19.000	19.000
Land side		20.000	20.800

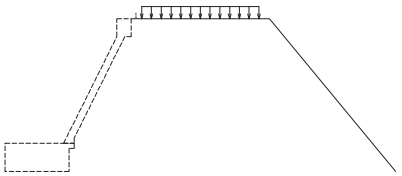
1.3 Backfill and Embankment



Level Difference Between Retaining Wall Crown And Ground Surface Start Point	(m)	0.000
Height Without Considering Earth Pressure Hr (in stability analysis) Hr	(m)	0.000

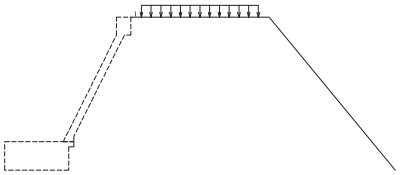
1.4 Loads

(1) Normal



Item	Loading Position (m)	Loading Width (m)	Load Strength (kN/m2)		Study to Be Considered		
			From	End Side	Stability Analysis	Vertical Wall	Bottom Slab
1	0.300	3.300	10.000	10.000	○	○	×

(2) Seismic



Item	Loading Position (m)	Loading Width (m)	Load Strength (kN/m2)		Study to Be Considered		
			From	End Side	Stability Analysis	Vertical Wall	Bottom Slab
1	0.300	3.300	5.000	5.000	○	○	×

1.5 Buoyancy

・Use the Water Level in Rear Side

1.6 Earth Pressure

・Earth Pressure Formulas: Trial Wedge

・Angle of Friction of Earth Pressure Acting Surface (Degrees)

Load Condition	Active Earth Pressure			Passive Earth Pressure
	In Case of Stability Analysis	In Case of Vertical Wall Design	Cut	
Normal Earth Pressure	23.333	23.33	——	——
Seismic Earth Pressure	17.500	17.500	——	——

・ The virtual rear surface of earth pressure in the stability analysis is at the heel end (a line extended vertically from the heel)

・ Angle between the earth pressure acting surface and the vertical plane in stability analysis
24.570 (degrees)

・ Angle between the earth pressure working surface and the vertical plane when designing the vertical wall
24.567 (degrees)

・The Design Horizontal Seismic Coefficient is applied to the inertia force during earthquakes when calculating the earth pressure below the water level.

・Cohesion (kN/m2)

Load Condition	For Sliding Surfaces	For Cohesive Height	For Passive Earth Pressure
Normal Condition	0.000	0.000	——
Seismic Condition	0.000	0.000	——

・Consideration of Earth Pressure Different from Direction of Earthquake Motion

	Consideration I...	Effectivity
Stability Analysis	Seismic Earth Pressure	0.500
Vertical Wall Design		0.500

1.7 Load Combination Case

No	Load Name	Comments
1	Normal	Normal Condition
2	Seismic	Seismic Seismic condition

	Load Name	1	2
Soil	Front Soil 1	○	○
Load	Load 1	○	
	Load 2		○
Active Earth Pressure	Not Considered		
	Normal Earth Pressure	○	
	Seismic Earth Pressure		○

1.8 Foundation Conditions

Bottom Slab Width Used for Analysis	All Width
Cohesion Between Foundation Bottom Surface And Ground C_B (kN/m2)	0.000
Friction Coefficient Between Foundation Bottom Surface and Ground tan φ_B	0.500

1.9 Allowable Values For Stability Analysis And Allowable Stresses of Members

1.9.1 Allowance in Stability Analysis

Load Condition	Allowable Eccentricity e_B/B (m)	Safety Factor for Overturning	Allowable Subgrade Reaction Intensity (kN/m2)
Normal	1/6	1.500	100.000
Seismic	1/3	1.200	100.000

Here,

B : Foundation Width (m)

e_B: load eccentricity (m), where $e_B = M_B/V$

M_B: moment acting on base (kNm)

V : vertical load acting on base (kN)

1.9.2 Allowable Stress of the Member

(1)Reinforced Concrete Member

1) Vertical Wall (General Member)

(N/mm2)

Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic	1.33	10.906	186.200	0.479	0.479

2) Bottom Slab (General Member)

(N/mm2)

Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic	1.33	10.906	186.200	0.479	0.479

Here,

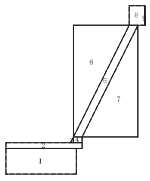
τa1: Shear Stress When Shear Force is Applied Only by Concrete

τa2: Shear Stress when Jointly Bearing with Oblique Tensile Reinforcement

2 Stability Analysis

2.1 Block Data

(1) Body Weight



2)Weight and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1							
2	x 0.652 x 1.000 x 22.500 x 1.800	26.406	0.900	0.326	23.765	8.608	bottom plate
3	x 0.148 x 1.000 x 22.500 x 1.950	6.494	0.975	0.726	6.331	4.714	bottom plate
4	1/2 x 0.076 x 0.153 x x 1.000 x 22.500	0.133	1.701	0.851	0.226	0.113	vertical wall
5	x 0.153 x 1.000 x 22.500 x 0.223	0.770	1.838	0.877	1.415	0.674	vertical wall
6	x 2.847 x 1.000 x 22.500 x 1.646	105.471	2.550	2.376	268.930	250.652	vertical wall
7	- 1/2 x 1.423 x 2.847 x 1.000 x 22.500	-45.594	2.201	2.851	-100.352	-129.989	vertical wall
8	- 1/2 x 1.423 x 2.847 x 1.000 x 22.500	-45.576	2.899	1.902	-132.111	-86.686	vertical wall
9	x 0.500 x 1.000 x 22.500 x 0.400	4.500	3.350	4.050	15.075	18.225	vertical wall
	1/2 x 0.005 x 0.500 x x 1.000 x 22.500	0.029	3.552	3.967	0.104	0.116	vertical wall
Σ		52.632	——	——	83.382	66.429	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 83.382/ 52.632 = 1.584 (m)

YG = Σ (Vi Yi)/ΣVi = 66.429/ 52.632 = 1.262 (m)

2.2 Body Weight, Weight of Soil, Arbitrary Load, Vertical Force by Buoyancy, Horizontal Force

(1) Working Force Due to Body Weight

1) Normal

2) Seismic

Position	Horizontal Load H = W kh (kN)			Acting Position Y (m)
Body(Reinforced)	52.632 ×	0.20	= 10.526	1.262

(2) Body Weight

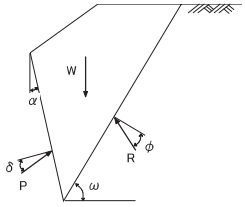
1) Normal

	Weight Ni (kN)	Horizontal force Hi (kN)	Position of action (m)		Moment (kNm)	
			Xi	Yi	Ni and Xi	Hi Yi
Body	52.632	0.000	1.584	0.000	83.383	0.000
Total	52.632	0.000	——	——	83.383	0.000

2) Seismic

	Weight Ni (kN)	Horizontal force Hi (kN)	Position of action (m)		Moment (kNm)	
			Xi	Yi	Ni and Xi	Hi Yi
Body	52.632	10.526	1.584	1.262	83.383	13.286
Total	52.632	10.526	——	——	83.383	13.286

2.3 Earth Pressure and Water Pressure



(1) Normal Condition

The earth pressure is obtained by the trial wedge method.

Position of Virtual Rear Surface (Distance from toe) xp = 1.584 m

yp = 0.000 m

Height of Virtual Rear Surface H = 4.3000 m

Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 24.570 °

Unit Weight of Soil γs = 19.000 kN/m3

Internal Friction Angle of Soil φ = 30.000 °

Angle between Ground Surface and Horizontal Plane β = 0.000 °

Wall Friction Angle δ = 23.333 °

Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °

Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)

Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
45.00	95.344	0.000	20.340	115.684	31.185

46.00	89.317	0.000	18.865	108.182	31.221

The maximum earth pressure is determined by the following equation:

when ω = 46.00 ° P = 31.221 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{108.182 \times \sin(46.00^\circ - 30.00^\circ)}{\cos(46.00^\circ - 30.00^\circ - -24.570^\circ - 23.333^\circ)}$$

= 31.221 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.

Horizontal Component

Ph = P · cos (α + δ) = 31.221 x cos (-24.570 ° + 23.333 °) = 31.214 kN

Vertical Component

Pv = P · sin (α + δ) = 31.221 x sin (-24.570 ° + 23.333 °) = -0.674 kN

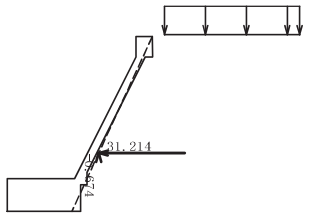
Acting Position

$$Ho = \frac{H}{3} = \frac{4.300}{3} = 1.433 \text{ m}$$

x = xp-Ho · tan α = 1.584 -1.433 × tan -24.570 ° = 2.239 m

y = yp + Ho = 0.000 + 1.433 = 1.433 m

・Earth Pressure Diagram



(2) Seismic Condition

The earth pressure is obtained by the trial wedge method considering the inertia force in the earthquake.

Position of Virtual Rear Surface (Distance from Toe) xp = 1.584 m

yp = 0.000 m

Height of Virtual Rear Surface H = 4.300 m

Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 24.570 °

Unit Weight of Soil γs = 19.000 kN/m3

Internal Friction Angle of Soil φ = 30.000 °

Wall Friction Angle δ = 17.5.000 °

Seismic Composite Angle

$$\theta = \tan^{-1}\frac{kh \cdot (WU + WL)}{WU + WL + Wq}$$

$$= \tan^{-1}\frac{0.20 \times (144.517 + 0.000)}{144.517 + 0.000 + 0.000}$$

= 11.310 °

Range of slip angle change ωi = 10.00 ° ~ 80.00 °

Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)

Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
37.00	152.791	0.000	0.000	152.791	50.465
38.00	144.517	0.000	0.000	144.517	50.471
39.00	136.605	0.000	0.000	136.605	50.321

The maximum earth pressure is determined by the following equation:

when ω = 38.00 ° P = 50.471 kN

Earth Pressure

$$P = \frac{W/\cos\theta \cdot \sin(\omega - \phi + \theta)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{144.517/\cos 11.310^\circ \times \sin(38.00^\circ - 30.00^\circ + 11.310^\circ)}{\cos(38.00^\circ - 30.00^\circ - -24.570^\circ - 17.500^\circ)}$$

= 50.471 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.

Horizontal Component

Ph = P, cos (α + δ) = 50.471 x cos (-24.570 ° + 17.500 °) = 50.087 kN

Vertical Component

Pv = P sin (α + δ) = 50.471 x sin (-24.570 ° + 17.500 °) = -6.212 kN

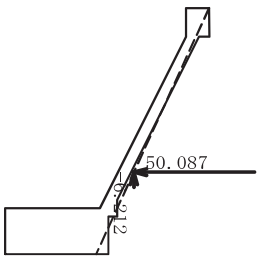
Acting Position

$$Ho = \frac{H}{3} = \frac{4.300}{3} = 1.433 \text{ m}$$

x = xp-Ho · tan α = 1.584 -1.433 × tan -24.570 ° = 2.239 m

y = yp + Ho = 0.000 + 1.433 = 1.433 m

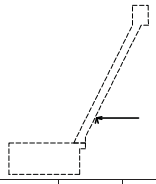
・Earth Pressure Diagram



2.4 Summary of Acting Forces

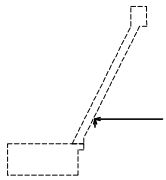
(1) Summary of forces acting on the footing front

1) Normal Condition



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	52.632	0.000	1.584	0.000	83.383	0.000
Earth Pressure	0.000	31.214	2.239	1.433	0.000	44.730
Total	52.632	31.214	——	——	83.383	44.730

2) Seismic Condition



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	52.632	10.526	1.584	1.262	83.383	13.286
Earth Pressure	0.000	50.087	2.239	1.433	0.000	71.775
Total	52.632	60.613	——	——	83.383	85.061

Load Condition (Water Level)	No (kN)	Ho (kN)	Mo (kN.m.)
Norma	52.632	31.214	38.653
Seismic	52.632	60.613	-1.678

(2)Summary of Forces Acting At the Footing Center

Vertical Force : Nc = No (kN)
Horizontal Force : Hc = Ho (kN)
Turning Moment : Mc = No Bj/2.0 - Mo (kN.m.)

Here,
Footing Width in Earth Pressure Direction : Bj = 1.800 (m)

■Per Unit Width

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Norma	52.632	31.214	8.716
Seismic	52.632	60.613	49.047

■Per full width (5.000 m)

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Norma	263.160	156.070	43.579
Seismic	263.160	303.067	245.234

2.5 Stability Analysis Results

2.5.1 Stability against Overturning

$$d = \frac{\Sigma Mr - \Sigma Mt}{\Sigma V}$$

Here,
d: Distance from the Toe of Bottom Slab to the Acting Point of Composited Force (m)
ΣMr: Resistive Moment of Toe of Bottom Slab (kN.m.)
ΣMt: Overturning Moment of Toe of Bottom Slab (kN.m.)
ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)

$$e = \frac{B}{2} - d$$

Here,
e: Eccentricity from the Center of Bottom Slab to the Acting Point of Composited Force (m);
B: Bottom Slab Width (m), B = 1.800

ea = B/n

Here,
ea: Allowable Eccentricity (m)
n: Safety Factor

Load Condition	Σ Mr (kN.m.)	Σ Mt (kN.m.)	ΣV (kN)	d (m)	e (m)	Ea (m)
Normal	83.383	44.730	52.632	0.734	0.166<0.300	
Seismic	83.383	85.061	52.632	-0.032	0.932>0.600	

The inclined wall does not satisfy with the requirement. Therefore, it is assumed that the moment acts on the coping of SSP revetment, and the moment shortage (M_L) calculated from the following formula is added to the design of revetment for low water channel.

$e = \left|\frac{b}{2} - \frac{M+M_L}{N}\right| = \frac{b}{6}$, in Normal Condition

Above formula is converted to $M_L = \left|\frac{b}{6}\right| \times N - M$

$e = \left|\frac{b}{2} - \frac{M+M_L}{N}\right| = \frac{b}{3}$ in Seismic Condition

Above formula is converted to $M_L = \left|\frac{b}{6}\right| \times N - M$

Where,
M_L : Moment Shortage（=Moment acting on SSP revetment） (kN・m)

Load Condition	Base Length (m)	Resistaince Moment at Toe ΣMr (kN・m)	Over-Turning Moment at Toe ΣMt (kN・m)	Vertical Load ΣV (kN)	Acceptable Eccentric Distance (m)	Judge	Moment of Acting to SSP (KN*m)
Normal	1.8	83.383	44.730	52.632	0.3	OK	0
Seismic	1.8	83.383	85.061	52.632	0.6	NG	17.5

2.5.2 Stability Against Sliding

$$F_s = \frac{\Sigma V \cdot \mu + C_B \cdot B}{\Sigma H}$$

Here,
ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)
ΣH: Total Horizontal Load in Lower Side of Bottom Slab (kN)
μ: Cohesion Between Bottom Slab and Supporting Ground, μ = 0.500
C_B: Cohesion Between Bottom Slab And Supporting Ground (kN/m2), C_B = 0.000
B: Bottom Slab Width (m), B = 1.800

Load Condition (Water Level)	Vertical Load ΣV (kN)	Horizontal Load ΣH (kN)	Safety Factor Fs	Required Safety Factor Fsa
NormalCondition	52.632	31.214	0.843<1.500	
SeismicCondition	52.632	60.613	0.434<1.200	

The inclined wall does not satisfy the minimum safety factor. Therefore, the horizontal shortage is assumed to affect the coping (head) of revetment for low water channel, and the horizontal shortage calculated by the following formula is added to the design of SSP revetment.

$$SF = \frac{\text{(Total Vertical Forces of Inclined Wall)} \times f}{\text{(Total Horizontal Forces of Inclined Wall)} + \text{(Horizontal Shortage)}}$$

Above formula is converted below,

$$\text{(Horizontal Shortage)} = \frac{\text{(Total Vertical Forces of Inclined Wall)} \times f}{\text{(Total Horizontal Forces of Inclined Wall)} \times SF}$$

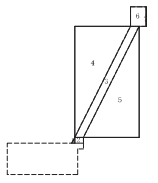
Where,
SF = 1.50 : in Normal Condition
SF = 1.20 : in Seismic and Wind Condition

3 Vertical Wall Design

3.1 Vertical Wall Base Design

3.1.1 Block data without considering water level

(1) Block Diversion



(2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	1/2× 0.076× 0.153× 1.000×22.500	0.133	0.051	0.051	0.007	0.007	Vertical Wall
2	0.223× 0.153× 1.000×22.500	0.770	0.188	0.077	0.145	0.059	Vertical Wall
3	1.646× 2.847× 1.000×22.500	105.471	0.900	1.577	94.924	166.328	Vertical Wall
4	-1/2× 1.423× 2.847× 1.000×22.500	-45.594	0.551	2.051	-25.122	-93.513	Vertical Wall
5	-1/2× 1.423× 2.847× 1.000×22.500	-45.576	1.249	1.102	-56.924	-50.225	Vertical Wall
6	0.400× 0.500× 1.000×22.500	4.500	1.700	3.250	7.650	14.625	Vertical Wall
7	1/2× 0.005× 0.500× 1.000×22.500	0.029	1.902	3.167	0.056	0.093	Vertical Wall
Σ		19.733	——	——	20.734	37.374	

Center of Gravity XG = Σ(Vi/Xi)/ΣVi = 20.734／19.733 = 1.051 (m)
YG = Σ(Vi Yi)/ΣVi = 37.374／19.733 = 1.894 (m)

3.1.2 Body Weight, Voluntary Load

(1) Body Weight

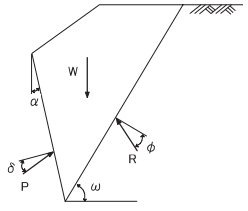
1) Seismic

Position	H = W kh (kN)	Acting Position Y (m)
Body(Reinforced)	19.733 × 0.200 = 3.947	1.894

Acting Position
X = Xc−XG = 0.150−1.051
= −0.901 m

Here,
Xc: Horizontal Distance from the Front of the Vertical Wall to the Center of the Design Section (m)

3.1.3 Earth Pressure and Water Pressure



(1) Normal

The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Section Center) xp = 0.150 m
yp = 0.000 m
Height of Virtual Rear Surface H = 3.500 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 24.567 °

Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 30.000 °
Wall Friction Angle δ = 20.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
45.00	63.175	0.000	16.000	79.175	21.343
46.00	59.182	0.000	14.799	73.981	21.350
47.00	55.321	0.000	13.638	68.959	21.228

The maximum earth pressure is determined by the following equation:
when ω = 46.00° P = 21.350 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{73.981 \times \sin(46.00° - 30.00°)}{\cos(46.00° - 30.00° - -24.567° - 23.333°)}$$

= 21.350 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P・cos(α+δ) = 21.350×cos(-24.567°+23.333°) = 21.345 kN
Vertical Component
Pv = P・sin(α+δ) = 21.350×sin(-24.567°+23.333°) = -0.460 kN

Acting Position

$$Ho = \frac{H}{3} = \frac{3.500}{3} = 1.167 \text{ m}$$

x = Ho ・ tan α-xp = 1.167×tan-24.567°−0.150 = -0.683 m
y = yp + Ho = 0.000+1.167 = 1.167 m

(2) Seismic

The earth pressure is obtained by the trial wedge method considering the inertia force in the earthquake.
Position of Virtual Rear Surface (Distance from Section Center) xp = 0.150 m
yp = 0.000 m
Height of Virtual Rear Surface H = 3.500 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = -24.567 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 30.000 °
Wall Friction Angle δ = 17.500 °
Seismic Composite Angle

$$\theta = \tan^{-1}\frac{kh \cdot (WU + WL)}{WU + WL + Wq}$$

$$= \tan^{-1}\frac{0.20 \times (95.753 + 0.000)}{95.753 + 0.000 + 0.000}$$

= 11.310°

Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
37.00	101.235	0.000	0.000	101.235	33.436
38.00	95.753	0.000	0.000	95.753	33.440
39.00	90.511	0.000	0.000	90.511	33.341

The maximum earth pressure is determined by the following equation:
when ω = 38.00 ° P = 33.440 kN

Earth Pressure

$$P = \frac{W/\cos\theta \cdot \sin(\omega - \phi + \theta)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{95.753/\cos 11.310° \times \sin(38.00° - 30.00° + 11.310°)}{\cos(38.00° - 30.00° - -24.567° - 17.500°)}$$

= 33.440 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P ・ cos (α + δ) = 33.440×cos(-24.567°+17.500°) = 33.186 kN
Vertical Component
Pv = P ・ sin (α + δ) = 33.440×sin(-24.567°+17.500°) = -4.114 kN
Acting Position

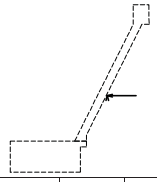
$$Ho = \frac{H}{3} = \frac{3.500}{3} = 1.167 \text{ m}$$

x = Ho ・ tan α-xp = 1.167×tan-24.567°−0.150 = -0.683 m
y = yp + Ho = 0.000+1.167 = 1.167 m

3.1.4 Calculation of Cross-Sectional Force

(Vertical forces are not summarized due to disregard of eccentric moments and axial forces)

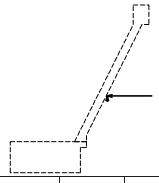
(1) Normal



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m)
Body Weight	19.733	0.000	-0.901	0.000	-17.775
Earth Pressure	-0.460	21.345	-0.683	1.167	25.224
Total	19.273	21.345	——	——	7.449

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

(2) Seismic

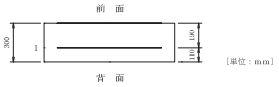


Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m)
Body Weight	19.733	3.947	-0.901	1.894	-10.300
Earth Pressure	-4.114	33.186	-0.683	1.167	41.538
Total	15.619	37.133	——	——	31.238

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

3.1.5 Section Calculations (Allowable Stress Method)

(1) Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	——	—	——	——	——
	2'	——	—	——	——	——
Back	1	11.0	φ20	3.142	8.00	25.133
	2	——	—	——	——	——

Required Reinforcement in Tension Side 9.901 (cm2)

(2) Verification of Bending Stress

(Reference)
Calculation of the neutral axis

$$x^2 + \frac{2 \cdot n}{b}\{As \cdot (x - d)\} = 0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

Here,
x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 300.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 15.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	N (kN)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
				Calculated	Allowance	Calculated	Allowance
Normal	7.449	0.000	8.782	1.056 ≦	8.200	18.433 ≦	140.000
Seismic	31.238	0.000	8.782	4.429 ≦	10.906	77.302 ≦	186.200

(3) Verification of Shear Stress

$$\tau_a = \frac{S_h}{b \cdot d} \leqq \tau_{a1}$$

Here,

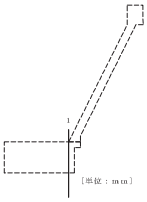
τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)		
			Calculated	Allowable τa1	Allowable τa2
Normal	21.345	19.000	0.112 ≦	0.360	0.360
Seismic	37.133	19.000	0.195 ≦	0.479	0.479

4 Design of Base Concrete

4.1 Design of Checking Position

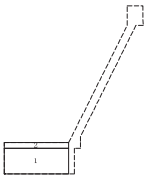
Distance from Wall = 0.000 m



4.2 Block Data Without Considering Water Level

(1) Body Weight

1) Block Diversion



2) Weight and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position Xi	Vi/Xi	Remarks
1	1.650× 0.652× 1.000×22.500	24.205	0.825	19.970	Base Concrete
2	1.650× 0.148× 1.000×22.500	5.495	0.825	4.533	Base Concrete
Σ		29.700	——	24.503	

Center of Gravity Position XG = Σ(Vi/Xi)/ΣVi = 24.503／29.700 = 0.825 (m)

4.3 Subgrade Reaction

Vertical Force

$$N = \frac{1}{2}(q1+q2) \cdot L$$

Acting Position

$$X = \frac{2 \cdot q1+q2}{3 \cdot (q1+q2)} \cdot L$$

Here,

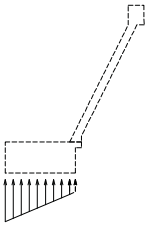
q1: Subgrade Reaction Force in the Front of Toe Slab(kN/m2)
q2: Subgrade Reaction Force at the Design Section of Toe Slab(kN/m2)
L : Subgrade Reaction Width (m)

(1) Normal

Subgrade Reaction Intensity (kN/m2)		Acting Width L (m)	Vertical Force N (kN)	Acting Position X (m)
q1	q2			
45.381	15.790	1.650	-50.466	0.958

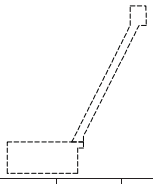
4.4 Calculation of Cross-Sectional Force

(1) Normal



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-29.700	0.825	-24.502
Subgrade Reaction	50.466	0.958	48.348
Total	20.766	——	23.846

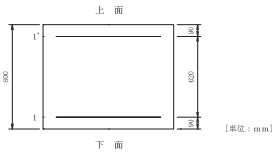
(2) Seismic



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-29.700	0.825	-24.502
Total	-29.700	——	-24.502

4.5 Section Calculations (Allowable Stress Method)

(1) Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Upper	1'	9.0	φ16	2.011	8.00	16.085
	2'	——	—	——	——	——
Bottom	1	9.0	φ16	2.011	8.00	16.085
	2	——	—	——	——	——

Required Reinforcement in Tension Side 2.480 (cm2)

(2) Verification of Bending Stress

(Reference)

Calculation of the neutral axis

$$x^2 + \frac{2 \cdot n}{b}\{As \cdot (x-d)\} = 0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
			Calculated	Allowance	Calculated	Allowance
Normal	23.846	16.250	0.447 ≦	8.200	22.606 ≦	140.000
Seismic	-24.502	16.250	0.460 ≦	10.906	23.229 ≦	186.200

(3) Verification of Shear Stress

$$\tau_m = \frac{S_h}{b \cdot d} \leqq \tau_{a1}$$

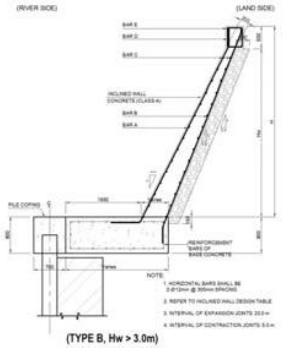
Here,

τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member (mm)
b : Member Section Width (mm)
τa1: Allowable Average Shear Stress of Concrete Alone (N/mm2)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (mm)	Shear Stress (N/mm2)	
			Calculated value τ	allowance τa1
Normal	20.766	710.000	0.029 ≦	0.360
Seismic	29.700	710.000	0.042 ≦	0.479

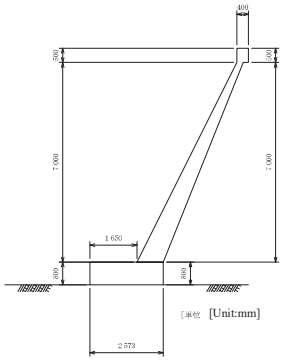
Type B

Hw :7.0m



1 Design Conditions

1.1 Geometry



Depth Width (Block Length) B = 5000 (mm)

1.2 Materials

[Concrete] Vertical wall (reinforced concrete) : σck = 20.7 (N/mm2)
Base concrete (reinforced concrete) : σck = 20.7 (N/mm2)

[Iron bar] Type: : Grade 275

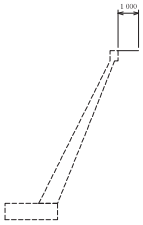
[Soil] Backfill : sand and gravel
Foudation : sandy gravel

[Internal Fdiction] Backfill : 30 degrees

[Unit weight]
(kN/m3)

Body	Base Concrete	22.500	
	Vertical wall	22.500	
Water		9.800	
Soil		Wet weight	Saturated weight
River side		19.000	19.000
Land side		20.000	20.800

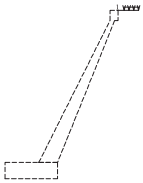
1.3 Backfill and Embankment



Level Difference Between Retaining Wall Crown And Ground Surface Start Point	(m)	0.000
Height Without Considering Earth Pressure Hr (in stability analysis) Hr	(m)	0.000

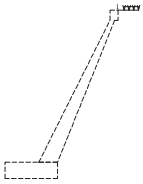
1.4 Loads

(1) Normal



Item	Loading Position (m)	Loading Width (m)	Load Strength (kN/m2)		Study to Be Considered		
			From	End Side	Stability Analysis	Vertical Wall	Bottom Slab
1	0.300	3.300	10.000	10.000	○	○	×

(2) Seismic



Item	Loading Position (m)	Loading Width (m)	Load Strength (kN/m2)		Study to Be Considered		
			From	End Side	Stability Analysis	Vertical Wall	Bottom Slab
1	0.300	3.300	5.000	5.000	○	○	×

1.5 Buoyancy

・Use the Water Level in Rear Side

1.6 Earth Pressure

・Earth Pressure Formulas: Trial Wedge

・Angle of Friction of Earth Pressure Acting Surface (Degrees)

Load Condition	Active Earth Pressure			Passive Earth Pressure
	In Case of Stability Analysis	In Case of Vertical Wall Design	Cut	
Normal Earth Pressure	23.333	23.33	——	——
Seismic Earth Pressure	17.500	17.500	——	——

・ The virtual rear surface of earth pressure in the stability analysis is at the heel end (a line extended vertically from the heel)

・ Angle between the earth pressure acting surface and the vertical plane in stability analysis
21.652 (degrees)

・ Angle between the earth pressure working surface and the vertical plane when designing the vertical wall
21.650 (degrees)

・The Design Horizontal Seismic Coefficient is applied to the inertia force during earthquakes when calculating the earth pressure below the water level.

・Cohesion (kN/m2)

Load Condition	For Sliding Surfaces	For Cohesive Height	For Passive Earth Pressure
Normal Condition	0.000	0.000	——
Seismic Condition	0.000	0.000	——

・Consideration of Earth Pressure Different from Direction of Earthquake Motion

	Consideration I...	Effectivity
Stability Analysis	Seismic Earth Pressure	0.500
Vertical Wall Design		0.500

1.7 Load Combination Case

No	Load Name	Comments
1	Normal	Normal Condition
2	Seismic	Seismic Seismic condition

	Load Name	1	2
Soil	Front Soil 1	○	○
Load	Load 1	○	
	Load 2		○
Active Earth Pressure	Not Considered		
	Normal Earth Pressure	○	
	Seismic Earth Pressure		○

1.8 Foundation Conditions

Bottom Slab Width Used for Analysis	All Width
Cohesion Between Foundation Bottom Surface And Ground C_B (kN/m2)	0.000
Friction Coefficient Between Foundation Bottom Surface and Ground tan φ_B	0.500

1.9 Allowable Values For Stability Analysis And Allowable Stresses of Members

1.9.1 Allowance in Stability Analysis

Load Condition	Allowable Eccentricity eB/B (m)	Safety Factor for Overturning	Allowable Subgrade Reaction Intensity (kN/m2)
Normal	1/6	1.500	100.000
Seismic	1/3	1.200	100.000

Here,

B : Foundation Width (m)

e_B: load eccentricity (m), where $e_B = M_B/V$

M_B: moment acting on base (kNm)

V : vertical load acting on base (kN)

1.9.2 Allowable Stress of the Member

(1)Reinforced Concrete Member

1) Vertical Wall (General Member)

(N/mm2)

Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic	1.33	10.906	186.200	0.479	0.479

2) Bottom Slab (General Member)

(N/mm2)

Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic	1.33	10.906	186.200	0.479	0.479

Here,

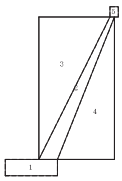
τa1: Shear Stress When Shear Force is Applied Only by Concrete

τa2: Shear Stress when Jointly Bearing with Oblique Tensile Reinforcement

2 Stability Analysis

2.1 Block Data

(1) Body Weight



2)Weight and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	2.573× 0.800× 1.000×22.500	46.314	1.286	0.400	59.583	18.526	bottom plate
2	3.723× 7.000× 1.000×22.500	586.372	3.511	4.300	2059.047	2521.402	vertical wall
3	-1/2× 3.500× 7.000× 1.000×22.500	-275.625	2.817	5.467	-776.353	-1506.759	vertical wall
4	-1/2× 2.800× 7.000× 1.000×22.500	-220.500	4.440	3.133	-978.954	-690.893	vertical wall
5	0.400× 0.500× 1.000×22.500	4.500	5.350	8.050	24.075	36.225	vertical wall
Σ		141.062	—	—	387.398	378.501	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 387.398／ 141.062 = 2.746 (m)

YG = Σ (Vi Yi)/ΣVi = 378.501／ 141.062 = 2.683 (m)

2.2 Body Weight, Weight of Soil, Arbitrary Load, Vertical Force by Buoyancy, Horizontal Force

(1) Working Force Due to Body Weight

1) Normal

2) Seismic

Position	Horizontal Load H = W kh (kN)	Acting Position Y (m)
Body(Reinforced)	141.062 × 0.20 = 28.212	2.633

(2) Body Weight

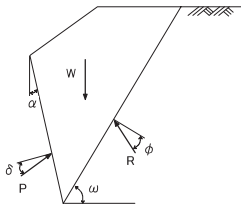
1) Normal

	Weight Ni (kN)	Horizontal force Hi (kN)	Position of action (m) Xi	Yi	Moment (kNm) Ni and Xi	Hi Yi
Body	141.062	0.000	2.746	0.000	387.398	0.000
Total	141.062	0.000	—	—	387.398	0.000

2) Seismic

	Weight Ni (kN)	Horizontal force Hi (kN)	Position of action (m) Xi	Yi	Moment (kNm) Ni and Xi	Hi Yi
Body	141.062	28.212	2.746	2.683	387.398	75.700
Total	141.062	28.212	—	—	387.398	75.700

2.3 Earth Pressure and Water Pressure



(1) Normal Condition

The earth pressure is obtained by the trial wedge method.

Position of Virtual Rear Surface (Distance from toe) xp = 2.255 m

yp = 0.000 m

Height of Virtual Rear Surface H = 8.300 m

Angle between the Earth Pressure Acting Surface and the Vertical Plane A = -21.652 °

Unit Weight of Soil γs = 19.000 kN/m3

Internal Friction Angle of Soil φ = 30.000 °

Angle between Ground Surface and Horizontal Plane β = 0.000 °

Wall Friction Angle δ = 23.333 °

Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °

Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)

Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
47.00	350.478	0.000	33.000	383.478	116.249
48.00	329.463	0.000	33.000	362.463	116.709
49.00	309.098	0.000	33.000	342.098	116.666

The maximum earth pressure is determined by the following equation:
when ω = 48.00 ° P = 116.709 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{362.463 \times \sin(48.00^\circ - 30.00^\circ)}{\cos(48.00^\circ - 30.00^\circ - -21.652^\circ - 23.333^\circ)}$$

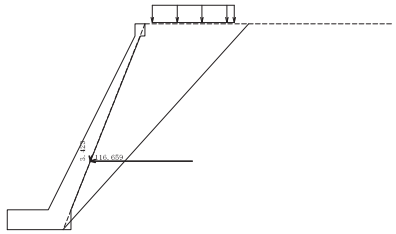
= 116.709 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 116.709×cos(-21.652°＋23.333°) ＝ 116.659 kN
Vertical Component
Pv = P · sin (α + δ) = 116.709×sin(-21.652°＋23.333°) ＝ 3.423 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{8.300}{3} = 2.767 \text{ m}$$

x = xp-Ho · tan α = 2.255－2.767×tan-21.652°＝ 3.353 m
y = yp + Ho = 0.000＋2.767 ＝ 2.767 m

・Earth Pressure Diagram



(2) Seismic Condition

The earth pressure is obtained by the trial wedge method considering the inertia force in the earthquake.
Position of Virtual Rear Surface (Distance from Toe) xp = 2.255 m
yp = 0.000 m
Height of Virtual Rear Surface H = 8.3000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 21.652 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 30.000 °
Wall Friction Angle δ = 17.5.000 °
Seismic Composite Angle

$$\theta = \tan^{-1}\frac{kh \cdot (WU + WL)}{WU + WL + Wq}$$

$$= \tan^{-1}\frac{0.20 \times (548.374 + 0.000)}{548.374 + 0.000 + 0.000}$$

= 11.310 °
Range of slip angle change ωi = 10.00 ° ~ 80.00 °

Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
38.00	577.854	0.000	0.000	577.854	199.335
39.00	548.374	0.000	0.000	548.374	199.338
40.00	520.138	0.000	0.000	520.138	198.802

The maximum earth pressure is determined by the following equation:
when ω = 39.00 ° P = 19900338 kN

Earth Pressure

$$P = \frac{W/\cos\theta \cdot \sin(\omega - \phi + \theta)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{548.374/\cos 11.310^\circ \times \sin(39.00^\circ - 30.00^\circ + 11.310^\circ)}{\cos(39.00^\circ - 30.00^\circ - -21.652^\circ - 17.500^\circ)}$$

= 199.338 kN

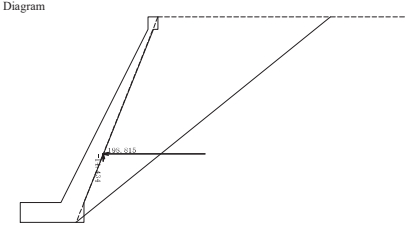
The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P, cos (α + δ) = 199.338 × cos(-21.652°＋17.500°) ＝ 198.815 kN
Vertical Component
Pv = P sin (α + δ) = 199.338 × sin(-21.652°＋17.500°) ＝ -14.434 kN

Acting Position

$$Ho = \frac{H}{3} = \frac{8.300}{3} = 2.767 \text{ m}$$

x = xp-Ho · tan α = 2.255－2.767×tan-21.652°＝ 3.353 m
y = yp + Ho = 0.000＋2.767 ＝ 2.767 m

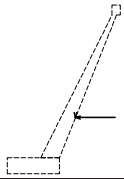
・Earth Pressure Diagram



2.4 Summary of Acting Forces

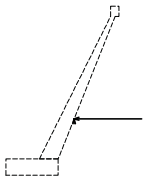
(1) Summary of forces acting on the footing front

1) Normal Condition



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	141.062	0.000	2.746	0.000	387.398	0.000
Earth Pressure	0.000	116.659	3.353	2.767	0.000	322.795
Total	141.062	116.659	——	——	387.398	322.795

2) Seismic Condition



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	141.062	28.212	2.746	2.683	387.398	75.700
Earth Pressure	0.000	198.815	3.353	2.767	0.000	550.121
Total	141.062	227.027	——	——	387.398	625.821

Load Condition (Water Level)	No (kN)	Ho (kN)	Mo (kN.m.)
Norma	141.062	116.659	64.603
Seismic	141.062	227.027	-238.423

(2)Summary of Forces Acting At the Footing Center

Vertical Force : Nc = No (kN)
Horizontal Force : Hc = Ho (kN)
Turning Moment : Mc = No Bj/2.0 - Mo (kN.m.)
Here,
Footing Width in Earth Pressure Direction : Bj = 2.573 (m)

■Per Unit Width

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Norma	141.062	116.659	116.873
Seismic	141.062	227.027	419.899

■Per full width (5.000 m)

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Norma	705.308	583.295	584.365
Seismic	705.308	1135.137	2099.494

2.5 Stability Analysis Results

2.5.1 Stability against Overturning

$$d = \frac{\Sigma Mr - \Sigma Mt}{\Sigma V}$$

Here,

d: Distance from the Toe of Bottom Slab to the Acting Point of Composited Force (m)
ΣMr: Resistive Moment of Toe of Bottom Slab (kN.m.)
ΣMt: Overturning Moment of Toe of Bottom Slab (kN.m.)
ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)

$$e = \frac{B}{2} - d$$

Here,

e: Eccentricity from the Center of Bottom Slab to the Acting Point of Composited Force (m);
B: Bottom Slab Width (m), B = 1.800

ea = B/n

Here,

ea: Allowable Eccentricity (m)
n: Safety Factor

Load Condition (Water Level)	Σ Mr (kN.m.)	Σ Mt (kN.m.)	ΣV (kN)	d (m)	e (m)		Ea (m)
Normal	387.398	322.795	141.062	0.458	0.829	>	0.429
Seismic	387.398	625.821	141.062	-1.690	2.977	>	0.858

The inclined wall does not satisfy with the requirement. Therefore, it is assumed that the moment acts on the coping of SSP revetment, and the moment shortage (M_L) calculated from the following formula is added to the design of revetment for low water channel.

$e = \left|\frac{b}{2} - \frac{M+M_L}{N}\right| = \frac{b}{6}$, in Normal Condition

Above formula is converted to $M_L = \left|\frac{b}{6}\right| \times N - M$

$e = \left|\frac{b}{2} - \frac{M+M_L}{N}\right| = \frac{b}{3}$ in Seismic Condition

Above formula is converted to $M_L = \left|\frac{b}{6}\right| \times N - M$

Where,

M_L : Moment Shortage（=Moment acting on SSP revetment） (kN・m)

Load Condition	Base Length (m)	Resistaince Moment at Toe ΣMr (kN・m)	Over-Turning Moment at Toe ΣMt (kN・m)	Vertical Load ΣV (kN)	Acceptable Eccentric Distance (m)	Judge	Moment of Acting to SSP (KN*m)
Normal	2.573	387.398	322.795	141.062	0.429	NG	56.4
Seismic	2.573	387.398	625.821	141.062	0.858	NG	298.9

2.5.2 Stability Against Sliding

$$F_s = \frac{\Sigma V \cdot \mu + C_B \cdot B}{\Sigma H}$$

Here,

ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)
ΣH: Total Horizontal Load in Lower Side of Bottom Slab (kN)
μ: Cohesion Between Bottom Slab and Supporting Ground, μ = 0.500
C_B: Cohesion Between Bottom Slab And Supporting Ground (kN/m2), C_B = 0.000
B: Bottom Slab Width (m), B = 1.800

Load Condition (Water Level)	Vertical Load ΣV (kN)	Horizontal Load ΣH (kN)	Safety Factor Fs		Required Safety Factor Fsa
NormalCondition	141.062	116.659	0.605	<	1.500
SeismicCondition	141.062	227.027	0.311	<	1.200

The inclined wall does not satisfy the minimum safety factor. Therefore, the horizontal shortage is assumed to affect the coping (head) of revetment for low water channel, and the horizontal shortage calculated by the following formula is added to the design of SSP revetment.

$$SF = \frac{(\text{Total Vertical Forces of Inclined Wall}) \times f}{(\text{Total Horizontal Forces of Inclined Wall}) + (\text{Horizontal Shortage})}$$

Above formula is converted below,

$$(\text{Horizontal Shortage}) = \frac{(\text{Total Vertical Forces of Inclined Wall}) \times f}{(\text{Total Horizontal Forces of Inclined Wall}) \times SF}$$

Where,

SF = 1.50 : in Normal Condition
SF = 1.20 : in Seismic and Wind Condition

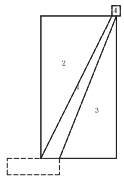
Load Condition	Vertical Load ΣV (kN)	Horozontal Load ΣH (kN)	Required Safety Factor	Judge	Forth of Acting to SSP (KN)
Normal	141.062	116.659	1.5	NG	69.7
Seismic	141.062	227.027	1.2	NG	168.3

3 Vertical Wall Design（ここから）

3.1 Vertical Wall Base Design

3.1.1 Block data without considering water level

(1) Block Diversion



(2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	3.723× 7.000× 1.000×22.500	586.372	1.862	3.500	1091.826	2052.304	Vertical Wall
2	-1/2× 3.500× 7.000× 1.000×22.500	-275.625	1.167	4.667	-321.654	-1286.342	Vertical Wall
3	-1/2× 2.800× 7.000× 1.000×22.500	-220.500	2.790	2.333	-615.195	-514.426	Vertical Wall
4	0.400× 0.500× 1.000×22.500	4.500	3.700	7.250	16.650	32.625	Vertical Wall
Σ		94.747	—	—	171.626	284.160	

Center of Gravity XG = Σ(Vi/Xi)/ΣVi = 171.626／ 94.747 = 1.811 (m)
YG = Σ(Vi Yi)/ΣVi = 284.160／ 94.747 = 2.999 (m)

3.1.2 Body Weight, Voluntary Load

(1) Body Weight

1) Seismic

Position	W = γ ・ V (kN)	Acting Position X (m)
Body(Reinforced)	94.747 × 0.200 = 18.949	2.999

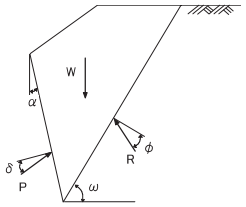
Acting Position

$$X = Xc - XG = 0.462 - 1.811$$
$$= -1.350 \text{ m}$$

Here,

Xc: Horizontal Distance from the Front of the Vertical Wall to the Center of the Design Section (m)

3.1.3 Earth Pressure and Water Pressure



1) Normal

The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Section Center) xp = 0.461 m
yp = 0.000 m
Height of Virtual Rear Surface H = 7.500 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = -21.650 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 30.000 °
Wall Friction Angle δ = 23.333 °
Range of Slip Angle Change ωi = 10.00 °～ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN) Above Water Level	Below Water Level	Vertical Load	Total	Earth Pressure P (kN)
47.00	286.201	0.000	33.000	319.201	96.762
48.00	269.042	0.000	33.000	302.042	97.253
49.00	252.414	0.000	32.427	284.841	97.138

The maximum earth pressure is determined by the following equation:
when ω = 48.00° P = 97.253 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{302.042 \times \sin(48.00^\circ - 30.00^\circ)}{\cos(48.00^\circ - 30.00^\circ - -21.650^\circ - 23.333^\circ)}$$

= 97.253 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.

Horizontal Component

Ph = P・cos(α+δ) = 97.253×cos(-21.650°+23.333°) = 97.211 kN

Vertical Component

Pv = P・sin(α+δ) = 97.253×sin(-21.650°+23.333°) = 2.857 kN

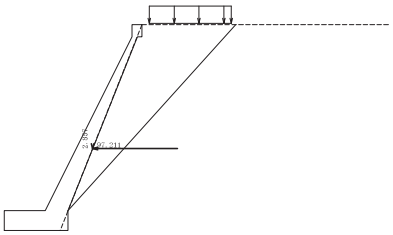
Acting Position

$Ho = \frac{H}{3} = \frac{7.500}{3} = 2.500$ m

x = Ho ・ tan α-xp = 2.500×tan-21.650°−0.461 = -1.453 m

y = yp + Ho = 0.000+2.500 = 2.500 m

・Earth Pressure Diagram



2) Seismic

The earth pressure is obtained by the trial wedge method considering the inertia force in the earthquake.

Position of Virtual Rear Surface (Distance from Section Center) xp = 0.491 m

yp = 0.000 m

Height of Virtual Rear Surface H = 7.5000 m

Angle between the Earth Pressure Acting Surface and the Vertical Plane A = -21.650 °

Unit Weight of Soil γs = 19.000 kN/m3

Internal Friction Angle of Soil φ = 30.000 °

Wall Friction Angle δ = 17.500 °

Range of Slip Angle Change ωi = 10.00 °～ 80.00 °

Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)

Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
38.00	471.858	0.000	0.000	471.858	162.769
39.00	447.787	0.000	0.000	447.787	162.772
40.00	424.732	0.000	0.000	424.732	162.335

The maximum earth pressure is determined by the following equation:

when ω = 39.00 ° P = 162.772 kN

Earth Pressure

$$P = \frac{W/\cos\theta \cdot \sin(\omega - \phi + \theta)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{447.787/\cos 11.310^\circ \times \sin(39.00^\circ - 30.00^\circ + 11.310^\circ)}{\cos(39.00^\circ - 30.00^\circ - -21.650^\circ - 17.500^\circ)}$$

= 162.772 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.

Horizontal Component

Ph = P ・ cos (α + δ) = 162.772×cos(-21.650°+17.500°) = 162.345 kN

Vertical Component

Pv = P・sin (α + δ) = 162.772×sin(-21.650°+17.500°) = -11.779 kN

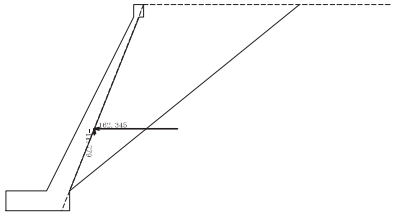
Acting Position

$Ho = \frac{H}{3} = \frac{7.500}{3} = 2.500$ m

x = Ho ・ tan α-xp = 2.500×tan-21.650°−0.461 = -1.453 m

y = yp + Ho = 0.000+2.500 = 2.500 m

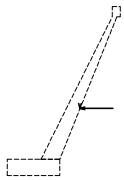
・Earth Pressure Diagram



3.1.4 Calculation of Cross-Sectional Force

(Vertical forces are not summarized due to disregard of eccentric moments and axial forces)

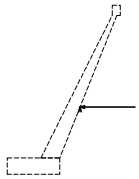
1) Normal



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	94.747	0.000	-1.350	0.000	-127.900
Earth Pressure	2.857	97.211	-1.453	2.500	238.875
Total	97.604	97.211	——	——	110.975

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

2) Seismic

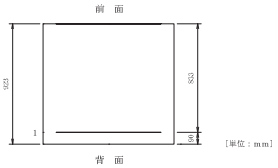


Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	94.747	18.949	-1.350	2.999	-71.068
Earth Pressure	-11.779	162.345	-1.453	2.500	422.983
Total	82.968	181.294	——	——	351.916

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

3.1.5 Section Calculations (Allowable Stress Method)

1) Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	——	—	——	——	——
	2'	——	—	——	——	——
Back	1	9.0	φ25	4.909	8.00	39.270
	2	——	—	——	——	——

Required Reinforcement in Tension Side 8.651 (cm2)

(2)Verification of Bending Stress

(Reference)

Calculation of the neutral axis

$$x^2 + \frac{2 \cdot n}{b}\{As \cdot (x - d)\} = 0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)

h : Member Section Height (mm), h = 923.000

b : Member Section Width (mm), b = 1000.000

d : Effective Height of Member (mm)

As: Total Cross-Sectional Area of Rebar in Tension (mm2)

n : Young's Modulus Ratio of Rebar to Concrete, n = 15.00

e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)

σc: Bending Compressive Stress of Concrete (N/mm2)

σs: Tensile Stress of Rebar (N/mm2)

M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	N (kN)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
				Calculated	Allowance	Calculated	Allowance
Normal	110.975	0.000	25.982	1.144 ≦	8.200	37.864 ≦	140.000
Seismic	351.916	0.000	25.982	3.629 ≦	10.906	120.072 ≦	186.200

(3)Verification of Shear Stress

$$\tau_a = \frac{S_h}{b \cdot d} \leqq \tau_{a1}$$

Here,

τm: Average Shear Stress of Concrete (N/mm2)

Sh : Shear Force (N)

d : Effective Height of Member Section (mm)

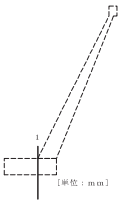
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)		
			Calculated	Allowable τa1	Allowable τa2
Normal	97.211	83.300	0.117 ≦	0.360	0.360
Seismic	181.294	83.300	0.218 ≦	0.479	0.479

4 Design of Base Concrete

4.1 Design of Checking Position

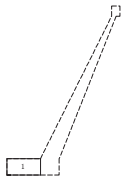
Distance from wall = 0.000 m



4.2 Block Data Without Considering Water Level

(1) Body Weight

1) Block Diversion



2) Weight and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position Xi	Vi/Xi	Remarks
1	1.650× 0.800× 1.000×22.500	29.700	0.825	24.503	Base Concrete
Σ		29.700	——	24.503	

Center of Gravity Position XG = Σ(Vi/Xi)/ΣVi = 24.503／29.700 ＝ 0.825 (m)

4.3 Subgrade Reaction

Vertical Force

$$N = \frac{1}{2}(q1+q2) \cdot L$$

Acting Position

$$X = \frac{2 \cdot q1+q2}{3 \cdot (q1+q2)} \cdot L$$

Here,

q1: Subgrade Reaction Force in the Front of Toe Slab(kN/m2)

q2: Subgrade Reaction Force at the Design Section of Toe Slab(kN/m2)

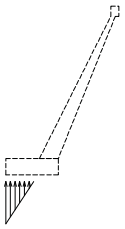
L : Subgrade Reaction Width (m)

(1) Normal

Subgrade Reaction Intensity (kN/m2)		Acting Width L (m)	Vertical Force N (kN)	Acting Position X (m)
q1	q2			
205.479	0.000	1.373	-141.061	1.192

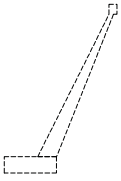
4.4 Calculation of Cross-Sectional Force

(1) Normal



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-29.700	0.825	-24.503
Subgrade Reaction	141.061	1.192	168.192
Total	111.361	——	143.690

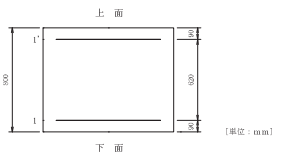
(2) Seismic



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-29.700	0.825	-24.503
Total	-29.700	——	-24.503

4.5 Section Calculations (Allowable Stress Method)

(1) Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Upper	1'	9.0	φ20	3.142	8.00	25.133
	2'	——	—	——	——	——
Bottom	1	9.0	φ20	3.142	8.00	25.133
	2	——	—	——	——	——

Required Reinforcement in Tension Side 15.634 (cm2)

(2) Verification of Bending Stress

(Reference)

Calculation of the neutral axis

$$x^2 + \frac{2 \cdot n}{b}\left\{As \cdot (x-d)\right\} = 0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)

h : Member Section Height (mm), h = 800.000

b : Member Section Width (mm), b = 1000.000

d : Effective Height of Member (mm)

As: Total Cross-Sectional Area of Rebar in Tension (mm2)

n : Young's Modulus Ratio of Rebar to Concrete, n = 15.00

e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
			Calculated	Allowance	Calculated	Allowance
Normal	143.690	19.668	2.266 ≦	8.200	88.725 ≦	140.000
Seismic	-24.503	19.668	0.386 ≦	10.906	15.130 ≦	186.200

(3) Verification of Shear Stress

$$\tau_a = \frac{S_h}{b \cdot d} \leqq \tau_{a1}$$

Here,

τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member (mm)
b : Member Section Width (mm)
τa1: Allowable Average Shear Stress of Concrete Alone (N/mm2)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (mm)	Shear Stress (N/mm2)	
			Calculated value τ	allowance τa1
Normal	111.361	710.000	0.157 ≦	0.360
Seismic	29.700	710.000	0.042 ≦	0.479

1.2.4 Inverted T-shaped Retarding Wall

(1) Cross-section for Structural Calculation

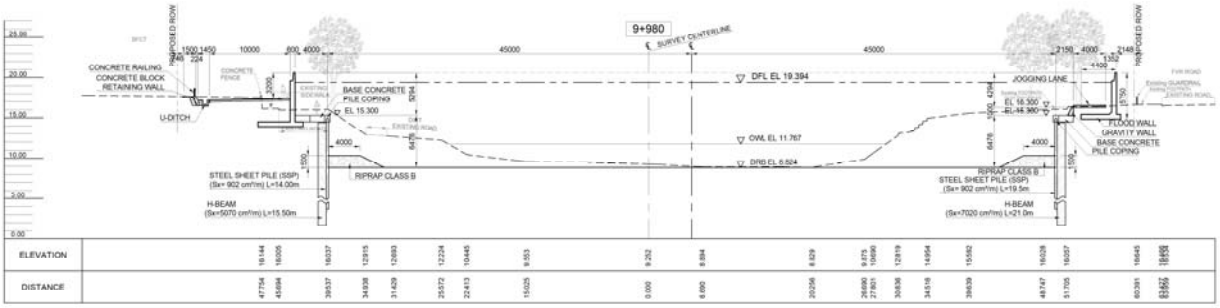
Cross-sections for the structural calculation are selected considering the following points.

- The wall height is high. (≒ acting force is large)
- Embedded depth is small.

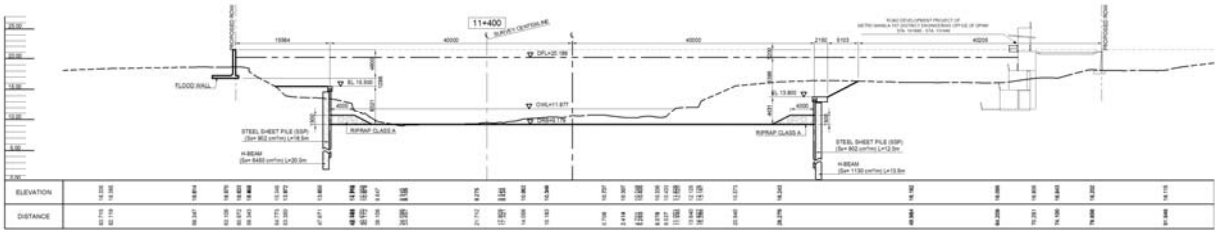
The selected cross-sections are shown below:

Left Side

[Sta 9+980] (Wall height is the highest class)

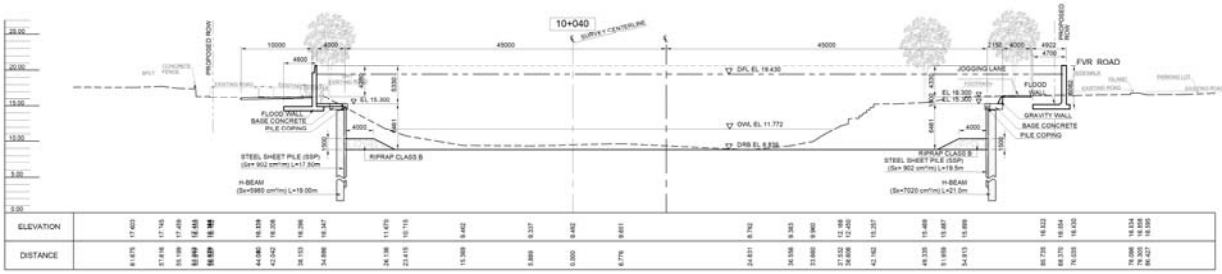


[Sta 11+400] (Embedded depth at the land side is small)



Right Side

[Sta 10+040] (Wall height is the highest class, and Embedded depth is small)



(2) Calculation Case

The calculation case are shown below:

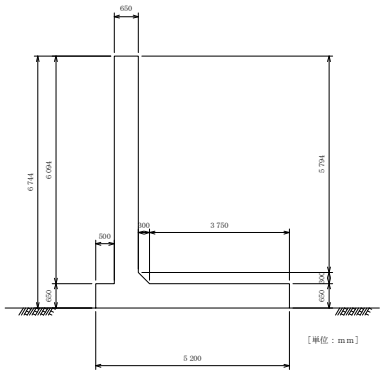
- Normal Condition
- Seismic Condition
- Flood Condition

The calculation sheets are shown in the following pages.

1 Invert T-shaped Wall, Left Bank Sta.9+980

1.1 Design Conditions

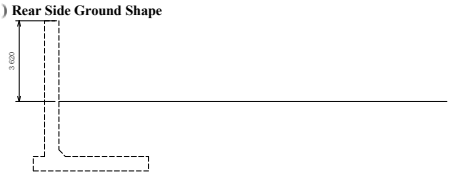
1.1.1 Geometry



Depth Width (Block Length) B = 5000 (mm)

1.1.2 Backfill and Embankment

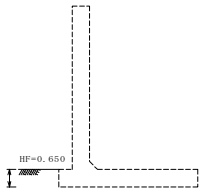
(1) Rear Side Ground Shape



Level Difference Between Retaining Wall Crown And Ground Surface Start Point	(m)	3.600
Height Without Considering Earth Pressure Hr (in stability analysis) Hr	(m)	0.000

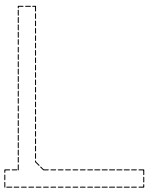
(2) Front Side Ground Shape

1) Normal and Flood Condition



Height	Stability Analysis		Design of Toe Slab
	Vertical	Horizontal	
0.650	Considered	Considered	Considered

2) Seismic Condition



Height	Stability Analysis		Design of Toe Slab
	Vertical	Horizontal	
0.00	Not Considered	Not Considered	Not Considered

1.1.3 Material

[Concrete] Vertical wall (reinforced concrete) : σck = 20.0 (N/mm2)
Base concrete (reinforced concrete) : σck = 20.0 (N/mm2)

[Iron bar] Type: : Grade 275

[Soil] Backfill : sand and gravel
Foudation : sandy gravel

[Internal Fdiction] Backfill : 30 degrees

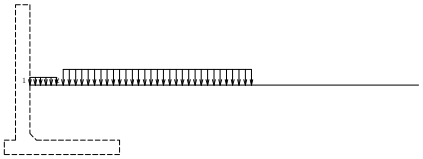
[Unit weight]
(kN/m3)

Body	24.500	
Water	9.800	
Soil	Wet weight	Saturated weight
River side	20.000	20.800
Land side	20.000	20.800

[Seismic Intensity] Body : 0.200
Foundation Riverside : 0.200
Foundation Landside : 0.200

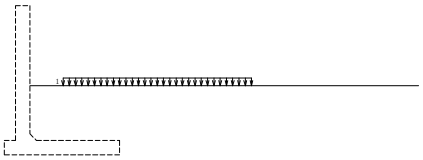
1.1.4 Loads

[1]Normal, Seismic



Item	Loading Position (m)	Loading Width (m)	Load Strength (kN/m2)		Study to Be Considered		
			Beginning	End	Stability Analysis	Vertical Wall	Bottom Slab
1	0.000	1.200	5.000	5.000	○	○	○
2	1.500	8.500	10.000	10.000	○	○	○

[2]Seismic



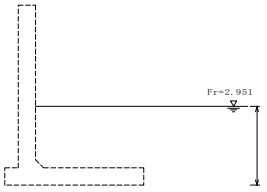
Item	Loading Position (m)	Loading Width (m)	Load Strength (kN/m2)		Study to Be Considered		
			Beginning	End	Stability Analysis	Vertical Wall	Bottom Slab
1	1.500	8.500	5.000	5.000	○	○	○

[2]Flood
Not Concidered

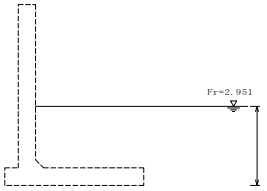
1.1.5 Water Level

[1]Normal

■With Buoyancy : Water Leve in Front Side level Ff = 0.000 m, Water Level in Rear Side Fr = 2.951 m

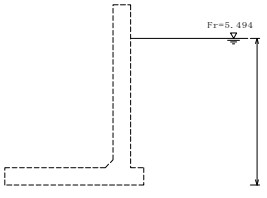


■Without Buoyancy : Water Leve in Front Side level Ff = 0.000 m, Water Level in Rear Side Fr = 2.951 m

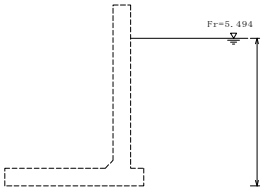


[2]Seidmic
Not Considered

[3]Flood
■With Buoyancy : Water Leve in Front Side level Ff = 0.000 m, Water Level in Rear Side Fr = 5.494 m



■Without Buoyancy : Water Leve in Front Side level Ff = 0.000 m, Water Level in Rear Side Fr = 5.494 m



1.1.6 Buoyancy

・Use the Water Level in Rear Side

1.1.7 Earth Pressure

・Earth Pressure Formulas: Trial Wedge

・Angle of Friction of Earth Pressure Acting Surface (Degrees)

Load Condition	Active Earth Pressure			Passive Earth Pressure
	In Case of Stability Analysis	In Case of Vertical Wall Design	Cut	
Normal Earth Pressure	0.000	23.333	———	———
Seismic Earth Pressure	30.303	17.500	———	———
Flood Earth Pressure	0.000	0.000	———	0.000

・ The virtual rear surface of earth pressure in the stability analysis is at the heel end (a line extended vertically from the heel)

・ Angle between the earth pressure acting surface and the vertical plane in stability analysis
0.000 (degrees)

・ Angle between the earth pressure working surface and the vertical plane when designing the vertical wall
Normal, Seismic 0.000 (degrees)
Flood 0.000 (degrees)

・The Design Horizontal Seismic Coefficient is applied to the inertia force during earthquakes when calculating the earth pressure below the water level.

・Passive Earth Pressure

Load Condition	Height of Acting	Effectivity
Flood	3.024	0.500

・Cohesion (kN/m2)

Load Condition	For Sliding Surfaces	For Cohesive Height	For Passive Earth Pressure
Normal Condition	0.000	0.000	———
Seismic Condition	0.000	0.000	0.000
Flood Condtion	0.000	0.000	0.000

・Consideration of Earth Pressure Different from Direction of Earthquake Motion

	Consideration I...	Effectivity
Stability Analysis	Normal Earth Pressure	0.500
Vertical Wall Design		0.500

1.1.8 Water Pressure

・Concept of Calculation of Hydrostatic Pressure

Load Condition	Rear Side	Front Side
Normal Condition	Considered	Considered
Seismic Condition	Considered	Considered
Flood Condition	Considered	Considered

・Consideration of Hydrostatic Pressure Different from the Direction of Earthquake Motion

Outside Water Level	Stability analysis	Considered
	Vertical Wall Design	Considered

・Consideration of Dynamic Water Pressure Calculation

Outside Water Level	Considered

1.1.9 Load Combination Case

No	Load Name	Comments
1	Normal	
2	Seismic	Seismic
3	Flood	Flood

	Load Name	1	2	3
Soil	Front Soil 1	○		
	Front Soil 2		○	
	Front Soil 3			○
Water Level	Buoyancy 1	○		
	Buoyancy 2		○	
	Buoyancy 3			○
Load	Load 1	○		
	Load 2		○	
Active Earth Pressure	Not Considered			
	Normal Earth Pressure	○		○
	Seismic Earth Pressure		○	
Passive Earth Pressure	Passive Earth Pressure 1			○

1.1.10 Foundation Conditions

1.1.10.1 Data for calculating allowable shear resistance

Bottom Slab Width Used for Analysis	All Width
Cohesion Between Foundation Bottom Surface And Ground C_B (kN/m2)	0.000

Friction Coefficient Between Foundation Bottom Surface and Ground tan φ_B	0.500

1.1.11 Allowable Values For Stability Analysis and Allowable Stresses of Members

1.1.11.1 Allowance in Stability Analysis

Load Condition	Allowable Eccentricity eB/B (m)	Safety Factor for Overturning	Allowable Subgrade Reaction Intensity (kN/m2)
Normal	1/6	1.500	200.000
Seismic, Flood	1/3	1.200	300.000

1.1.11.2 Allowable Stress of the Member

(1)Reinforced Concrete Member

1) Vertical Wall (General Member)

(N/mm2)

Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic, Flood	1.33	10.906	186.200	0.479	0.479

2) Bottom Slab (General Member)

(N/mm2)

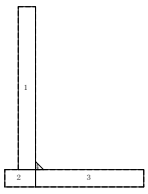
Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic, Flood	1.33	10.906	186.200	0.479	0.479

Here,
τa1: Shear Stress When Shear Force is Applied Only by Concrete
τa2: Shear Stress When Jointly Bearing With Oblique Tensile Reinforcement

1.2 Stability Analysis

1.2.1 Block Data Not Considering Water Level

(1)Body Weight
1)Block Diversion

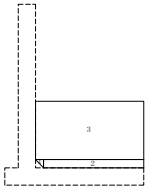


2)Weight and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	0.650× 6.094× 1.000	3.961	0.825	3.697	3.268	14.644	
2	1.150× 0.650× 1.000	0.748	0.575	0.325	0.430	0.243	
3	4.050× 0.650× 1.000	2.632	3.175	0.325	8.358	0.856	
4	1/2× 0.300× 0.300× 1.000	0.045	1.250	0.750	0.056	0.034	
Σ		7.386	——	——	12.112	15.776	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 12.112／ 7.386 ＝ 1.640 (m)
YG = Σ (Vi Yi)/ΣVi = 15.776／ 7.386 ＝ 2.136 (m)

(2)Soil in Rear Side
1)Block Diversion



2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	1/2× 0.300× 0.300× 1.000	0.045	1.350	0.850	0.061	0.038	
2	3.750× 0.300× 1.000	1.125	3.325	0.800	3.741	0.900	
3	4.050× 2.174× 1.000	8.805	3.175	2.037	27.955	17.935	
Σ		9.975	——	——	31.756	18.873	

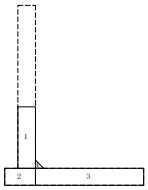
Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 31.756／ 9.975 ＝ 3.184 (m)
YG = Σ (Vi Yi)/ΣVi = 18.873／ 9.975 ＝ 1.892 (m)

1.2.2 Block Data Considering Water Level

(1)Body Weight

[1]Normal (With Buoyancy)

1)Block Diversion



2)Volume and Center of Gravity

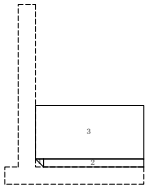
Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	0.650× 2.301× 1.000	1.496	0.825	1.801	1.234	2.693	
2	1.150× 0.650× 1.000	0.748	0.575	0.325	0.430	0.243	
3	4.050× 0.650× 1.000	2.632	3.175	0.325	8.358	0.856	
4	1/2× 0.300× 0.300× 1.000	0.045	1.250	0.750	0.056	0.034	
Σ		4.921	——	——	10.078	3.825	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 10.078／ 4.921 ＝ 2.048 (m)
YG = Σ (Vi Yi)/ΣVi = 3.825／ 4.921 ＝ 0.777 (m)

(2)Soil in Rear Side

[1]Normal (With Buoyancy 2)

1)Block Diversion



2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	1/2× 0.300× 0.300× 1.000	0.045	1.350	0.850	0.061	0.038	
2	3.750× 0.300× 1.000	1.125	3.325	0.800	3.741	0.900	
3	4.050× 2.001× 1.000	8.104	3.175	1.951	25.730	15.807	
Σ		9.274	——	——	29.532	16.745	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 29.532／ 9.274 ＝ 3.184 (m)
YG = Σ (Vi Yi)/ΣVi = 16.745／ 9.274 ＝ 1.806 (m)

1.2.3 Body Weight, Weight of Soil, Arbitrary Load, Vertical Force by Buoyancy, Horizontal Force

(1)Working Force Due to Body Weight

[1]Normal

Position	Vertical Force W = γ ・ V (kN)	Acting Position X (m)
Body(Reinforced)	24.500 × 7.386 ＝ 180.959	1.640
Soil (Rear Side)	20.000 × 9.975 ＝ 199.494	3.184
Total	380.453	2.449

[2]Seismic

Position	Vertical Force W = γ ・ V (kN)	Acting Position X (m)
Body(Reinforced)	24.500 × 7.386 ＝ 180.959	1.640
Soil (Rear Side)	20.000 × 9.975 ＝ 199.494	3.184
Total	380.453	2.449

Position	Horizontal Load H = W kh (kN)	Acting Position Y (m)
Body(Reinforced)	180.959 × 0.20 ＝ 36.192	2.136
Soil (Rear Side)	199.494 × 0.20 ＝ 39.899	1.892
Total	76.091	2.008

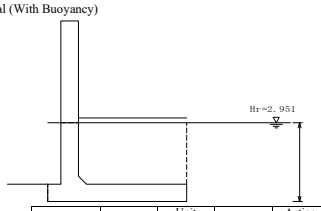
[3]Flood

Position	Vertical Force W = γ ・ V (kN)	Acting Position X (m)

Body(Reinforced)	24.500 × 7.386 ＝ 180.959	3.560
Soil (Rear Side)	19.000 × 9.975 ＝ 189.519	2.016
Total	370.479	2.770

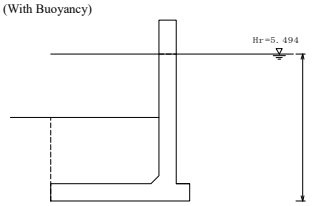
(2)Acting Force by Weight of Soil And Buoyancy

[1]Normal (With Buoyancy)



Position	Volume V (m3)	Unit Weight γ (kN/m3)	Buoyancy Fi (kN)	Acting Position Xi (m)	Fi/Xi
Body	4.921	9.800	48.223	2.048	98.767
Soil (Rear Side)	9.274	9.800	90.885	3.184	289.409
Total	——	——	139.108	——	388.176

[3]Flood (With Buoyancy)



Position	Volume V (m3)	Unit Weight γ (kN/m3)	Buoyancy Fi (kN)	Acting Position Xi (m)	Fi/Xi
Body	6.574	9.800	64.421	3.459	222.861
Soil (Front Side)	9.975	9.800	97.752	2.016	197.099
Soil (Rear Side)	——	——	162.173	——	419.960
Total	6.574	9.800	64.421	3.459	222.861

1.2.4 Load on the Surface

Vertical Force

$$N = \frac{1}{2} \cdot (q1+q2) \cdot L$$

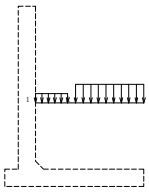
Horizontal Load

$$H = N \cdot kh$$

Here,

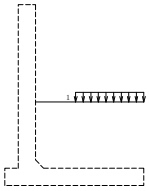
q : Load Intensity
L : Loading Length
kh: Design Horizontal Seismic Coefficient, kh = 0.200 (Medium)
X : Distance from the Toe to the Acting Position of Composited Force
Y : Distance from the Lower Surface of the Bottom Slab to the Acting Position of Composited Force

[1]Normal



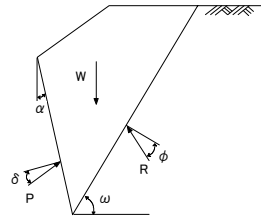
Item	q1 (kN/m2)	q2 (kN/m2)	L (m)	Vertical Force N (kN)	Horizontal Load H (kN)	Acting Position X (m)	Acting Position Y (m)
1	5.000	5.000	1.200	6.000	———	1.750	———
2	10.000	10.000	2.550	25.500	———	3.925	———

[2]Seismic



Item	q1 (kN/m2)	q2 (kN/m2)	L (m)	Vertical Force N (kN)	Horizontal Load H (kN)	Acting Position X (m)	Acting Position Y (m)
1	5.000	5.000	2.550	12.750	2.550	3.925	3.124

1.2.5 Earth Pressure and Water Pressure



[1]Normal (With Buoyancy 1)
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 3.124 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 2.95 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
61.00	5.826	24.618	17.317	47.761	23.295
62.00	5.588	23.615	16.611	45.814	23.343
63.00	5.355	22.629	15.918	43.902	23.343

The maximum earth pressure is determined by the following equation:
when ω = 62.00 ° P = 123.343 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)} = \frac{45.814 \times \sin(62.00^\circ - 35.00^\circ)}{\cos(62.00^\circ - 35.00^\circ - 0.000^\circ - 0.000^\circ)} = 23.343 \text{ kN}$$

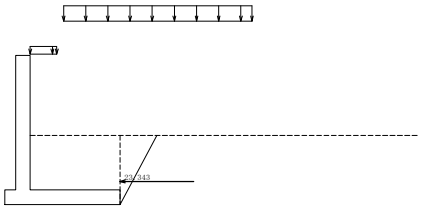
The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 23.343×cos(0.000°+ 0.000°) = 23.343 kN

Vertical Component
Pv = P · sin (α + δ) = 23.343×sin(0.000°+ 0.000°) = 0.000 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{3.124}{3} = 1.041 \text{ m}$$

x = xp-Ho · tan α = 5.200－1.041×tan0.000°= 5.200 mm
y = yp + Ho = 0.000＋1.041 ＝ 1.041 m

・Earth Pressure Diagram



[2]Normal (Without Buoyancy)
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 3.124 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 2.951 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
61.00	54.097	0.000	17.317	71.414	34.831
62.00	51.892	0.000	16.611	68.503	34.904
63.00	49.727	0.000	15.918	65.645	34.904

The maximum earth pressure is determined by the following equation:
when ω = 62.00 ° P = 34.904 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{68.503 \times \sin(62.00^\circ - 35.00^\circ)}{\cos(62.00^\circ - 35.00^\circ - 0.000^\circ - 0.000^\circ)} = 34.904 \text{ kN}$$

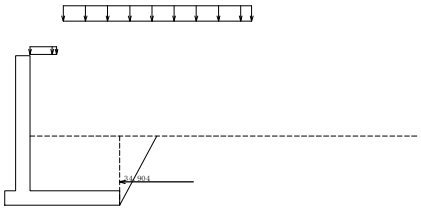
The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 34.904×cos(0.000°+ 0.000°) = 34.904 kN
Vertical Component
Pv = P · sin (α + δ) = 34.904×sin(0.000°+ 0.000°) = 0.000 kN

Acting Position

$$Ho = \frac{H}{3} = \frac{3.124}{3} = 1.041 \text{ m}$$

x = xp-Ho · tan α =5.200－1.041×tan0.000°= 5.200 m
y = yp + Ho =0.000＋1.041 ＝ 1.041 m

・Earth Pressure Diagram



[3]Seismic
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 3.124 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Combined angle during earthquake θ = $\tan^{-1}$kh = $\tan^{-1}$0.20 = 11.310°
Wall Friction Angle

$$\delta = \tan^{-1}\frac{\sin\phi \cdot \sin(\theta + \Delta - \beta)}{1 - \sin\phi \cdot \cos(\theta + \Delta - \beta)} = \tan^{-1}\frac{\sin35.00^\circ \times \sin(11.310^\circ + 19.994^\circ - 0.000^\circ)}{1 - \sin35.00^\circ \times \cos(11.310^\circ + 19.994^\circ - 0.000^\circ)} = 30.303^\circ$$

$$\Delta = \sin^{-1}\frac{\sin(\beta + \theta)}{\sin\phi} = \sin^{-1}\frac{\sin(0.000^\circ + 11.310^\circ)}{\sin35.00^\circ} = 19.994^\circ$$

Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
46.00	94.245	0.000	15.084	109.329	44.846
47.00	91.008	0.000	14.566	105.574	44.874
48.00	87.874	0.000	14.064	101.938	44.825

The maximum earth pressure is determined by the following equation:
when ω = 47.00 ° P = 44.874 kN

Earth Pressure

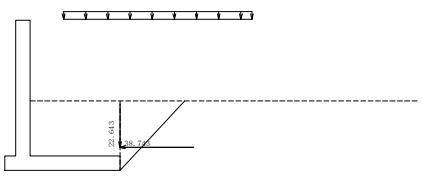
$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)} = \frac{105.574 / \cos11.310^\circ \times \sin(47.00^\circ - 35.00^\circ + 11.310^\circ)}{\cos(47.00^\circ - 35.00^\circ - 0.000^\circ - 30.303^\circ)} = 44.874 \text{ kN}$$

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 44.874×cos(0.000°+30.303°) = 38.743 kN
Vertical Component
Pv = P · sin (α + δ) = 44.874×sin(0.000°+30.303°) = 22.643 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{3.124}{3} = 1.041 \text{ m}$$

x = xp-Ho · tan α = 5.200－1.041×tan0.000°= 5.200 m
y = yp + Ho =0.000＋1.041 ＝ 1.041 m

・Earth Pressure Diagram



[4] Flood (With Buoyancy)
The earth pressure is obtained by the trial wedge method.

Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 0.650 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 30.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 5.494 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
59.00	0.000	1.168	0.000	1.168	0.647
60.00	0.000	1.122	0.000	1.122	0.648
61.00	0.000	1.077	0.000	1.077	0.647

The maximum earth pressure is determined by the following equation:
when ω = 60.00 ° 0.648 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{1.122 \times \sin(60.00^\circ - 30.00^\circ)}{\cos(60.00^\circ - 30.00^\circ - 0.000^\circ - 0.000^\circ)}$$

$$= 0.648 \text{ kN}$$

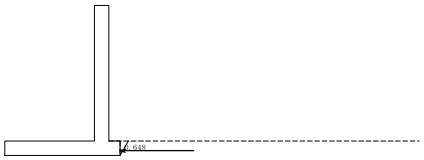
The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 0.648×cos(0.000°+ 0.000°) = 0.648 kN
Vertical Component
Pv = P · sin (α + δ) = 0.648×sin(0.000°+ 0.000°) = 0.000 kN

Acting Position

$$Ho = \frac{H}{3} = \frac{0.650}{3} = 0.217 \text{ m}$$

x = xp-Ho · tan α = 5.200−0.217×tan0.000°= 5.200 m
y = yp + Ho =0.000+0.217 = 0.217 m

・Earth Pressure Diagram



[5]Flood Without Buoyancy
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 0.650 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 30.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 5494 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
59.00	2.412	0.000	0.000	2.412	1.337
60.00	2.317	0.000	0.000	2.317	1.338
61.00	2.225	0.000	0.000	2.225	1.337

The maximum earth pressure is determined by the following equation:
when ω = 60.00 ° P = 1.338 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{2.317 \times \sin(60.00^\circ - 30.00^\circ)}{\cos(60.00^\circ - 30.00^\circ - 0.000^\circ - 0.000^\circ)}$$

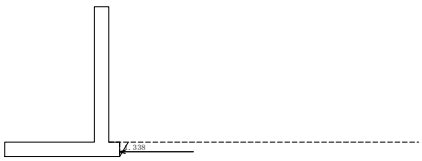
$$= 1.338 \text{ kN}$$

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 1.338×cos(0.000°+ 0.000°) = 1.338 kN
Vertical Component
Pv = P · sin (α + δ) = 1.338×sin(0.000°+ 0.000°) = 0.000 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{0.650}{3} = 0.217 \text{ m}$$

x = xp-Ho · tan α = 5.200−0.217×tan0.000°= 5.200 m
y = yp + Ho =0.000+0.217 = 0.217 m

・Earth Pressure Diagram



Passive earth Pressure
(This pressure is considered for the stability against Sliding)

[1]Flood
The earth pressure is obtained by the Mononobe ad Okabe method.
Height of the ground surface H = 3.024 m
Height above water surface H1 = 3.024 m
Height below water surface H2 = 0.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °

Coefficient of passive earth pressure

$$K = \frac{\cos^2(\phi + \alpha)}{\cos^2\alpha \cdot \cos(\alpha - \delta) \cdot \left[1 - \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi + \beta)}{\cos(\alpha - \delta) \cdot \cos(\alpha - \beta)}}\right]^2}$$

$$= \frac{\cos^2(35.00^\circ + 0.000^\circ)}{\cos^2 0.000^\circ \cdot \cos(0.000^\circ - 0.000^\circ)} \times \frac{1}{\left[1 - \sqrt{\frac{\sin(35.00^\circ + 0.000^\circ) \cdot \sin(35.00^\circ + 0.000^\circ)}{\cos(0.000^\circ - 0.000^\circ) \cdot \cos(0.000^\circ - 0.000^\circ)}}\right]^2}$$

$$= 3.6902$$

Earth pressure at the upper edge
p1= q・K = 9.500×3.6902 = 35.057 kN/m²

Earth pressure at the water surface
p2= K・γs・H1+p1
= 3.6902×19.000×3.024+35.057
= 247.081 kN/m²

Earth pressure at the bottom
p3= p2 = 247.081 kN/m²

Earth pressure above water surface

$$P1 = \frac{1}{2} \cdot (p1 + p2) \cdot H1 = \frac{1}{2} \times (35.057 + 247.081) \times 3.024 = 426.592 \text{ kN}$$

Earth pressure below water surface

$$P2 = \frac{1}{2} \cdot (p2 + p3) \cdot H2 = \frac{1}{2} \times (247.081 + 247.081) \times 0.000 = 0.000 \text{ kN}$$

Total Earth pressure
P = P1+P2 = 426.592+0.000 = 426.592 kN

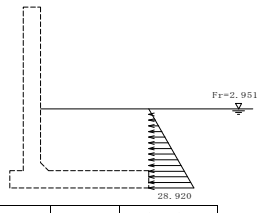
Total Earth pressure at horizontal direction
Ph = P・cos(α−δ) = 426.592×cos(0.000°− 0.000°) = 426.592 kN

Hydrostatic Pressure

$$P = \frac{1}{2} \cdot \gamma w \cdot h^2$$

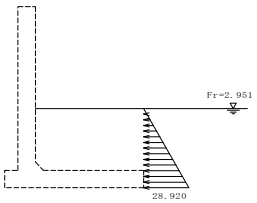
$$Y = \frac{h}{3}$$

Where、
γw : unit weiht of water (kN/m³), γw=9.800
h : water head (m)
Y : acting point (m)
[1]Normal with Buoyancy



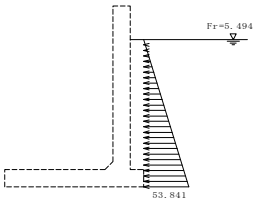
	h (m)	P (kN)	Acting Point Y (m)
Rear	2.951	42.671	0.984

[2]Normal without Buoyancy



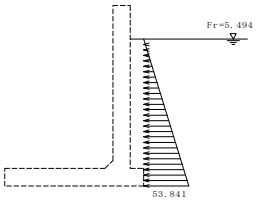
	h (m)	P (kN)	Acting Point Y (m)
Rear	2.951	42.671	0.984

[3]Flood with Buoyancy



	h (m)	P (kN)	Acting Point Y (m)
Front	5.494	147.902	1.831

[4]Flood without Buoyancy

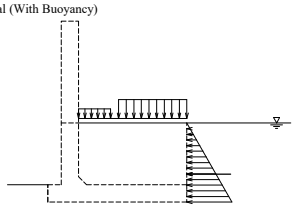


	h (m)	P (kN)	Acting Point Y (m)
Front	5.494	147.902	1.831

1.2.6 Summary of Acting Forces

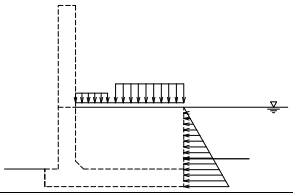
(1)Summary of Forces Acting On the Footing Front

[1]Normal (With Buoyancy)



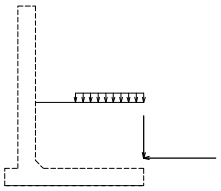
Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length Xi (m)	Arm length Yi (m)	Angular Moment (kN.m.) Mxi = Ni, Xi	Angular Moment (kN.m.) Myi = Hi Yi
Body Weight	380.453	0.000	2.449	0.000	931.874	0.000
Buoyancy	-139.108	0.000	2.790	0.000	-388.176	0.000
Load on Surface	31.500	0.000	3.511	0.000	110.588	0.000
Rear Side Water Pressure	0.000	42.671	0.000	0.984	0.000	41.974
Earth Pressure	0.000	23.343	5.200	1.041	0.000	24.300
Total	272.845	66.014	———	———	654.286	66.274

[2]Normal (Without Buoyancy)



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length Xi (m)	Arm length Yi (m)	Angular Moment (kN.m.) Mxi = Ni, Xi	Angular Moment (kN.m.) Myi = Hi Yi
Body Weight	380.453	0.000	2.449	0.000	931.874	0.000
Load on Surface	31.500	0.000	3.511	0.000	110.588	0.000
Rear Side Water Pressure	0.000	42.671	0.000	0.984	0.000	41.974
Earth Pressure	0.000	34.904	5.200	1.041	0.000	36.335
Total	411.953	77.575	———	———	1042.462	78.309

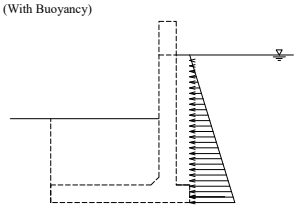
[3]Seismic (With Buoyancy)



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length Xi (m)	Arm length Yi (m)	Angular Moment (kN.m.) Mxi = Ni, Xi	Angular Moment (kN.m.) Myi = Hi Yi
Body Weight	380.453	76.091	2.449	2.008	931.874	152.798
Load on Surface	12.750	2.550	3.925	3.124	50.044	7.966
Earth Pressure	22.643	38.743	5.200	1.041	117.744	40.331
Total	415.846	117.384	———	———	1099.661	201.096

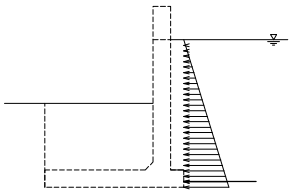
Load Condition (Water Level)	No (kN)	Ho (kN)	Mo (kN.m.)
Normal (With Buoyancy)	272.845	66.014	588.011
Normal (Without Buoyancy)	411.953	77.575	964.152
Seismic (With Buoyancy)	415.846	117.384	898.565
Seismic (Without Buoyancy)	415.846	117.384	898.565

[4]Flood (With Buoyancy)



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length Xi (m)	Arm length Yi (m)	Angular Moment (kN.m.) Mxi = Ni, Xi	Angular Moment (kN.m.) Myi = Hi Yi
Body Weight	370.479	0.000	2.770	0.000	1026.372	0.000
Buoyancy	-162.173	0.000	2.590	0.000	-419.960	0.000
Load on Surface	0.000	147.902	0.000	1.831	0.000	270.857
Rear Side Water Pressure	0.000	0.648	5.200	0.217	0.000	0.141
Earth Pressure	208.305	148.550	———	———	606.412	270.998
Total	370.479	0.000	2.770	0.000	1026.372	0.000

[5] Flood (Without Buoyancy)



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length Xi (m)	Arm length Yi (m)	Angular Moment (kN.m.) Mxi = Ni, Xi	Angular Moment (kN.m.) Myi = Hi Yi
Body Weight	370.479	0.000	2.770	0.000	1026.372	0.000
Rear Side Water Pressure	0.000	147.902	0.000	1.831	0.000	270.857
Earth Pressure	0.000	1.338	5.200	0.217	0.000	0.290
Total	370.479	149.240	———	———	1026.372	271.148

Load Condition (Water Level)	No (kN)	Ho (kN)	Mo (kN.m.)
Flood (With Buoyancy)	208.305	148.550	335.414
Flood (Without Buoyancy)	370.479	149.240	755.224

(2)Summary of Forces Acting At the Footing Center

Vertical Force : Nc = No (kN)
Horizontal Force : Hc = Ho (kN)
Turning Moment : Mc = No Bj/2.0 - Mo (kN.m.)

Here,

Footing Width in Earth Pressure Direction : Bj = 7.500 (m)

■Per Unit Width

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Normal (With Buoyancy)	272.845	66.014	121.386
Normal (Without Buoyancy)	411.953	77.575	106.927
Seismic (With Buoyancy)	415.846	117.384	182.635
Seismic (Without Buoyancy)	415.846	117.384	182.635
Flood (With Buoyancy)	208.305	148.550	206.180
Flood (Without Buoyancy)	370.479	149.240	208.020

■Per full width (9.000 m)

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Normal (With Buoyancy)	1364.226	330.071	606.932
Normal (Without Buoyancy)	2059.767	387.876	534.633
Seismic (With Buoyancy)	2079.232	586.918	913.177

Seismic (Without Buoyancy)	2079.232	586.918	913.177
Flood (With Buoyancy)	1041.527	742.749	1030.898
Flood (Without Buoyancy)	1852.394	746.199	1040.102

1.2.7 Stability Analysis Results

1.2.7.1 Stability against Overturning

(1)Calculation of Acting Point of Composited Force and Eccentricity

$$d = \frac{\Sigma Mr - \Sigma Mt}{\Sigma V}$$

Here,

d: Distance from the Toe of Bottom Slab to the Acting Point of Composited Force (m)
ΣMr: Resistive Moment of Toe of Bottom Slab (kN.m.)
ΣMt: Overturning Moment of Toe of Bottom Slab (kN.m.)
ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)

$$e = \frac{B}{2} - d$$

Here,

e: Eccentricity from the Center of Bottom Slab to the Acting Point of Composited Force (m);
B: Bottom Slab Width (m), B = 7.500

ea = B/n

Here,

ea: Allowable Eccentricity (m)
n: Safety Factor

Load Condition (Water Level)	Σ Mr (kN.m.)	Σ Mt (kN.m.)	ΣV (kN)	d (m)	e (m)		Ea (m)
Normal (With Buoyancy)	654.286	66.274	272.845	2.155	0.445	≦	0.867
Seismic (With Buoyancy)	1099.661	201.096	415.846	2.161	0.439	≦	1.733
Flood (With Buoyancy)	606.412	270.998	208.305	1.610	0.990	≦	1.733

1.2.7.2 Stability Against Sliding

$$F_s = \frac{\Sigma V \cdot \mu + C_B \cdot B + \alpha \cdot Pp}{\Sigma H}$$

Here,

ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)
ΣH: Total Horizontal Load in Lower Side of Bottom Slab (kN)
m.: Cohesion Between Bottom Slab and Supporting Ground, m = 0.577
C_B: Cohesion Between Bottom Slab And Supporting Ground (kN/m2), C_B = 0.000
B: Bottom Slab Width (m), B = 7.500
α: Effeective Rate of Passive Earth Pressure
Pp: Passive Earth Pressure

Load Condition (Water Level)	Vertical Load ΣV (kN)	Horizontal Load ΣH (kN)	Passive Earth Pressure Pp(kN)	Effectiive Rate	Safety Factor Fs		Required Safety Factor Fsa
Normal (With Buoyancy)	272.845	66.014	—	—	2.067	≧	1.500
Seismic (With Buoyancy)	415.846	117.384	—	—	1.771	≧	1.200
Flood (With Buoyancy)	208.305	148.550	426.592	0.500	2.137	≧	1.200

1.2.7.3 Verification of Bearing

1)When the Acting Point of Composited Force is within the 1/3 of Bottom Slab Width (middle third) in the Center of the Bottom Slab.

$$q_1 = \frac{\Sigma V}{B} \cdot \left(1 + \frac{6e}{B}\right)$$

$$q_2 = \frac{\Sigma V}{B} \cdot \left(1 - \frac{6e}{B}\right)$$

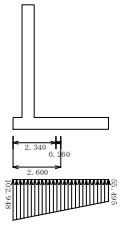
2)When the Acting Point of Composited Force is within the 2/3 of Bottom Slab Width in the Center of the Bottom Slab.

$$q_1 = \frac{2\Sigma V}{3 \cdot (B/2 - e)}$$

Here,

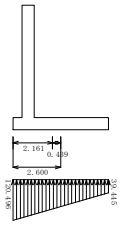
ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)
B: Bottom Slab Width (m), B = 7.500
e: Eccentricity (m)

[1]Normal (Without Buoyancy)



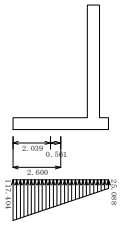
Subgrade Reaction Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2) qmin	qmax		Allowance
5.200	Trapezoid	55.495	102.948	≦	200.000

[2]Seismic (With Buoyancy)



Subgrade Reaction Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2) qmin	qmax		Allowance
5.200	Trapezoid	39.445	120.496	≦	300.000

[3]Flood (With Buoyancy)



Subgrade Reaction Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2) qmin	qmax		Allowance
5.200	Trapezoid	25.088	117.404	≦	300.000

1.3 Vertical Wall Design

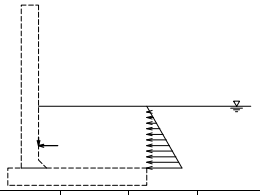
1.3.1 Checking Position

Distance from Base = 0.000 m

1.3.2 Calculation of Cross-Sectional Force

(Vertical forces are not summarized due to disregard of eccentric moments and axial forces)

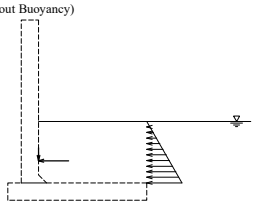
[1]Normal (With Buoyancy)



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	98.149	0.000	-0.005	0.000	0.000
Hydrostatic on Rear Side	0.000	25.944	0.000	0.767	19.899
Earth Pressure	4.480	10.386	-0.325	0.825	8.568
Total	0.000	36.330	———	———	28.467

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

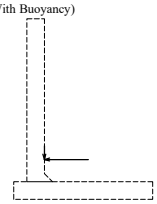
[2]Normal (Without Buoyancy)



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	98.149	0.000	-0.005	0.000	0.000
Hydrostatic on Rear Side	0.000	25.944	0.000	0.767	19.899
Earth Pressure	6.957	16.128	-0.325	0.825	13.306
Total	0.000	42.072	———	———	33.204

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

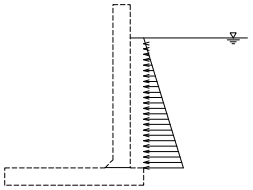
[3]Seismic (With Buoyancy)



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	98.149	19.630	-0.005	3.014	59.162
Earth Pressure	7.450	23.628	-0.325	0.825	19.493
Total	0.000	43.258	———	———	78.656

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

[5]Flood

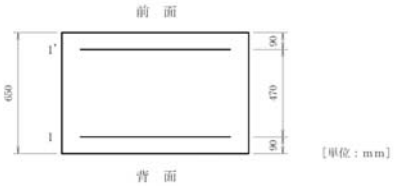


Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	98.149	0.000	0.005	0.000	0.000
Hydrostatic on Rear Side	0.000	114.975	0.000	1.615	185.647
Hydrostatic on Front Side	0.000	114.975	———	———	185.647
Earth Pressure	98.149	0.000	0.005	0.000	0.000
Total	0.000	114.975	0.000	1.615	185.647

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

1.3.3 Section Calculations (Allowable Stress Method)

(1)Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	9.0	D25	5.067	8.00	40.536
	2'	—	–	——	—	——
Back	1	9.0	D25	5.067	8.00	40.536
	2	—	–	——	—	——

Required Reinforcement in Tension Side 7.923 (cm2)

(2)Verification of Bending Stress

Calculation of the neutral axis

$$x^2+\frac{2\cdot n}{b}\{As\cdot(x-d)\}=0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c=\frac{M}{\frac{b\cdot x}{2}\cdot\left(\frac{h}{2}-\frac{x}{3}\right)+n\cdot As\cdot\frac{(x-d)\cdot(h/2-d)}{x}}$$

$$\sigma_s=n\cdot\sigma_c\cdot\frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	N (kN)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
				Calculated	Allowance	Calculated	Allowance
Normal (Without Buoyancy)	33.204	0.000	15.671	0.705 ≦	8.200	16.333 ≦	140.000
Seismic (With Buoyancy)	78.656	0.000	15.671	1.670 ≦	10.906	38.691 ≦	186.200

Flood (Without Buoyancy)	185.647	0.000	11.846	5.312 ≦ 10.906	178.199 ≦ 186.200

(3)Verification of Shear Stress

$$\tau_m=\frac{S_h}{b\cdot d}\leqq\tau_{a1}$$

Here,

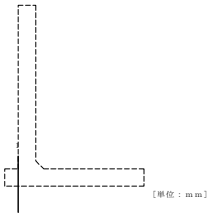
τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)		
			Calculated	Allowable τa1	Allowable τa2
Normal (With Buoyancy)	36.330	56.000	0.065 ≦	0.360	0.360
Seismic (With Buoyancy)	43.258	56.000	0.077 ≦	0.479	0.479
Flood (With Buoyancy)	114.975	56.000	0.205 ≦	0.479	0.479

1.4 Design of Toe Slab

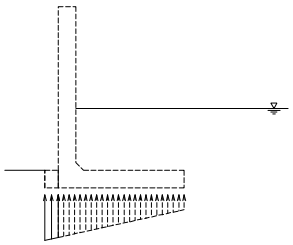
1.4.1 Checking Position

Distance from Base = 0.000 m



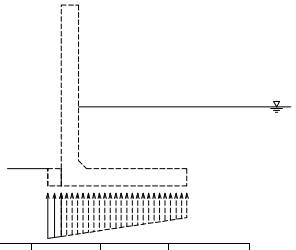
1.4.2 Calculation of Cross-Sectional Force

[1]Normal (With Buoyancy)



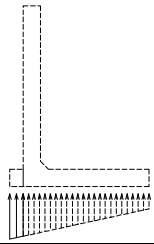
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-7.963	0.250	-1.991
Buoyancy	3.185	0.250	0.796
Subgrade Reaction	38.408	0.253	9.710
Total	33.630	———	8.516

[2]Normal (Without Buoyancy)



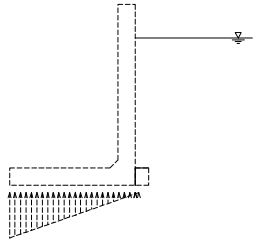
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-7.963	0.250	-1.991
Subgrade Reaction	50.333	0.252	12.678
Total	42.371	———	10.688

[3]Seismic 1 (With Buoyancy)



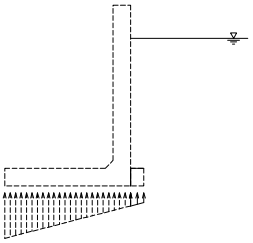
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-7.963	0.250	-1.991
Subgrade Reaction	58.300	0.253	14.737
Total	50.337	———	12.747

[5]Flood (With Buoyancy)



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	7.963	0.250	1.991
Buoyancy	-3.185	0.250	-0.796
Subgrade Reaction	-0.151	0.043	-0.007
Total	4.627	———	1.188

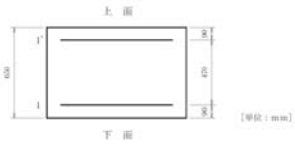
[6]Flood (Without Buoyancy)



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	7.963	0.250	1.991
Subgrade Reaction	-14.763	0.237	-3.506
Total	-6.801	———	-1.515

1.4.3 Section Calculations (Allowable Stress Method)

(1)Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	9.0	D25	5.067	8.00	40.536
	2'	—	–	——	—	——
Back	1	9.0	D25	5.067	8.00	40.536
	2	—	–	——	—	——

Required Reinforcement in Tension Side 0.144 (cm2)

(2)Verification of Bending Stress

Calculation of the neutral axis

$$x^2+\frac{2\cdot n}{b}\{As\cdot(x-d)\}=0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c=\frac{M}{\frac{b\cdot x}{2}\cdot\left(\frac{h}{2}-\frac{x}{3}\right)+n\cdot As\cdot\frac{(x-d)\cdot(h/2-d)}{x}}$$

$$\sigma_s=n\cdot\sigma_c\cdot\frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
			Calculated	Allowance	Calculated	Allowance
Normal (Without Buoyancy)	10.688	16.893	0.227 ≦	8.200	5.257 ≦	140.000
Seismic (With Buoyancy)	12.747	16.893	0.271 ≦	10.906	6.270 ≦	186.200
Flood (Without Buoyancy)	-1.515	15.671	0.032 ≦	10.906	0.745 ≦	186.200

(3)Verification of Shear Stress

$$\tau_m=\frac{S_h}{b\cdot d}\leqq\tau_{a1}$$

Here,

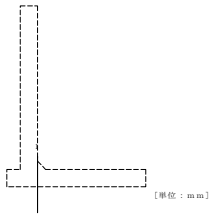
τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)	
			Calculated	Allowable τa
Normal (With Buoyancy)	15.088	560.000	0.027 ≦	0.360
Seismic 1 (With Buoyancy)	18.060	560.000	0.032 ≦	0.479
Flood (With Buoyancy)	6.801	560.000	0.012 ≦	0.479

1.5 Design of the Heel Slab

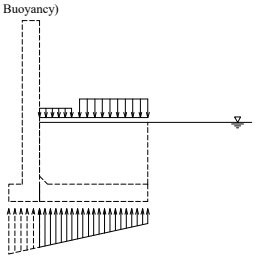
1.5.1 Checking Position

Distance from Base = 0.000 m



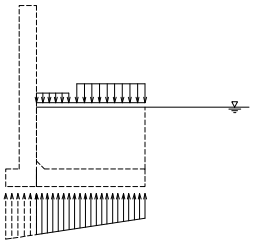
1.5.2 Calculation of Cross-Sectional Force

[1]Normal (With Buoyancy)



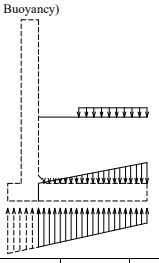
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	265.093	2.023	536.423
Buoyancy	-117.125	2.025	-237.178
Load on Surface	31.500	2.361	74.363
Subgrade Reaction	-188.379	1.721	-324.117
Total	-8.911	———	49.491

[2]Normal (Without Buoyancy)



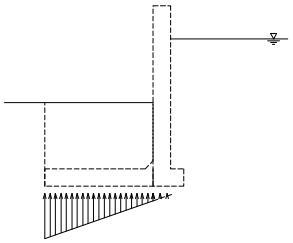
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	265.093	2.023	536.423
Load on Surface	31.500	2.361	74.363
Subgrade Reaction	-299.596	1.856	-556.164
Total	-3.003	———	54.622

[3]Seismic (With Buoyancy)



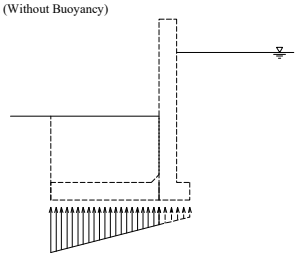
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	265.093	2.023	536.423
Load on Surface	12.750	2.775	35.381
Earth Pressure	22.643	2.700	61.136
Subgrade Reaction	-287.583	1.725	-496.070
Total	12.903	———	136.870

[4]Flood (With Buoyancy)



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-255.118	2.023	-516.138
Buoyancy	123.992	2.025	251.083
Subgrade Reaction	202.873	2.512	509.679
Total	71.747	———	244.624

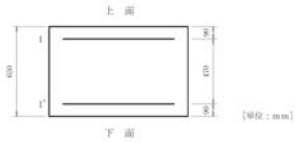
[6]Flood (Without Buoyancy)



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-255.118	2.023	-516.138
Subgrade Reaction	329.889	2.323	766.303
Total	74.771	———	250.166

1.5.3 Section Calculations (Allowable Stress Method)

(1)Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	9.0	D25	5.067	8.00	40.536
	2'	—	–	——	—	——
Back	1	9.0	D25	5.067	8.00	40.536
	2	—	–	——	—	——

Required Reinforcement in Tension Side 26.183 (cm2)

(2)Verification of Bending Stress

Calculation of the neutral axis

$$x^2 + \frac{2 \cdot n}{b}\left\{As \cdot (x-d)\right\} = 0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	x (cm)	Compressive Stress (N/mm2) Calculated	Allowance	Tensile Stress (N/mm2) Calculated	Allowance
Normal (Without Buoyancy)	33.204	15.671	0.705 ≦	8.200	16.333 ≦	140.000
Seismic (With Buoyancy)	78.656	15.671	1.670 ≦	10.906	38.691 ≦	186.200
Flood (Without Buoyancy)	250.166	15.671	5.313 ≦	10.906	123.057 ≦	186.200

(3)Verification of Shear Stress

$$\tau_m = \frac{S_h}{b \cdot d} \leqq \tau_{a1}$$

Here,

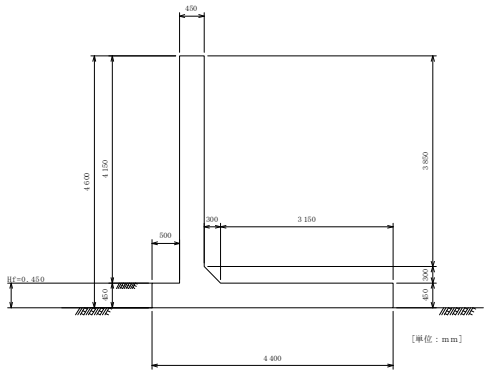
τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2) Calculated	Allowable τa2
Normal (With Buoyancy)	8.911	560.000	0.016 ≦	0.360
Seismic (With Buoyancy)	12.903	560.000	0.023 ≦	0.479
Flood (With Buoyancy)	79.745	560.000	0.142 ≦	0.479

2 Invert T-shaped Wall, Left Bank Sta.11+400

2.1 Design Conditions

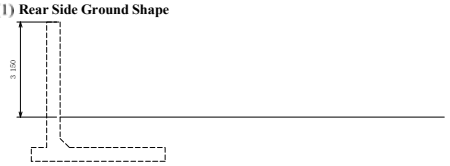
2.1.1 Geometry



Depth Width (Block Length) B = 5000 (mm)

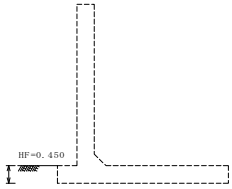
2.1.2 Backfill and Embankment

(1) Rear Side Ground Shape



Level Difference Between Retaining Wall Crown And Ground Surface Start Point	(m)	3.150
Height Without Considering Earth Pressure Hr (in stability analysis) Hr	(m)	0.000

(2) Front Side Ground Shape



Height	Stability Analysis		Design of Toe Slab
	Vertical	Horizontal	
0.00	Not Considered	Not Considered	Not Considered

2.1.3 Material

[Concrete] Vertical wall (reinforced concrete) : σck = 20.0 (N/mm2)
Base concrete (reinforced concrete) : σck = 20.0 (N/mm2)

[Iron bar] Type: : Grade 275

[Soil] Backfill : sand and gravel
Foudation : sandy gravel

[Internal Fdiction] Backfill : 30 degrees

[Unit weight]
(kN/m3)

Body	24.500	
Water	9.800	
Soil	Wet weight	Saturated weight

River side	20.000	20.800
Land side	20.000	20.800

[Seismic Intensity] Body : 0.200
Foundation Riverside : 0.200
Foundation Landside : 0.200

2.1.4 Loads

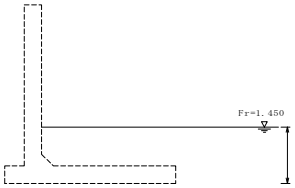
[1]Normal
Not Concidered

[2]Seismic
Not Concidered

[3]Flood
Not Concidered

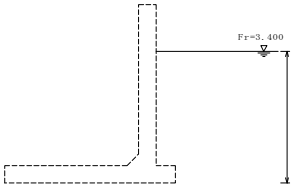
2.1.5 Water Level

[1]Normal
■With Buoyancy : Water Leve in Front Side level Ff = 0.000 m, Water Level in Rear Side Fr = 1.450 m



[2]Seidmic
Not Considered

[3]Flood
■With Buoyancy : Water Leve in Front Side level Ff = 0.000 m, Water Level in Rear Side Fr = 3.400 m



2.1.6 Buoyancy

・Use the Water Level in Rear Side

2.1.7 Earth Pressure

・Earth Pressure Formulas: Trial Wedge

・Angle of Friction of Earth Pressure Acting Surface (Degrees)

Load Condition	Active Earth Pressure			Passive Earth Pressure
	In Case of Stability Analysis	In Case of Vertical Wall Design	Cut	
Normal Earth Pressure	0.000	20.000	———	———
Seismic Earth Pressure	25.683	15.000	———	———
Flood Earth Pressure	0.000	0.000	———	0.000

・ The virtual rear surface of earth pressure in the stability analysis is at the heel end (a line extended vertically from the heel)

・ Angle between the earth pressure acting surface and the vertical plane in stability analysis
0.000 (degrees)

・ Angle between the earth pressure working surface and the vertical plane when designing the vertical wall
Normal, Seismic 0.000 (degrees)
Flood 0.000 (degrees)

・The Design Horizontal Seismic Coefficient is applied to the inertia force during earthquakes when calculating the earth pressure below the water level.

・Passive Earth Pressure

Load Condition	Height of Acting	Effectivity
Flood	0.950	0.500

・Cohesion (kN/m2)

Load Condition	For Sliding Surfaces	For Cohesive Height	For Passive Earth Pressure
Normal Condition	0.000	0.000	———
Seismic Condition	0.000	0.000	0.000
Flood Condtion	0.000	0.000	0.000

・Consideration of Earth Pressure Different from Direction of Earthquake Motion

	Consideration I...	Effectivity
Stability Analysis	Seismic Earth Pressure	0.500
Vertical Wall Design		0.500

2.1.8 Water Pressure

・Concept of Calculation of Hydrostatic Pressure

Load Condition	Rear Side	Front Side
Normal Condition	Considered	Considered
Seismic Condition	Considered	Considered
Flood Condition	Considered	Considered

・Consideration of Hydrostatic Pressure Different from the Direction of Earthquake Motion

Outside Water Level	Stability analysis	Considered
	Vertical Wall Design	Considered

・Consideration of Dynamic Water Pressure Calculation

Outside Water Level	Considered

2.1.9 Load Combination Case

No	Load Name	Comments
1	Normal	
2	Seismic	Seismic
3	Flood	Flood

	Load Name	1	2	3
Soil	Front Soil 1	○	○	
	Front Soil 2			○
Water Level	Buoyancy 1	○		
	Buoyancy 2		○	
	Buoyancy 3			○
Load	Load 1			○
Active Earth Pressure	Not Considered			
	Normal Earth Pressure	○		○
	Seismic Earth Pressure		○	
Passive Earth Pressure	Passive Earth Pressure 1			○

2.1.10 Foundation Conditions

2.1.10.1 Data For Calculating Allowable Shear Resistance

Bottom Slab Width Used for Analysis		All Width
Cohesion Between Foundation Bottom Surface And Ground	C_B (kN/m2)	0.000
Friction Coefficient Between Foundation Bottom Surface and Ground	tan φ_B	0.500

2.1.11 Allowable Values For Stability Analysis And Allowable Stresses of Members

2.1.11.1 Allowance in Stability Analysis

Load Condition	Allowable Eccentricity eB/B (m)	Safety Factor for Overturning	Allowable Subgrade Reaction Intensity (kN/m2)
Normal	1/6	1.500	200.000
Seismic, Flood	1/3	1.200	300.000

2.1.11.2 Allowable Stress of the Member

(1)Reinforced Concrete Member

1) Vertical Wall (General Member)

(N/mm2)

Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic, Flood	1.33	10.906	186.200	0.479	0.479

2) Bottom Slab (General Member)

(N/mm2)

Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic, Flood	1.33	10.906	186.200	0.479	0.479

Here,

τa1: Shear Stress When Shear Force is Applied Only by Concrete

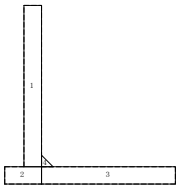
τa2: Shear Stress when Jointly Bearing with Oblique Tensile Reinforcement

2.2 Stability Analysis

2.2.1 Block Data Not Considering Water Level

(1)Body Weight

1)Block Diversion



2)Weight and Center of Gravity

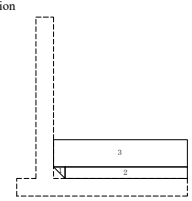
Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	0.450× 4.150× 1.000	1.867	0.725	2.525	1.354	4.715	
2	0.950× 0.450× 1.000	0.428	0.475	0.225	0.203	0.096	
3	3.450× 0.450× 1.000	1.553	2.675	0.225	4.153	0.349	
4	1/2× 0.300× 0.300× 1.000	0.045	1.050	0.550	0.047	0.025	
Σ		3.893	——	——	5.757	5.186	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 5.757／ 3.893 ＝ 1.479 (m)

YG = Σ (Vi Yi)/ΣVi = 5.186／ 3.893 ＝ 1.332 (m)

(2)Soil in Rear Side

1)Block Diversion



2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	1/2× 0.300× 0.300× 1.000	0.045	1.150	0.650	0.052	0.029	
2	3.150× 0.300× 1.000	0.945	2.825	0.600	2.670	0.567	
3	3.450× 0.700× 1.000	2.415	2.675	1.100	6.460	2.657	
Σ		3.405	——	——	9.181	3.253	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 9.181／ 3.405 ＝ 2.696 (m)

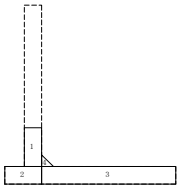
YG = Σ (Vi Yi)/ΣVi = 3.253／ 3.405 ＝ 0.955 (m)

2.2.2 Block Data Considering Water Level

(1)Body Weight

[1]Normal (With Buoyancy 2)

1)Block Diversion



2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	0.450× 1.000× 1.000	0.450	0.725	0.950	0.326	0.427	
2	0.950× 0.450× 1.000	0.428	0.475	0.225	0.203	0.096	
3	3.450× 0.450× 1.000	1.553	2.675	0.225	4.153	0.349	
4	1/2× 0.300× 0.300× 1.000	0.045	1.050	0.550	0.047	0.025	
Σ		2.475	——	——	4.729	0.898	

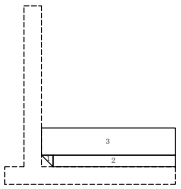
Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 4.729／ 2.475 ＝ 1.911 (m)

YG = Σ (Vi Yi)/ΣVi = 0.898／ 2.475 ＝ 0.363 (m)

(2)Soil in Rear Side

[1]Normal (With Buoyancy 2)

1)Block Diversion



2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m)		Vi/Xi	Vi Yi	Remarks
			Xi	Yi			
1	1/2× 0.300× 0.300× 1.000	0.045	1.150	0.650	0.052	0.029	
2	3.150× 0.300× 1.000	0.945	2.825	0.600	2.670	0.567	
3	3.450× 0.700× 1.000	2.415	2.675	1.100	6.460	2.657	
Σ		3.405	——	——	9.181	3.253	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 9.181／ 3.405 ＝ 2.696 (m)
YG = Σ (Vi Yi)/ΣVi = 3.253／ 3.405 ＝ 0.955 (m)

2.2.3 Body Weight, Weight of Soil, Arbitrary Load, Vertical Force by Buoyancy, Horizontal Force

(1)Working Force Due to Body Weight
[1]Normal

Position	Vertical Force W = γ ・ V (kN)			Acting Position X (m)
Body(Reinforced)	24.500 ×	3.893 ＝	95.366	1.479
Soil (Rear Side)	19.000 ×	3.405 ＝	64.695	2.696
Total			160.061	1.971

[2]Seismic

Position	Vertical Force W = γ ・ V (kN)			Acting Position X (m)
Body(Reinforced)	24.500 ×	3.893 ＝	95.366	1.479
Soil (Rear Side)	19.000 ×	3.405 ＝	64.695	2.696
Total			160.061	1.971

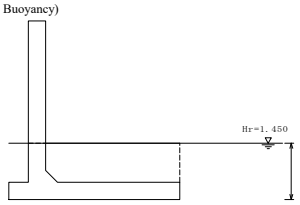
Position	Horizontal Load H = W kh (kN)			Acting Position Y (m)
Body(Reinforced)	95.366 ×	0.20 ＝	19.073	1.332
Soil (Rear Side)	64.695 ×	0.20 ＝	12.939	0.955
Total			32.012	1.180

[3]Flood

Position	Vertical Force W = γ ・ V (kN)			Acting Position X (m)
Body(Reinforced)	24.500 ×	3.892 ＝	95.366	2.921

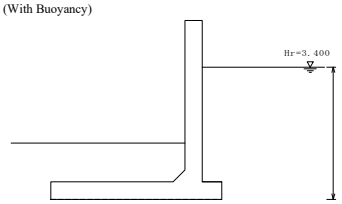
Soil (Rear Side)	19.000 ×	3.405 ＝	64.695	1.704
Total			160.061	2.429

(2)Acting Force by Weight of Soil And Buoyancy
[1]Normal (With Buoyancy)



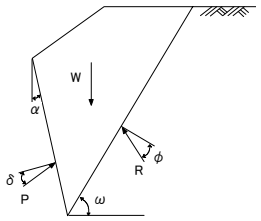
Position	Volume V (m3)	Unit Weight γ (kN/m3)	Buoyancy Fi (kN)	Acting Position Xi (m)	Fi/Xi
Body	2.475	9.800	24.255	1.911	46.349
Soil (Rear Side)	3.405	9.800	33.369	2.696	89.979
Total	——	——	57.624	——	136.328

[3]Flood (With Buoyancy)



Position	Volume V (m3)	Unit Weight γ (kN/m3)	Buoyancy Fi (kN)	Acting Position Xi (m)	Fi/Xi
Body	0.225	9.800	2.205	4.150	9.151
Total	——	——	2.205	——	9.151

2.2.4 Earth Pressure and Water Pressure



[1]Normal (With Buoyancy)
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 4.400 m
yp = 0.000 m
Height of Virtual Rear Surface H = 1.450 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 30.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 1.450 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
59.00	0.000	5.811	0.000	5.811	3.221
60.00	0.000	5.584	0.000	5.584	3.224
61.00	0.000	5.361	0.000	5.361	3.221

The maximum earth pressure is determined by the following equation:
when ω = 60.00 ° P = 3.224 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{5.584 \times \sin(60.00^\circ - 30.00^\circ)}{\cos(60.00^\circ - 30.00^\circ - 0.000^\circ - 0.000^\circ)}$$

$$= 3.224 \text{ kN}$$

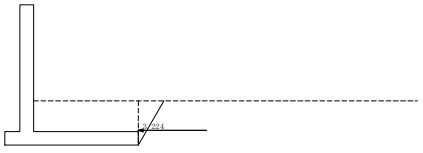
The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P ・ cos (α + δ) = 3.224×cos(0.000°＋ 0.000°) ＝ 3.224 kN
Vertical Component

Pv = P ・ sin (α + δ) = 3.224×sin(0.000°＋ 0.000°) ＝ 0.000 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{1.450}{3} = 0.483 \text{ m}$$

x = xp-Ho ・ tan α = 4.400－0.483×tan0.000°＝ 4.400 m
y = yp + Ho =0.000＋0.483 ＝ 0.483 m

・Earth Pressure Diagram



[2]Seismic
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 4.400 m
yp = 0.000 m
Height of Virtual Rear Surface H = 1.450 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 30.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Combined angle during earthquake θ ＝ $\tan^{-1}$kh ＝ $\tan^{-1}$0.20 ＝ 11.310°
Wall Friction Angle

$$\delta = \tan^{-1}\frac{\sin\phi \cdot \sin(\theta + \Delta - \beta)}{1 - \sin\phi \cdot \cos(\theta + \Delta - \beta)}$$

$$= \tan^{-1}\frac{\sin 30.00^\circ \times \sin(11.310^\circ + 23.094^\circ - 0.000^\circ)}{1 - \sin 30.00^\circ \times \cos(11.310^\circ + 23.094^\circ - 0.000^\circ)}$$

$$= 25.683^\circ$$

$$\Delta = \sin^{-1}\frac{\sin(\beta + \theta)}{\sin\phi} = \sin^{-1}\frac{\sin(0.000^\circ + 11.310^\circ)}{\sin 30.00^\circ} = 23.094^\circ$$

Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
42.00	22.183	0.000	0.000	22.183	9.213
43.00	21.419	0.000	0.000	21.419	9.217
44.00	20.683	0.000	0.000	20.683	9.208

The maximum earth pressure is determined by the following equation:

when ω = 43.00 °　P = 9.217 kN

Earth Pressure

$$P = \frac{W/\cos\theta \cdot \sin(\omega-\phi+\theta)}{\cos(\omega-\phi-\alpha-\delta)}$$

$$= \frac{21.419/\cos 11.310^\circ \times \sin(43.00^\circ - 30.00^\circ + 11.310^\circ)}{\cos(43.00^\circ - 30.00^\circ - 0.000^\circ - 25.683^\circ)}$$

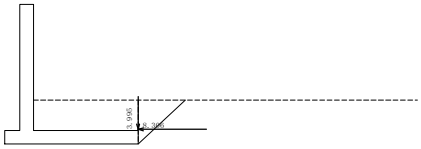
$$= 9.217 \text{ kN}$$

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P ・ cos (α + δ) = 9.217×cos(0.000°+25.683°) = 8.306 kN
Vertical Component
Pv = P · sin (α + δ) = 9.217×sin(0.000°+25.683°) = 3.995 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{1.450}{3} = 0.483 \text{ m}$$

x = xp-Ho ・ tan α = 4.400－0.483×tan0.000°= 4.400 m
y = yp + Ho =0.000＋0.483 = 0.483 m

・Earth Pressure Diagram



[3]Flood (With Buoyancy)
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 4.400 m
yp = 0.000 m
Height of Virtual Rear Surface H = 0.450 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 27.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 °～ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 2.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
57.00	0.000	0.605	0.000	0.605	0.349
58.00	0.000	0.582	0.000	0.582	0.350
59.00	0.000	0.560	0.000	0.560	0.350

The maximum earth pressure is determined by the following equation:
when ω = 58.00 °　P = 0.350 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega-\phi)}{\cos(\omega-\phi-\alpha-\delta)}$$

$$= \frac{0.582 \times \sin(58.00^\circ - 27.00^\circ)}{\cos(58.00^\circ - 27.00^\circ - 0.000^\circ - 0.000^\circ)}$$

$$= 0.350 \text{ kN}$$

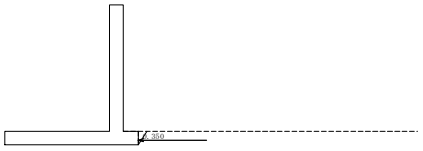
The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P ・ cos (α + δ) = 0.350×cos(0.000°+ 0.000°) = 0.350 kN
Vertical Component
Pv = P · sin (α + δ) = 0.350×sin(0.000°+ 0.000°) = 0.000 kN

Acting Position

$$Ho = \frac{H}{3} = \frac{0.450}{3} = 0.150 \text{ m}$$

x = xp-Ho ・ tan α = 4.400－0.150×tan0.000°= 4.400 m
y = yp + Ho =0.000＋0.150 = 0.150 m

・Earth Pressure Diagram



Passive earth Pressure
(This pressure is considered for the stability against Sliding)

[1]Flood
The earth pressure is obtained by the Mononobe ad Okabe method.
Height of the ground surface H = 0.950 m
Height above water surface H1 = 0.950 m
Height below water surface H2 = 0.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 19.000 kN/m3
Internal Friction Angle of Soil φ = 30.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °

Coefficient of passive earth pressure

$$K = \frac{\cos^2(\phi+\alpha)}{\cos^2\alpha \cdot \cos(\alpha-\delta) \cdot \left[1-\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi+\beta)}{\cos(\alpha-\delta)\cdot\cos(\alpha-\beta)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ + 0.000^\circ)}{\cos^2 0.000^\circ \cdot \cos(0.000^\circ - 0.000^\circ)} \times \frac{1}{\left[1-\sqrt{\frac{\sin(30.00^\circ + 0.000^\circ)\cdot\sin(30.00^\circ + 0.000^\circ)}{\cos(0.000^\circ - 0.000^\circ)\cdot\cos(0.000^\circ - 0.000^\circ)}}\right]^2}$$

$$= 3.0000$$

Earth pressure at the upper edge
p1= q・K = 10.000×3.0000 = 30.000 kN/m²

Earth pressure at the water surface
p2= K・γs・H1＋p1
= 3.0000×19.000×0.950＋30.000
= 84.150 kN/m²

Earth pressure at the bottom
p3= p2 = 84.150 kN/m²

Earth pressure above water surface

$$P1 = \frac{1}{2} \cdot (p1+p2) \cdot H1 = \frac{1}{2} \times (30.000 + 84.150) \times 0.950 = 54.221 \text{ kN}$$

Earth pressure below water surface

$$P2 = \frac{1}{2} \cdot (p2+p3) \cdot H2 = \frac{1}{2} \times (84.150 + 84.150) \times 0.000 = 0.000 \text{ kN}$$

Total Earth pressure
P = P1＋P2 = 54.221＋0.000 = 54.221 kN

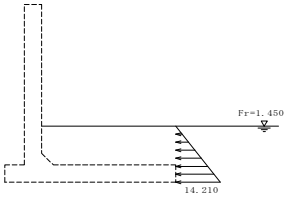
Total Earth pressure at horizontal direction
Ph = P・cos(α－δ) = 54.221×cos(0.000°－ 0.000°) = 54.221 kN

Hydrostatic Pressure

$$P = \frac{1}{2} \cdot \gamma w \cdot h^2$$

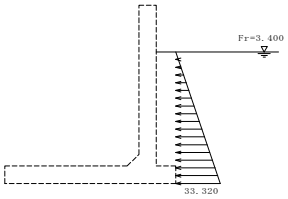
$$Y = \frac{h}{3}$$

Where、
γw : unit weiht of water (kN/m³), γw=9.800
h : water head (m)
Y : acting point (m)
[1]Normal with Buoyancy



	h (m)	P (kN)	Acting Point Y (m)
Rear	1.450	10.302	0.483

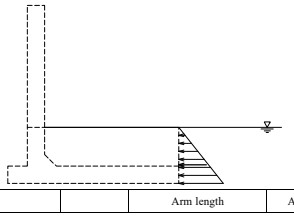
[3]Flood



	h (m)	P (kN)	Acting Point Y (m)
Front	3.400	56.644	1.133

2.2.5 Summary of Acting Forces

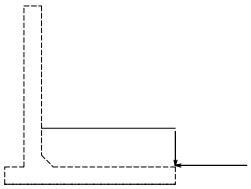
(1)Summary of Forces Acting On the Footing Front
[1]Normal



Item			Arm length	Angular Moment (kN.m.)

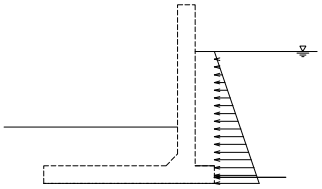
	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	160.061	0.000	1.971	0.000	315.500	0.000
Buoyancy	-57.624	0.000	2.366	0.000	-136.328	0.000
Rear Side Water Pressure	0.000	10.302	0.000	0.483	0.000	4.979
Earth Pressure	0.000	3.224	4.400	0.483	0.000	1.557
Total	102.437	13.526	———	———	179.172	6.537

[3]Seismic



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	160.061	32.012	1.971	1.180	315.500	37.770
Earth Pressure	3.995	8.306	4.400	0.483	17.578	4.012
Total	164.056	40.318	———	———	333.078	41.782

[3]Flood (With Buoyancy)



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	160.061	0.000	2.429	0.000	388.770	0.000
Buoyancy	-2.205	0.000	4.150	0.000	-9.151	0.000
Rear Side Water Pressure	0.000	56.644	0.000	1.133	0.000	64.197
Earth Pressure	0.000	0.350	4.400	0.150	0.000	0.053
Total	157.856	56.994	———	———	379.619	64.249

Load Condition (Water Level)	No (kN)	Ho (kN)	Mo (kN.m.)
Normal	102.437	13.526	172.635
Seismic	164.056	40.318	291.296
Flood	157.856	56.994	315.370

(2)Summary of Forces Acting At the Footing Center

Vertical Force : Nc = No (kN)
Horizontal Force : Hc = Ho (kN)
Turning Moment : Mc = No Bj/2.0 - Mo (kN.m.)

Here,

Footing Width in Earth Pressure Direction : Bj = 7.500 (m)

■Per Unit Width

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Normal	102.437	13.526	52.727
Seismic	164.056	40.318	69.628
Flood	157.856	56.994	31.914

■Per full width (5.000 m)

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Normal	512.187	67.631	263.633
Seismic	820.282	201.591	348.141
Flood	789.281	284.970	159.569

2.2.6 Stability Analysis Results

2.2.6.1 Stability against Overturning

(1)Calculation of Acting Point of Composited Force and Eccentricity

$$d = \frac{\Sigma Mr - \Sigma Mt}{\Sigma V}$$

Here,

d: Distance from the Toe of Bottom Slab to the Acting Point of Composited Force (m)
ΣMr: Resistive Moment of Toe of Bottom Slab (kN.m.)
ΣMt: Overturning Moment of Toe of Bottom Slab (kN.m.)
ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)

$$e = \frac{B}{2} - d$$

Here,

e: Eccentricity from the Center of Bottom Slab to the Acting Point of Composited Force (m);
B: Bottom Slab Width (m), B = 7.500

ea = B/n

Here,

ea: Allowable Eccentricity (m)
n: Safety Factor

Load Condition (Water Level)	Σ Mr (kN.m.)	Σ Mt (kN.m.)	ΣV (kN)	d (m)	e (m)		Ea (m)
Normal	179.172	6.537	102.437	1.685	0.515	≦	0.733
Seismic	333.078	41.782	164.056	1.776	0.424	≦	1.467
Flood	379.619	64.249	157.856	1.998	0.202	≦	1.467

2.2.6.2 Stability Against Sliding

$$F_s = \frac{\Sigma V \cdot \mu + C_B \cdot B + \alpha \cdot Pp}{\Sigma H}$$

Here,

ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)
ΣH: Total Horizontal Load in Lower Side of Bottom Slab (kN)
m.: Cohesion Between Bottom Slab and Supporting Ground, m = 0.577
C_B: Cohesion Between Bottom Slab And Supporting Ground (kN/m2), C_B = 0.000
B: Bottom Slab Width (m), B = 7.500
α: Effeective Rate of Passive Earth Pressure
Pp: Passive Earth Pressure

Load Condition (Water Level)	Vertical Load ΣV (kN)	Horizontal Load ΣH (kN)	Passive Earth Pressure Pp(kN)	Effective Rate	Safety Factor Fs		Required Safety Factor Fsa
Normal	102.437	13.526	—	—	3.787	≧	1.500

Seismic	164.056	40.318	—	—	2.035	≧ 1.200
Flood	157.856	56.994	54.221	0.500	1.861	≧ 1.200

2.2.6.3 Verification of Bearing

1)When the Acting Point of Composited Force is within the 1/3 of Bottom Slab Width (middle third) in the Center of the Bottom Slab.

$$q_1 = \frac{\Sigma V}{B} \cdot \left(1 + \frac{6e}{B}\right)$$

$$q_2 = \frac{\Sigma V}{B} \cdot \left(1 - \frac{6e}{B}\right)$$

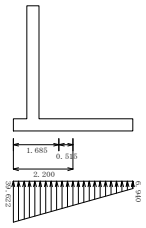
2)When the Acting Point of Composited Force is within the 2/3 of Bottom Slab Width in the Center of the Bottom Slab.

$$q_1 = \frac{2\Sigma V}{3 \cdot (B/2 - e)}$$

Here,

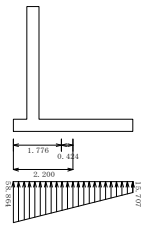
ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)
B: Bottom Slab Width (m), B = 7.500
e: Eccentricity (m)

[1]Normal (Without Buoyancy)



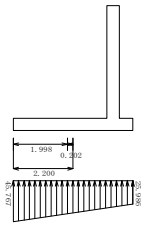
Subgrade Reaction Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2)		
		qmin	qmax	Allowance
4.400	Trapezoid	6.940	39.622 ≦	200.000

[2]Seismic (With Buoyancy)



Subgrade Reaction Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2)		
		qmin	qmax	Allowance
4.400	Trapezoid	15.707	58.864 ≦	300.000

[3]Flood (With Buoyancy)



Subgrade Reaction Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2)		
		qmin	qmax	Allowance
4.400	Trapezoid	25.986	45.979 ≦	300.000

2.3 Vertical Wall Design

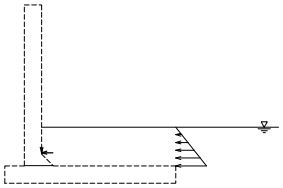
2.3.1 Checking Position

Distance from Base = 0.000 m

2.3.2 Calculation of Cross-Sectional Force

(Vertical forces are not summarized due to disregard of eccentric moments and axial forces)

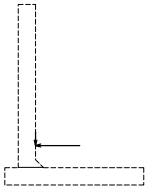
[1]Normal



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	46.856	0.000	-0.008	0.000	0.000
Hydrostatic on Rear Side	0.000	4.900	0.000	0.333	1.633
Earth Pressure	0.468	1.286	-0.225	0.333	0.428
Total	0.000	6.186	———	———	2.062

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

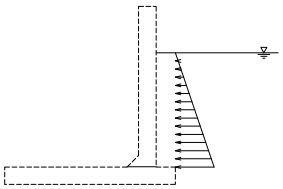
[2]Seismic



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	46.856	9.371	-0.008	2.029	19.010
Earth Pressure	1.111	4.148	-0.225	0.333	1.381
Total	0.000	13.519	———	———	20.391

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

[3]Flood



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	46.856	0.000	0.008	0.000	0.000
Hydrostatic on Rear Side	0.000	42.642	0.000	0.983	41.932
Total	0.000	42.642	———	———	41.932

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

2.3.3 Section Calculations (Allowable Stress Method)

(1)Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	9.0	D19	2.865	8.00	22.920
	2'	——	—	——	——	——
Back	1	9.0	D19	2.865	8.00	22.920
	2	——	—	——	——	——

Required Reinforcement in Tension Side 6.510 (cm2)

(2)Verification of Bending Stress

Calculation of the neutral axis

$$x^2+\frac{2\cdot n}{b}\left\{As\cdot(x-d)\right\}=0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c=\frac{M}{\frac{b\cdot x}{2}\cdot\left(\frac{h}{2}-\frac{x}{3}\right)+n\cdot As\cdot\frac{(x-d)\cdot(h/2-d)}{x}}$$

$$\sigma_s=n\cdot\sigma_c\cdot\frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	N (kN)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
				Calculated	Allowance	Calculated	Allowance
Normal	2.062	0.000	10.107	0.120 ≦	8.200	2.777 ≦	140.000
Seismic	20.391	0.000	10.107	1.192 ≦	10.906	27.472 ≦	186.200
Flood	41.932	0.000	10.107	2.450 ≦	11.010	56.493 ≦	186.200

(3)Verification of Shear Stress

$$\tau_m=\frac{S_h}{b\cdot d}\leqq\tau_{a1}$$

Here,

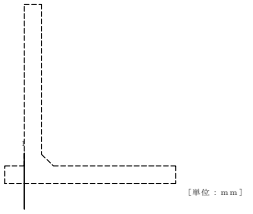
τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)		
			Calculated	Allowable τa1	Allowable τa2
Normal	6.186	36.000	0.017 ≦	0.360	0.360
Seismic	13.519	36.000	0.038 ≦	0.479	0.479
Flood	42.642	36.000	0.118 ≦	0.470	0.470

2.4 Design of Toe Slab

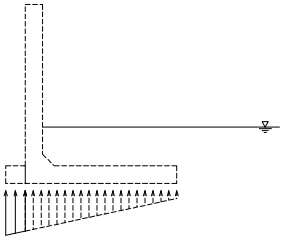
2.4.1 Checking Position

Distance from Base = 0.000 m



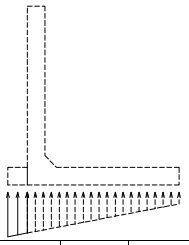
2.4.2 Calculation of Cross-Sectional Force

[1]Normal



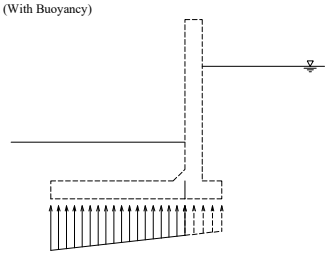
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-5.512	0.250	-1.378
Buoyancy	2.205	0.250	0.551
Subgrade Reaction	18.883	0.254	4.798
Total	15.575	———	3.971

[2]Seismic



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-5.512	0.250	-1.378
Subgrade Reaction	28.206	0.254	7.154
Total	22.693	———	5.776

[3]Flood (With Buoyancy)



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-103.834	1.721	-178.711
Subgrade Reaction	131.141	1.842	241.603
Total	27.307	———	62.892

2.4.3 Section Calculations (Allowable Stress Method)

(1)Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	9.0	D19	2.865	8.00	22.920
	2'	——	–	——	——	——
Back	1	9.0	D19	2.865	8.00	22.920
	2	——	–	——	——	——

Required Reinforcement in Tension Side 10.054 (cm2)

(2)Verification of Bending Stress

Calculation of the neutral axis

$$x^2+\frac{2\cdot n}{b}\left\{As\cdot(x-d)\right\}=0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c=\frac{M}{\frac{b\cdot x}{2}\cdot\left(\frac{h}{2}-\frac{x}{3}\right)+n\cdot As\cdot\frac{(x-d)\cdot(h/2-d)}{x}}$$

$$\sigma_s=n\cdot\sigma_c\cdot\frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
			Calculated	Allowance	Calculated	Allowance
Normal	3.971	10.107	0.232 ≦	8.200	5.350 ≦	140.000
Seismic	5.776	10.107	0.337 ≦	10.906	7.781 ≦	186.200
Flood	-2.515	10.107	0.147 ≦	11.010	3.389 ≦	186.200

(3)Verification of Shear Stress

$$\tau_m=\frac{S_h}{b\cdot d}\leqq\tau_{sa}$$

Here,

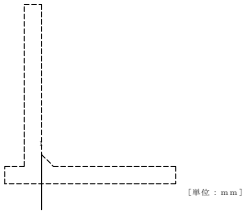
τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)	
			Calculated	Allowable τa
Normal	8.795	360.000	0.024 ≦	0.360
Seismic	12.784	360.000	0.036 ≦	0.479
Flood	10.247	360.000	0.028 ≦	0.470

2.5 Design of the Heel Slab

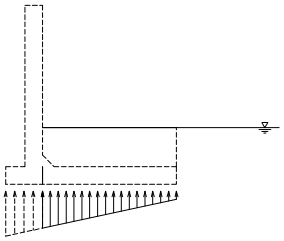
2.5.1 Checking Position

Distance from Base = 0.000 m



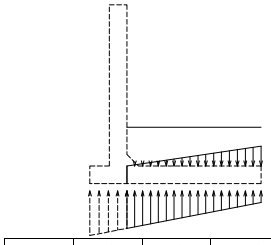
2.5.2 Calculation of Cross-Sectional Force

[1]Normal



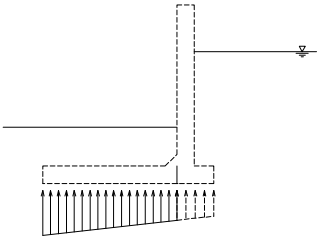
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	103.834	1.721	178.711
Buoyancy	-49.024	1.725	-84.567
Subgrade Reaction	-68.147	1.352	-92.137
Total	-13.338	———	2.007

[2]Seismic



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	103.834	1.721	178.711
Earth Pressure	3.995	2.300	9.189
Subgrade Reaction	-112.561	1.427	-160.604
Total	-4.733	———	27.295

[3]Flood



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-103.834	1.721	-178.711
Subgrade Reaction	131.141	1.842	241.603
Total	27.307	———	62.892

2.5.3 Section Calculations (Allowable Stress Method)

(1)Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	9.0	D19	2.865	8.00	22.920
	2'	—	–	——	—	——
Back	1	9.0	D19	2.865	8.00	22.920
	2	—	–	——	—	——

Required Reinforcement in Tension Side 10.054 (cm2)

(2)Verification of Bending Stress

Calculation of the neutral axis

$$x^2+\frac{2\cdot n}{b}\left\{As\cdot(x-d)\right\}=0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c=\frac{M}{\frac{b\cdot x}{2}\cdot\left(\frac{h}{2}-\frac{x}{3}\right)+n\cdot As\cdot\frac{(x-d)\cdot(h/2-d)}{x}}$$

$$\sigma_s=n\cdot\sigma_c\cdot\frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
			Calculated	Allowance	Calculated	Allowance
Normal	2.007	10.107	0.117 ≦	8.200	2.704 ≦	140.000
Seismic	20.391	10.107	1.192 ≦	10.906	27.472 ≦	186.200
Flood	62.892	10.107	3.675 ≦	11.010	84.732 ≦	186.200

(3)Verification of Shear Stress

$$\tau_m=\frac{S_h}{b\cdot d}\leqq\tau_{a1}$$

Here,

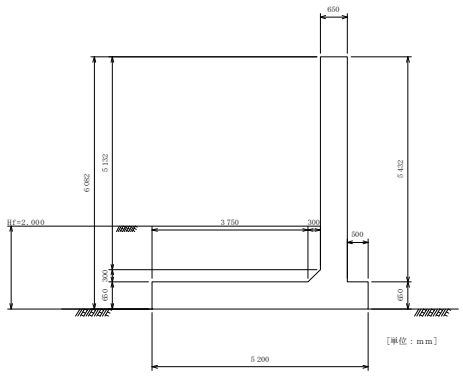
τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)	
			Calculated	Allowable τa2
Normal	13.338	360.000	0.037 ≦	0.360
Seismic	4.733	360.000	0.013 ≦	0.479
Flood	27.372	360.000	0.076 ≦	0.470

3 Invert T-shaped Wall, Right Bank Sta.10+040.00

3.1 Design Conditions

3.1.1 Geometry



Depth Width (Block Length) B = 5000 (mm)

3.1.2 Backfill and Embankment

(1)Rear Side Ground Shape



Level Difference Between Retaining Wall Crown And Ground Surface Start Point	(m)	0.000
Height Without Considering Earth Pressure Hr (in stability analysis) Hr	(m)	0.000

3.1.3 Material

[Concrete] Vertical wall (reinforced concrete) : σck = 20.0 (N/mm2)
Base concrete (reinforced concrete) : σck = 20.0 (N/mm2)

[Iron bar] Type: : Grade 275

[Soil] Backfill : sand and gravel
Foudation : sandy gravel

[Internal Fdiction] Backfill : 30 degrees

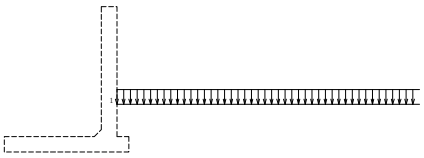
[Unit weight]
(kN/m3)

Body	24.500	
Water	9.800	
Soil	Wet weight	Saturated weight
River side	20.000	20.800
Land side	20.000	20.800

[Seismic Intensity] Body : 0.200
Foundation Riverside : 0.200
Foundation Landside : 0.200

3.1.4 Loads

[1]Normal



Item	Loading Position (m)	Loading Width (m)	Load Strength (kN/m2)		Study to Be Considered		
			From	End Side	Stability Analysis	Vertical Wall	Bottom Slab
1	0.000	infinity	10.000	10.000	○	○	×

[2]Seismic

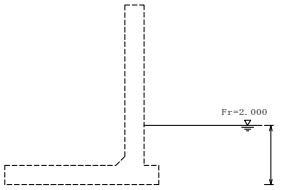


Item	Loading Position (m)	Loading Width (m)	Load Strength (kN/m2)		Study to Be Considered		
			From	End Side	Stability Analysis	Vertical Wall	Bottom Slab
1	0.000	infinity	5.000	5.000	○	○	×

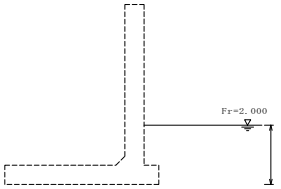
[2]Flood
Not concidered

3.1.5 Water Level

[1]Normal
■With Buoyancy : Water Leve in Front Side level Ff = 0.000 m, Water Level in Rear Side Fr = 2.000 m

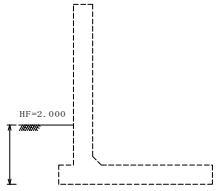


■Without Buoyancy : Water Leve in Front Side level Ff = 0.000 m, Water Level in Rear Side Fr = 2.000 m

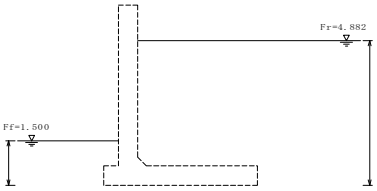


[2]Seidmic
Not Considered

[3]Flood
■With Buoyancy : Water Leve in Front Side level Ff = 1.500 m, Water Level in Rear Side Fr = 4.882 m



■Without Buoyancy : Water Leve in Front Side level Ff = 1.500 m, Water Level in Rear Side Fr = 4.882 m



3.1.6 Buoyancy

・Use the Water Level in Rear Side

3.1.7 Earth Pressure

・Earth Pressure Formulas: Trial Wedge

・Angle of Friction of Earth Pressure Acting Surface (Degrees)

Load Condition	Active Earth Pressure			Passive Earth Pressure
	In Case of Stability Analysis	In Case of Vertical Wall Design	Cut	
Normal Earth Pressure	0.000	23.333	———	———
Seismic Earth Pressure (Rear→Front)	30.303	17.500	———	0.000
Seismic Earth Pressure (Front→Rear)	0.000	23.333	———	0.000
Flood Earth Pressure	0.000	23.333	———	0.000

・ The virtual rear surface of earth pressure in the stability analysis is at the heel end (a line extended vertically from the heel)

・ Angle between the earth pressure acting surface and the vertical plane in stability analysis

0.000 (degrees)

・ Angle between the earth pressure working surface and the vertical plane when designing the vertical wall
Normal, Seismic 0.000 (degrees)
Flood 0.000 (degrees)

・The Design Horizontal Seismic Coefficient is applied to the inertia force during earthquakes when calculating the earth pressure below the water level.

・Passive Earth Pressure

Load Condition	Height of Acting	Effectivity
Seismic Condition (Rear → Front)	1.500	0.500
Seismic Condition (Front → Rear)	1.500	0.500
Flood	2.000	0.500

・Cohesion (kN/m2)

Load Condition	For Sliding Surfaces	For Cohesive Height	For Passive Earth Pressure
Normal Condition	0.000	0.000	———
Seismic Condition	0.000	0.000	0.000
Flood Condtion	0.000	0.000	0.000

・Consideration of Earth Pressure Different from Direction of Earthquake Motion

	Consideration I...	Effectivity
Stability Analysis	Normal Earth Pressure	0.500
Vertical Wall Design		0.500

3.1.8 Water Pressure

・Concept of Calculation of Hydrostatic Pressure

Load Condition	Rear Side	Front Side
Normal Condition	Considered	Considered
Seismic Condition	Considered	Considered
Flood Condition	Considered	Considered

・Consideration of Hydrostatic Pressure Different from the Direction of Earthquake Motion

Outside Water Level	Stability analysis	Considered
	Vertical Wall Design	Considered

・Consideration of Dynamic Water Pressure Calculation

Outside Water Level	Considered

3.1.9 Load Combination Case

No	Load Name	Comments
1	Normal	
2	Seismic	Seismic (Rear → Front)
3	Seismic	Seismic (Front → Rear)
4	Flood	Flood

	Load Name	1	2	3	4
Soil	Front Soil 1	○	○	○	
	Front Soil 2				○
Water Level	Buoyancy 1	○			
	Buoyancy 2		○	○	
	Buoyancy 3				○
Load	Load 1	○			○
	Load 2		○	○	
Active Earth Pressure	Not Considered				
	Normal Earth Pressure	○			○
	Seismic Earth Pressure		○	○	
Passive Earth Pressure	Passive Earth Pressure 1		○	○	
	Passive Earth Pressure 2				○

3.1.10 Foundation Conditions

3.1.10.1 Data For Calculating Allowable Shear Resistance

Bottom Slab Width Used for Analysis	All	Width
Cohesion Between Foundation Bottom Surface And Ground C_B (kN/m2)		0.000
Friction Coefficient Between Foundation Bottom Surface and Ground tan φ_B		0.500

3.1.11 Allowable Values For Stability Analysis And Allowable Stresses of Members

3.1.11.1 Allowance in Stability Analysis

Load Condition	Allowable Eccentricity eB/B (m)	Safety Factor for Overturning	Safety Factor for Sliding	Allowable Subgrade Reaction Intensity (kN/m2)
Normal	1/6	1.500	1.500	200.000
Seismic, Flood	1/3	1.200	1.200	300.000

3.1.11.2 Allowable Stress of the Member

(1)Reinforced Concrete Member

1) Vertical Wall (General Member)

(N/mm2)

Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic, Flood	1.33	10.906	186.200	0.479	0.479

2) Bottom Slab (General Member)

(N/mm2)

Load Condition	Premium Coefficient	Compressive Stress of Concrete σca	Tensile Stress of Rebar σsa	Shear Stress Intensity τa1	τa2
Normal	1.00	8.200	140.000	0.360	0.360
Seismic, Flood	1.33	10.906	186.200	0.479	0.479

Here,

τa1: Shear Stress When Shear Force is Applied Only by Concrete

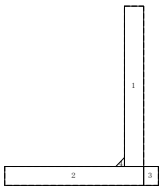
τa2: Shear Stress when Jointly Bearing with Oblique Tensile Reinforcement

3.2 Stability Analysis

3.2.1 Block Data Not Considering Water Level

(1)Body Weight

1)Block Diversion



2)Weight and Center of Gravity

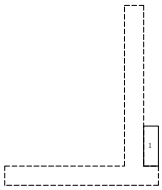
Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	0.650× 5.432× 1.000	3.531	4.375	3.366	15.447	11.885	
2	4.700× 0.650× 1.000	3.055	2.350	0.325	7.179	0.993	
3	0.500× 0.650× 1.000	0.325	4.950	0.325	1.609	0.106	
4	1/2× 0.300× 0.300× 1.000	0.045	3.950	0.750	0.178	0.034	
Σ		6.956	——	——	24.413	13.017	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 24.413／ 6.956 ＝ 3.510 (m)

YG = Σ (Vi Yi)/ΣVi = 13.017／ 6.956 ＝ 1.871 (m)

(2)Soil in Rear Side

1)Block Diversion



2)Volume and Center of Gravity

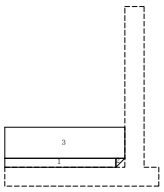
Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	0.500× 1.350× 1.000	0.675	4.950	1.325	3.341	0.894	
Σ		0.675	——	——	3.341	0.894	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 3.341／ 0.675 ＝ 4.950 (m)

YG = Σ (Vi Yi)/ΣVi = 0.894／ 0.675 ＝ 1.325 (m)

(3)Soil in Front Side

1)Block Diversion



2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	3.750× 0.300× 1.000	1.125	1.875	0.800	2.109	0.900	
2	1/2× 0.300× 0.300× 1.000	0.045	3.850	0.850	0.173	0.038	
3	4.050× 1.050× 1.000	4.253	2.025	1.475	8.611	6.272	
Σ		5.423	——	——	10.894	7.211	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 10.894／ 5.423 ＝ 2.009 (m)

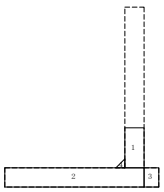
YG = Σ (Vi Yi)/ΣVi = 7.211／ 5.423 ＝ 1.330 (m)

3.2.2 Block Data Considering Water Level

(1)Body Weight

[1]Normal (With Buoyancy 2)

1)Block Diversion



2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	0.650× 1.350× 1.000	0.877	4.375	1.325	3.839	1.163	
2	4.700× 0.650× 1.000	3.055	2.350	0.325	7.179	0.993	
3	0.500× 0.650× 1.000	0.325	4.950	0.325	1.609	0.106	
4	1/2× 0.300× 0.300× 1.000	0.045	3.950	0.750	0.178	0.034	
Σ		4.303	——	——	12.805	2.295	

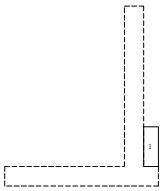
Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 12.805／ 4.303 ＝ 2.976 (m)

YG = Σ (Vi Yi)/ΣVi = 2.295／ 4.303 ＝ 0.533 (m)

(2)Soil in Rear Side

[1]Normal (With Buoyancy 2)

1)Block Diversion



2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	0.500× 1.350× 1.000	0.675	4.950	1.325	3.341	0.894	
Σ		0.675	——	——	3.341	0.894	

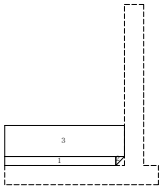
Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 3.341／ 0.675 ＝ 4.950 (m)

YG = Σ (Vi Yi)/ΣVi = 0.894／ 0.675 ＝ 1.325 (m)

(3)Soil in Front Side

[1]Normal (With Buoyancy 2)

1)Block Diversion



2)Volume and Center of Gravity

Number	Equation Width x Height x Depth	Volume Vi (m3)	Center of Gravity Position (m) Xi	Yi	Vi/Xi	Vi Yi	Remarks
1	3.750× 0.300× 1.000	1.125	1.875	0.800	2.109	0.900	
2	1/2× 0.300× 0.300× 1.000	0.045	3.850	0.850	0.173	0.038	
3	4.050× 1.050× 1.000	4.253	2.025	1.475	8.611	6.272	
Σ		5.423	——	——	10.894	7.211	

Center of Gravity Position XG = Σ (Vi/Xi)/ΣVi = 10.894／ 5.423 ＝ 2.009 (m)

YG = Σ (Vi Yi)/ΣVi = 7.211／ 5.423 ＝ 1.330 (m)

3.2.3 Body Weight, Weight of Soil, Arbitrary Load, Vertical Force by Buoyancy, Horizontal Force

(1)Working Force Due to Body Weight

[1]Normal

Position	Vertical Force W = γ ・ V (kN)	Acting Position X (m)
Body(Reinforced)	24.500 × 6.956 ＝ 170.417	3.510
Soil (Rear Side)	20.000 × 0.675 ＝ 13.500	4.950
Soil (Front Side)	20.000 × 5.423 ＝ 108.450	2.009
Total	292.367	3.020

[2]Seismic 1

Position	Vertical Force W = γ ・ V (kN)	Acting Position X (m)
Body(Reinforced)	24.500 × 6.956 ＝ 170.417	3.510
Soil (Rear Side)	20.000 × 0.675 ＝ 13.500	4.950
Soil (Front Side)	20.000 × 5.423 ＝ 108.450	2.009
Total	292.367	3.020

Position	Horizontal Load H = W kh (kN)	Acting Position Y (m)
Body(Reinforced)	170.417 × 0.20 ＝ 34.083	1.871
Soil (Rear Side)	13.500 × 0.20 ＝ 2.700	1.325
Total	36.783	1.831

[2]Seismic 2

Position	Vertical Force W = γ ・ V (kN)	Acting Position X (m)
Body(Reinforced)	24.500 × 6.956 ＝ 170.417	3.510
Soil (Rear Side)	20.000 × 0.675 ＝ 13.500	4.950
Total	183.917	3.615

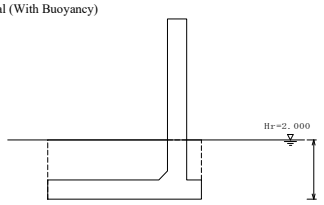
Position	Horizontal Load H = W kh (kN)	Acting Position Y (m)
Body(Reinforced)	170.417 × 0.20 ＝ 34.083	1.871
Total	-34.083	1.871

[3]Flood

Position	Vertical Force W = γ ・ V (kN)	Acting Position X (m)
Body(Reinforced)	24.500 × 6.956 ＝ 170.417	1.690
Soil (Rear Side)	20.000 × 5.423 ＝ 108.450	3.191
Soil (Front Side)	20.000 × 0.675 ＝ 13.500	0.250
Total	292.367	2.180

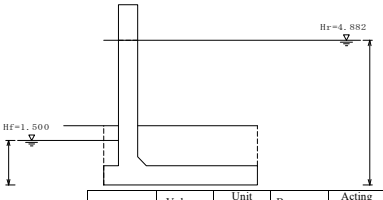
(2)Acting Force by Weight of Soil And Buoyancy

[1]Normal (With Buoyancy)



Position	Volume V (m3)	Unit Weight γ (kN/m3)	Buoyancy Fi (kN)	Acting Position Xi (m)	Fi/Xi
Body	4.303	9.800	42.165	2.976	125.487
Soil (Rear Side)	0.675	9.800	6.615	4.950	32.744
Soil (Front Side)	5.423	9.800	53.140	2.009	106.761
Total	——	——	101.920	——	264.992

[3]Flood (With Buoyancy)



Position	Volume V (m3)	Unit Weight γ (kN/m3)	Buoyancy Fi (kN)	Acting Position Xi (m)	Fi/Xi
Body	6.176	9.800	60.523	1.800	108.914
Soil (Front Side)	5.423	9.800	53.140	3.191	169.570
Soil (Rear Side)	0.675	9.800	6.615	0.250	1.654
Total	——	——	120.278	——	280.138

3.2.4 Load on the Surface

Vertical Force

$$N = \frac{1}{2} \cdot (q1+q2) \cdot L$$

Horizontal Load

$$H = N \cdot kh$$

Here,

q : Load Intensity

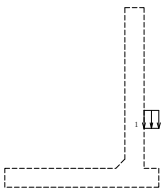
L : Loading Length

kh : Design Horizontal Seismic Coefficient, kh = 0.200 (Medium)

X : Distance from the Toe to the Acting Position of Composited Force

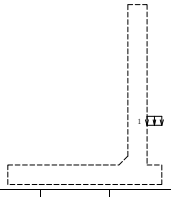
Y : Distance from the Lower Surface of the Bottom Slab to the Acting Position of Composited Force

[1]Normal



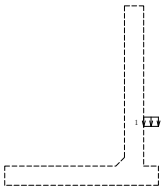
Item	q1 (kN/m2)	q2 (kN/m2)	L (m)	Vertical Force N (kN)	Horizontal Load H (kN)	Acting Position X (m)	Acting Position Y (m)
1	10.000	10.000	0.500	5.000	———	4.950	———

[2]Seismic 1



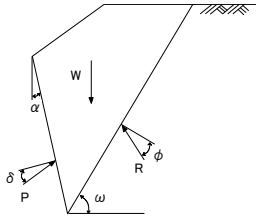
Item	q1 (kN/m2)	q2 (kN/m2)	L (m)	Vertical Force N (kN)	Horizontal Load H (kN)	Acting Position X (m)	Acting Position Y (m)
1	5.000	5.000	0.500	2.500	0.500	4.950	———

[3]Seismic 2



Item	q1 (kN/m2)	q2 (kN/m2)	L (m)	Vertical Force N (kN)	Horizontal Load H (kN)	Acting Position X (m)	Acting Position Y (m)
1	5.000	5.000	0.500	2.500	———	4.950	———

3.2.5 Earth Pressure and Water Pressure



[1]Normal (With Buoyancy 1), Normal Without Buoyancy 1
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 2.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 2.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
61.00	0.000	11.308	11.086	22.394	10.922
62.00	0.000	10.847	10.634	21.481	10.945

63.00	0.000	10.394	10.191	20.585	10.945

The maximum earth pressure is determined by the following equation:
when ω = 62.00 ° P = 10.945 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{21.481 \times \sin(62.00^\circ - 35.00^\circ)}{\cos(62.00^\circ - 35.00^\circ - 0.000^\circ - 0.000^\circ)}$$

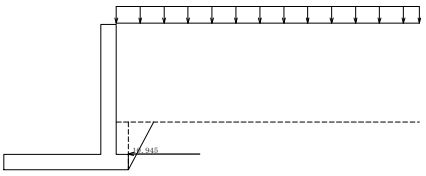
= 10.945 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 10.945×cos(0.000°+ 0.000°) = 10.945 kN
Vertical Component
Pv = P · sin (α + δ) = 10.945×sin(0.000°+ 0.000°) = 0.000 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{2.000}{3} = 0.667 \text{ m}$$

x = xp-Ho · tan α = 5.200−0.667×tan0.000°= 5.200 m
y = yp + Ho =0.000+0.667 = 0.667 m

・Earth Pressure Diagram



[2]Normal (Without Buoyancy)
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 2.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 2.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
61.00	22.172	0.000	11.086	33.258	16.221
62.00	21.268	0.000	10.634	31.902	16.255
63.00	20.381	0.000	10.191	30.572	16.255

The maximum earth pressure is determined by the following equation:
when ω = 62.00 ° P = 16.255 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{31.902 \times \sin(62.00^\circ - 35.00^\circ)}{\cos(62.00^\circ - 35.00^\circ - 0.000^\circ - 0.000^\circ)}$$

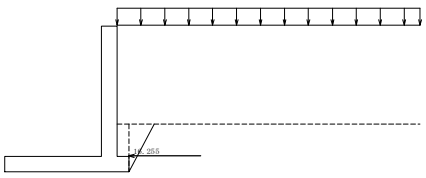
= 16.255 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 16.255×cos(0.000°+ 0.000°) = 16.255 kN
Vertical Component
Pv = P · sin (α + δ) = 16.255×sin(0.000°+ 0.000°) = 0.000 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{2.000}{3} = 0.667 \text{ m}$$

x = xp-Ho · tan α = 5.200−0.667×tan0.000°= 5.200 m
y = yp + Ho =0.000+0.667 = 0.667 m

・Earth Pressure Diagram



[3]Seismic 1
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 2.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °

Angle between Ground Surface and Horizontal Plane β = 0.000 °
Combined angle during earthquake θ = $\tan^{-1}$kh = $\tan^{-1}$0.20 = 11.310°
Wall Friction Angle

$$\delta = \tan^{-1}\frac{\sin\phi \cdot \sin(\theta + \Delta - \beta)}{1 - \sin\phi \cdot \cos(\theta + \Delta - \beta)}$$

$$= \tan^{-1}\frac{\sin 35.00^\circ \times \sin(11.310^\circ + 19.994^\circ - 0.000^\circ)}{1 - \sin 35.00^\circ \times \cos(11.310^\circ + 19.994^\circ - 0.000^\circ)}$$

= 30.303°

$\sin\phi$ sin35.00

Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
46.00	38.628	0.000	9.657	48.285	19.806
47.00	37.301	0.000	9.325	46.626	19.818
48.00	36.016	0.000	9.004	45.020	19.796

The maximum earth pressure is determined by the following equation:
when ω = 47.00 ° P = 19.818 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$= \frac{46.626 / \cos 11.310^\circ \times \sin(47.00^\circ - 35.00^\circ + 11.310^\circ)}{\cos(47.00^\circ - 35.00^\circ - 0.000^\circ - 30.303^\circ)}$$

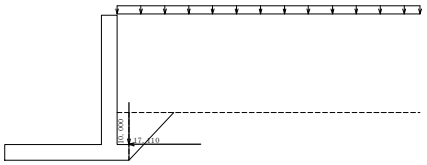
= 19.818 kN

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 19.818×cos(0.000°+30.303°) = 17.110 kN
Vertical Component
Pv = P · sin (α + δ) = 19.818×sin(0.000°+30.303°) = 10.000 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{2.000}{3} = 0.667 \text{ m}$$

x = xp-Ho · tan α = 5.200−0.667×tan0.000°= 5.200 m
y = yp + Ho =0.000+0.667 = 0.667 m

・Earth Pressure Diagram



[4]Seismic 2
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 2.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = β = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °

Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 0.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
61.00	22.172	0.000	5.543	27.715	6.759
62.00	21.268	0.000	5.317	26.585	6.773
63.00	20.381	0.000	5.095	25.476	6.773

The maximum earth pressure is determined by the following equation:
when ω = 62.00 ° P = 6.773 kN

Earth Pressure

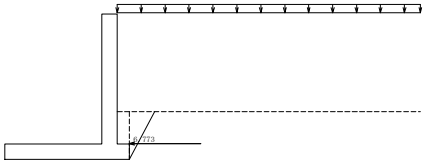
$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$
$$= \frac{26.585 \times \sin(62.00^\circ - 35.00^\circ)}{\cos(62.00^\circ - 35.00^\circ - 0.000^\circ - 0.000^\circ)} \times 0.500$$
$$= 6.773 \text{ kN}$$

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 6.773×cos(0.000°+ 0.000°) = 6.773 kN
Vertical Component
Pv = P · sin (α + δ) = 6.773×sin(0.000°+ 0.000°) = 0.000 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{2.000}{3} = 0.667 \text{ m}$$

x = xp-Ho · tan α = 5.200−0.667×tan0.000°= 5.200 m
y = yp + Ho =0.000+0.667 = 0.667 m

・Earth Pressure Diagram



[4]Normal (With Buoyancy)
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 2.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 2.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
61.00	0.000	11.308	0.000	11.308	5.515
62.00	0.000	10.847	0.000	10.847	5.527
63.00	0.000	10.394	0.000	10.394	5.527

The maximum earth pressure is determined by the following equation:
when ω = 62.00 ° P = 5.527 kN

Earth Pressure

$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$
$$= \frac{10.847 \times \sin(62.00^\circ - 35.00^\circ)}{\cos(62.00^\circ - 35.00^\circ - 0.000^\circ - 0.000^\circ)}$$
$$= 5.527 \text{ kN}$$

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.

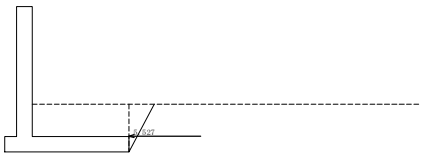
Horizontal Component
Ph = P · cos (α + δ) = 5.527×cos(0.000°+ 0.000°) = 5.527 kN
Vertical Component
Pv = P · sin (α + δ) = 5.527×sin(0.000°+ 0.000°) = 0.000 kN

Acting Position

$$Ho = \frac{H}{3} = \frac{2.000}{3} = 0.667 \text{ m}$$

x = xp-Ho · tan α = 5.200−0.667×tan0.000°= 5.200 m
y = yp + Ho =0.000+0.667 = 0.667 m

・Earth Pressure Diagram



[5]Flood Without Buoyancy
The earth pressure is obtained by the trial wedge method.
Position of Virtual Rear Surface (Distance from Toe) xp = 5.200 m
yp = 0.000 m
Height of Virtual Rear Surface H = 2.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °
Wall Friction Angle δ = 0.000 °
Range of Slip Angle Change ωi = 10.00 ° ~ 80.00 °
Soil Weight (W) against Slip Angle (ω), Earth Pressure (P)
Water Level hw = 2.000 m

Slip Angle ω (°)	Weight of Soil W (kN)				Earth Pressure P (kN)
	Above Water Level	Below Water Level	Vertical Load	Total	
61.00	22.172	0.000	0.000	22.172	10.814
62.00	21.268	0.000	0.000	21.268	10.837
63.00	20.381	0.000	0.000	20.381	10.837

The maximum earth pressure is determined by the following equation:
when ω = 62.00 ° P = 10.837 kN

Earth Pressure

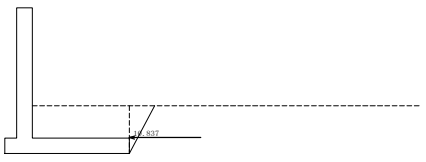
$$P = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$
$$= \frac{21.268 \times \sin(62.00^\circ - 35.00^\circ)}{\cos(62.00^\circ - 35.00^\circ - 0.000^\circ - 0.000^\circ)}$$
$$= 10.837 \text{ kN}$$

The horizontal component, vertical component, and acting position of earth pressure at this time are as follows.
Horizontal Component
Ph = P · cos (α + δ) = 10.837×cos(0.000°+ 0.000°) = 10.837 kN
Vertical Component
Pv = P · sin (α + δ) = 10.837×sin(0.000°+ 0.000°) = 0.000 kN
Acting Position

$$Ho = \frac{H}{3} = \frac{2.000}{3} = 0.667 \text{ m}$$

x = xp-Ho · tan α = 5.200−0.667×tan0.000°= 5.200 m
y = yp + Ho =0.000+0.667 = 0.667 m

・Earth Pressure Diagram



Passive earth Pressure
(This pressure is considered for the stability against Sliding)

[2]Seismic 1
The earth pressure is obtained by the Mononobe ad Okabe method.
Height of the ground surface H = 1.500 m
Height above water surface H1 = 1.500 m
Height below water surface H2 = 0.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane A = 0.000 °
Unit Weight of Soil γs = 20.000 kN/m3
Internal Friction Angle of Soil φ = 35.000 °
Angle between Ground Surface and Horizontal Plane β = 0.000 °

Combined angle during earthquake below water surface
θ = $\tan^{-1}$kh = $\tan^{-1}$0.20 = 11.310 °

Coefficient of passive earth pressure

$$K = \frac{\cos^2(\phi+\alpha-\theta)}{\cos\theta\cdot\cos^2\alpha\cdot\cos(\alpha-\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\alpha-\delta-\theta)\cdot\cos(\alpha-\beta)}}\right]^2}$$

$$= \frac{\cos^2(35.00^\circ+0.000^\circ-11.310^\circ)}{\cos 11.310^\circ\cdot\cos^2 0.000^\circ\cdot\cos(0.000^\circ-0.000^\circ-11.310^\circ)} \times \frac{1}{\left[1-\sqrt{\frac{\sin(35.00^\circ+0.000^\circ)\cdot\sin(35.00^\circ+0.000^\circ-11.310^\circ)}{\cos(0.000^\circ-0.000^\circ-11.310^\circ)\cdot\cos(0.000^\circ-0.000^\circ)}}\right]^2}$$

$$= 3.2855$$

Notod that when $\varphi+\beta-\theta<0$,it is assumed $\sin(\varphi+\beta-\theta) = 0$

Earth pressure at the upper edge

$p1 = q\cdot K = 0.000\times 3.2855 = 0.000\ \mathrm{kN/m^2}$

Earth pressure at the water surface

$p2 = K\cdot\gamma s\cdot H1+p1$

$= 3.2855\times 20.000\times 1.500+0.000$

$= 98.565\ \mathrm{kN/m^2}$

Earth pressure at the bottom

$p3 = p2 = 98.565\ \mathrm{kN/m^2}$

Earth pressure above water surface

$P1 = \frac{1}{2}\cdot(p1+p2)\cdot H1 = \frac{1}{2}\times(0.000+98.565)\times 1.500 = 73.924\ \mathrm{kN}$

Earth pressure below water surface

$P2 = \frac{1}{2}\cdot(p2+p3)\cdot H2 = \frac{1}{2}\times(98.565+98.565)\times 0.000 = 0.000\ \mathrm{kN}$

Total Earth pressure

$P = P1+P2 = 73.924+0.000 = 73.924\ \mathrm{kN}$

Total Earth pressure at horizontal direction

$Ph = P\cdot\cos(\alpha-\delta) = 73.924\times\cos(0.000^\circ-0.000^\circ) = 73.924\ \mathrm{kN}$

[3]Seismic 1

The earth pressure is obtained by the Mononobe ad Okabe method.

Height of the ground surface	H =	1.500 m
Height above water surface	H1 =	1.500 m
Height below water surface	H2 =	0.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane	A =	0.000 °
Unit Weight of Soil	γs =	20.000 kN/m3
Internal Friction Angle of Soil	φ =	35.000 °
Angle between Ground Surface and Horizontal Plane	β =	0.000 °

Combined angle during earthquake below water surface

$\theta = \tan^{-1}kh = \tan^{-1}0.20 = 11.310^\circ$

Coefficient of passive earth pressure

$$K = \frac{\cos^2(\phi+\alpha-\theta)}{\cos\theta\cdot\cos^2\alpha\cdot\cos(\alpha-\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\alpha-\delta-\theta)\cdot\cos(\alpha-\beta)}}\right]^2}$$

$$= \frac{\cos^2(35.00^\circ+0.000^\circ-11.310^\circ)}{\cos 11.310^\circ\cdot\cos^2 0.000^\circ\cdot\cos(0.000^\circ-0.000^\circ-11.310^\circ)} \times \frac{1}{\left[1-\sqrt{\frac{\sin(35.00^\circ+0.000^\circ)\cdot\sin(35.00^\circ+0.000^\circ-11.310^\circ)}{\cos(0.000^\circ-0.000^\circ-11.310^\circ)\cdot\cos(0.000^\circ-0.000^\circ)}}\right]^2}$$

$$= 3.2855$$

Notod that when $\varphi+\beta-\theta<0$,it is assumed $\sin(\varphi+\beta-\theta) = 0$

Earth pressure at the upper edge

$p1 = q\cdot K = 0.000\times 3.2855 = 0.000\ \mathrm{kN/m^2}$

Earth pressure at the water surface

$p2 = K\cdot\gamma s\cdot H1+p1$

$= 3.2855\times 20.000\times 1.500+0.000$

$= 98.565\ \mathrm{kN/m^2}$

Earth pressure at the bottom

$p3 = p2 = 98.565\ \mathrm{kN/m^2}$

Earth pressure above water surface

$P1 = \frac{1}{2}\cdot(p1+p2)\cdot H1 = \frac{1}{2}\times(0.000+98.565)\times 1.500 = 73.924\ \mathrm{kN}$

Earth pressure below water surface

$P2 = \frac{1}{2}\cdot(p2+p3)\cdot H2 = \frac{1}{2}\times(98.565+98.565)\times 0.000 = 0.000\ \mathrm{kN}$

Total Earth pressure

$P = P1+P2 = 73.924+0.000 = 73.924\ \mathrm{kN}$

Total Earth pressure at horizontal direction

$Ph = P\cdot\cos(\alpha-\delta) = 73.924\times\cos(0.000^\circ-0.000^\circ) = 73.924\ \mathrm{kN}$

[3]Flood with bouyancy

The earth pressure is obtained by the Mononobe ad Okabe method.

Height of the ground surface	H =	2.000 m
Height above water surface	H1 =	0.500 m
Height below water surface	H2 =	0.000 m
Angle between the Earth Pressure Acting Surface and the Vertical Plane	A =	0.000 °
Unit Weight of Soil	γs =	20.000 kN/m3
Internal Friction Angle of Soil	φ =	35.000 °
Angle between Ground Surface and Horizontal Plane	β =	0.000 °

Coefficient of passive earth pressure

$$K = \frac{\cos^2(\phi+\alpha)}{\cos^2\alpha\cdot\cos(\alpha-\delta)\cdot\left[1-\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi+\beta)}{\cos(\alpha-\delta)\cdot\cos(\alpha-\beta)}}\right]^2}$$

$$= \frac{\cos^2(35.00^\circ+0.000^\circ)}{\cos^2 0.000^\circ\cdot\cos(0.000^\circ-0.000^\circ)} \times \frac{1}{\left[1-\sqrt{\frac{\sin(35.00^\circ+0.000^\circ)\cdot\sin(35.00^\circ+0.000^\circ)}{\cos(0.000^\circ-0.000^\circ)\cdot\cos(0.000^\circ-0.000^\circ)}}\right]^2}$$

$$= 3.6902$$

Earth pressure at the upper edge

$p1 = q\cdot K = 5.000\times 3.6902 = 18.451\ \mathrm{kN/m^2}$

Earth pressure at the water surface

$p2 = K\cdot\gamma s\cdot H1+p1$

$= 3.6902\times 20.000\times 0.500+18.451$

$= 55.353\ \mathrm{kN/m^2}$

Earth pressure at the bottom

$p3 = K\cdot(\gamma s-\gamma w')\cdot H2+p2$

$= 3.6902\times(20.000-9.800)\times 1.500+55.353$

$= 111.813\ \mathrm{kN/m^2}$

Earth pressure above water surface

$P1 = \frac{1}{2}\cdot(p1+p2)\cdot H1 = \frac{1}{2}\times(18.451+55.353)\times 0.500 = 18.451\ \mathrm{kN}$

Earth pressure below water surface

$P2 = \frac{1}{2}\cdot(p2+p3)\cdot H2 = \frac{1}{2}\times(55.353+111.813)\times 1.500 = 125.375\ \mathrm{kN}$

Total Earth pressure

$P = P1+P2 = 18.451+125.375 = 143.826\ \mathrm{kN}$

Total Earth pressure at horizontal direction

$Ph = P\cdot\cos(\alpha-\delta) = 143.826\times\cos(0.000^\circ-0.000^\circ) = 143.826\ \mathrm{kN}$

Hydrostatic Pressure

$$P = \frac{1}{2}\cdot\gamma w\cdot h^2$$

$$Y = \frac{h}{3}$$

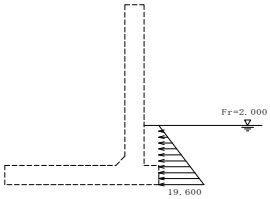
Where、

γw : unit weiht of water (kN/m^3), γw=9.800

h : water head (m)

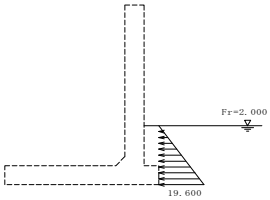
Y : acting point (m)

[1]Normal with Buoyancy



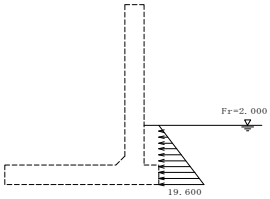
	h (m)	P (kN)	Acting Point Y (m)
Rear	2.000	19.600	0.667

[2]Normal without Buoyancy



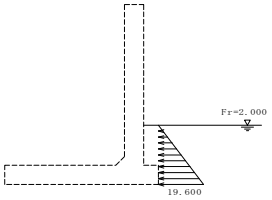
	h (m)	P (kN)	Acting Point Y (m)
Rear	2.000	19.600	0.667

[3]Flood with Buoyancy



	h (m)	P (kN)	Acting Point Y (m)
Front	1.500	-11.025	0.500
Rear	4.882	116.786	1.627

[4]Flood without Buoyancy

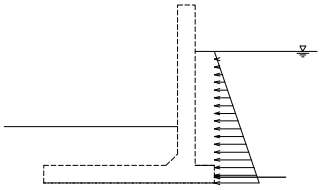


	h (m)	P (kN)	Acting Point Y (m)
Front	1.500	-11.025	0.500
Rear	4.882	116.786	1.627

3.2.6 Summary of Acting Forces

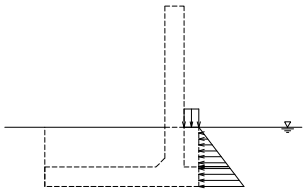
(1)Summary of Forces Acting On the Footing Front

[1]Normal (With Buoyancy)



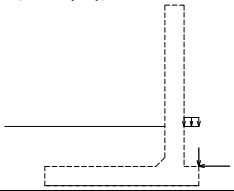
Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	292.367	0.000	3.020	0.000	882.822	0.000
Buoyancy	-101.920	0.000	2.600	0.000	-264.992	0.000
Load on Surface	5.000	0.000	4.950	0.000	24.750	0.000
Rear Side Water Pressure	0.000	19.600	0.000	0.667	0.000	13.067
Earth Pressure	0.000	10.945	5.200	0.667	0.000	7.300
Total	195.447	30.545	———	———	642.580	20.367

[2]Normal (Without Buoyancy)



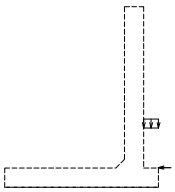
Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	292.367	0.000	3.020	0.000	882.822	0.000
Load on Surface	5.000	0.000	4.950	0.000	24.750	0.000
Rear Side Water Pressure	0.000	19.600	0.000	0.667	0.000	13.067
Earth Pressure	0.000	16.255	5.200	0.667	0.000	10.842
Total	297.367	35.855	———	———	907.572	23.909

[3]Seismic 1 (With Buoyancy)



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	292.367	36.783	3.020	1.831	882.822	67.360
Load on Surface	2.500	0.500	4.950	2.000	12.375	1.000
Earth Pressure	10.000	17.110	5.200	0.667	52.000	11.412
Total	304.867	54.393	———	———	947.197	79.773

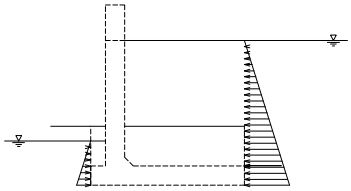
[4]Seismic 2 (With Buoyancy)



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	183.917	-34.083	3.615	1.871	664.944	-63.783
Load on Surface	2.500	0.000	4.950	0.000	12.375	0.000
Earth Pressure	0.000	6.773	5.200	0.667	0.000	4.518
Total	186.417	-27.310	———	———	677.319	-59.265

Load Condition (Water Level)	No (kN)	Ho (kN)	Mo (kN.m.)
Normal (With Buoyancy)	195.447	30.545	622.213
Normal (Without Buoyancy)	297.367	35.855	883.664
Seismic 1 (With Buoyancy)	304.867	54.393	867.425
Seismic 1 (Without Buoyancy)	304.867	54.393	867.425
Seismic 2 (With Buoyancy)	186.417	-27.310	736.584
Seismic 2 (Without Buoyancy)	186.417	-27.310	736.584

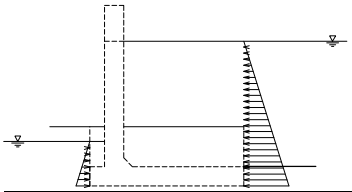
[5]Flood (With Buoyancy)



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	292.367	0.000	2.180	0.000	637.487	0.000
Buoyancy	-120.278	0.000	2.329	0.000	-280.138	0.000
Load on Surface	0.000	116.786	0.000	1.627	0.000	190.050
Rear Side Water Pressure	0.000	-11.025	0.000	0.500	0.000	-5.513
Earth Pressure	0.000	5.527	5.200	0.667	0.000	3.687

Total	172.089	111.288	———	———	357.349	188.224

[5] Flood (Without Buoyancy)



Item	Vertical Force Ni (kN)	Horizontal Load Hi (kN)	Arm length		Angular Moment (kN.m.)	
			Xi (m)	Yi (m)	Mxi = Ni, Xi	Myi = Hi Yi
Body Weight	292.367	0.000	2.180	0.000	637.487	0.000
Front Side Water Pressure	0.000	116.786	0.000	1.627	0.000	190.050
Rear Side Water Pressure	0.000	-11.025	0.000	0.500	0.000	-5.513
Earth Pressure	0.000	10.837	5.200	0.667	0.000	7.228
Total	292.367	116.598	———	———	637.487	191.766

Load Condition (Water Level)	No (kN)	Ho (kN)	Mo (kN.m.)
Flood (With Buoyancy)	172.089	111.288	169.125
Flood (Without Buoyancy)	292.367	116.598	445.721

(2)Summary of Forces Acting At the Footing Center

Vertical Force : Nc = No (kN)
Horizontal Force : Hc = Ho (kN)
Turning Moment : Mc = No Bj/2.0 - Mo (kN.m.)

Here,

Footing Width in Earth Pressure Direction : Bj = 7.500 (m)

■Per Unit Width

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Normal (With Buoyancy)	297.367	35.855	-110.509
Seismic 1 (With Buoyancy)	304.867	54.393	-74.770
Seismic 1 (Without Buoyancy)	304.867	54.393	-74.770
Seismic 2 (With Buoyancy)	186.417	-27.310	-251.899
Seismic 2 (Without Buoyancy)	186.417	-27.310	-251.899
Flood (With Buoyancy)	172.089	111.288	278.306
Flood (Without Buoyancy)	292.367	116.598	314.434

■Per full width (9.000 m)

Load Condition (Water Level)	Nc (kN)	Hc (kN)	Mc (kN.m.)
Normal (With Buoyancy)	977.235	152.725	-570.254
Normal (Without Buoyancy)	1486.835	179.275	-552.546
Seismic 1 (With Buoyancy)	1524.335	271.967	-373.850
Seismic 1 (Without Buoyancy)	1524.335	271.967	-373.850
Seismic 2 (With Buoyancy)	932.085	-136.552	-1259.497
Seismic 2 (Without Buoyancy)	932.085	-136.552	-1259.497
Flood (With Buoyancy)	860.444	556.441	1391.529
Flood (Without Buoyancy)	1461.835	582.991	1572.168

3.2.7 Stability Analysis Results

3.2.7.1 Stability against Overturning

(1)Calculation of Acting Point of Composited Force and Eccentricity

$$d = \frac{\Sigma Mr - \Sigma Mt}{\Sigma V}$$

Here,

d: Distance from the Toe of Bottom Slab to the Acting Point of Composited Force (m)
ΣMr: Resistive Moment of Toe of Bottom Slab (kN.m.)
ΣMt: Overturning Moment of Toe of Bottom Slab (kN.m.)
ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)

$$e = \frac{B}{2} - d$$

Here,

e: Eccentricity from the Center of Bottom Slab to the Acting Point of Composited Force (m);
B: Bottom Slab Width (m), B = 7.500

ea = B/n

Here,

ea: Allowable Eccentricity (m)
n: Safety Factor

Load Condition (Water Level)	Σ Mr (kN.m.)	Σ Mt (kN.m.)	ΣV (kN)	d (m)	e (m)		Ea (m)
Normal (With Buoyancy)	642.580	20.367	195.447	3.184	0.584	≦	0.867
Seismic 1 (With Buoyancy)	947.197	79.773	304.867	2.845	0.245	≦	1.733
Seismic 2 (With Buoyancy)	677.319	-59.265	186.417	3.951	1.351	≦	1.733
Flood (With Buoyancy)	357.349	188.224	172.089	0.983	1.617	≦	1.733

3.2.7.2 Stability Against Sliding

$$F_s = \frac{\Sigma V \cdot \mu + C_B \cdot B + \alpha \cdot Pp}{\Sigma H}$$

Here,

ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)
ΣH: Total Horizontal Load in Lower Side of Bottom Slab (kN)
m.: Cohesion Between Bottom Slab and Supporting Ground, m = 0.577
C_B: Cohesion Between Bottom Slab And Supporting Ground (kN/m2), C_B = 0.000
B: Bottom Slab Width (m), B = 7.500
α: Effeective Rate of Passive Earth Pressure
Pp: Passive Earth Pressure

Load Condition (Water Level)	Vertical Load ΣV (kN)	Horizontal Load ΣH (kN)	Passive Earth Pressure Pp(kN)	Effective Rate	Safety Factor Fs		Required Safety Factor Fsa
Normal (With Buoyancy)	195.447	30.545	0.000	0.000	3.199	≧	1.500
Seismic 1 (With Buoyancy)	304.867	54.393	73.924	0.500	3.482	≧	1.200

Seismic 2 (With Buoyancy)	186.417	-27.310	73.924	0.500	4.766	≧	1.200
Flood (With Buoyancy)	172.089	111.288	143.826	0.500	1.419	≧	1.200

3.2.7.3 Verification of Bearing

1)When the Acting Point of Composited Force is within the 1/3 of Bottom Slab Width (middle third) in the Center of the Bottom Slab.

$$q_1 = \frac{\Sigma V}{B} \cdot \left(1 + \frac{6e}{B}\right)$$

$$q_2 = \frac{\Sigma V}{B} \cdot \left(1 - \frac{6e}{B}\right)$$

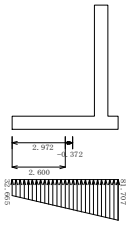
2)When the Acting Point of Composited Force is within the 2/3 of Bottom Slab Width in the Center of the Bottom Slab.

$$q_1 = \frac{2\Sigma V}{3 \cdot (B/2 - e)}$$

Here,

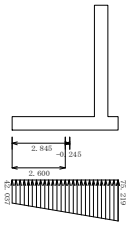
ΣV: Total Vertical Load in Lower Side of Bottom Slab (kN)
B: Bottom Slab Width (m), B = 7.500
e: Eccentricity (m)

[1]Normal (Without Buoyancy)



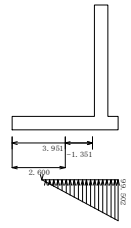
Subgrade Reaction Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2)			
		qmin	qmax		Allowance
5.200	Trapezoid	32.665	81.707	≦	200.000

[2]Seismic 1 (With Buoyancy)



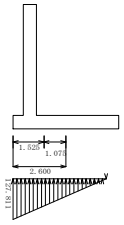
Subgrade Reaction Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2)			
		qmin	qmax		Allowance
5.200	Trapezoid	42.037	75.219	≦	300.000

[3]Seismic 2 (With Buoyancy)



Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2)			
		qmin	qmax		Allowance
3.747	Triangle	0.0000	99.502	≦	300.000

[4]Flood (With Buoyancy)



Acting Width (m)	Subgrade Reaction Shape	Subgrade Reaction Intensity (kN/m2)		
		qmin	qmax	Allowance
5.200	Triangle	0.000	127.811 ≦	300.000

3.3 Vertical Wall Design

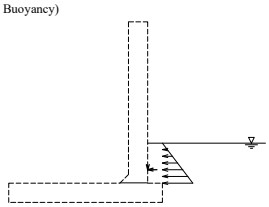
3.3.1 Checking Position

Distance from Base = 0.000 m

3.3.2 Calculation of Cross-Sectional Force

(Vertical forces are not summarized due to disregard of eccentric moments and axial forces)

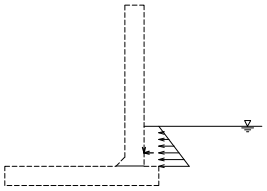
[1]Normal (With Buoyancy)



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	87.607	0.000	0.005	0.000	0.000
Hydrostatic on Rear Side	0.000	8.930	0.000	0.450	4.019
Earth Pressure	2.207	5.115	-0.325	0.450	2.302
Total	0.000	14.045	———	———	6.320

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

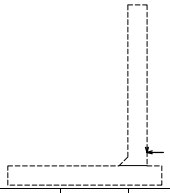
[2]Normal (Without Buoyancy)



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	87.607	0.000	0.005	0.000	0.000
Hydrostatic on Rear Side	0.000	8.930	0.000	0.450	4.019
Earth Pressure	3.071	7.120	-0.325	0.450	3.204
Total	0.000	16.050	———	———	7.223

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

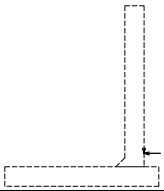
[3]Seismic 1 (With Buoyancy)



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	87.607	17.521	0.005	2.683	47.011
Earth Pressure	2.852	9.044	-0.325	0.450	4.070
Total	0.000	26.565	———	———	51.081

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

[4]Seismic 2 (With Buoyancy)

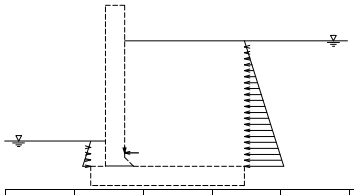


Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	87.607	-17.521	0.005	2.683	-47.011

Earth Pressure	1.209	2.802	-0.325	0.450	1.261
Total	0.000	-14.719	———	———	-45.750

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

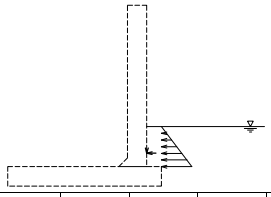
[5]Flood (With Buoyancy)



Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	87.607	0.000	-0.005	0.000	0.000
Hydrostatic on Rear Side	0.000	87.758	0.000	1.411	123.797
Hydrostatic on Front Side	0.000	-3.540	0.000	0.283	-1.003
Earth Pressure	0.900	2.086	-0.325	0.450	0.939
Total	0.000	86.304	———	———	123.733

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

[6]Flood (Without Buoyancy)

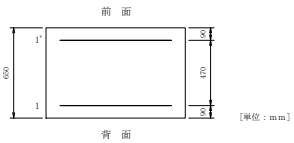


Item	Ni (kN)	Hi (kN)	Xi (m)	Yi (m)	M = Mxi + Myi (kN.m.)
Body Weight	87.607	0.000	-0.005	0.000	0.000
Hydrostatic on Rear Side	0.000	87.758	0.000	1.411	123.797
Hydrostatic on Front Side	0.000	-3.540	0.000	0.283	-1.003
Earth Pressure	1.764	4.090	-0.325	0.450	1.840
Total	0.000	88.308	———	———	124.635

*Xi is the distance from the design section center (+ toward front) and Yi is the height from the design section

3.3.3 Section Calculations (Allowable Stress Method)

(1)Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	9.0	D25	5.067	8.00	40.536
	2'	—	–	—	—	—
Back	1	9.0	D25	5.067	8.00	40.536
	2	—	–	—	—	—

Required Reinforcement in Tension Side 12.755 (cm2)

(2)Verification of Bending Stress

(Reference)

Calculation of the neutral axis

$$x^2 + \frac{2 \cdot n}{b}\{As \cdot (x-d)\} = 0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	N (kN)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
				Calculated	Allowance	Calculated	Allowance
Normal (Without Buoyancy)	7.223	0.000	15.671	0.153 ≦	8.200	3.553 ≦	140.000
Seismic 1 (With Buoyancy)	51.081	0.000	15.671	1.085 ≦	10.906	25.127 ≦	247.380
Seismic 2 (With Buoyancy)	-45.750	0.000	15.671	0.972 ≦	10.906	22.505 ≦	247.380

Flood (Without Buoyancy)	124.635	0.000	15.671	2.647	≦	10.906	61.308	≦ 186.200

(3)Verification of Shear Stress

$$\tau_m = \frac{S_h}{b \cdot d} \leqq \tau_{a1}$$

Here,

τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

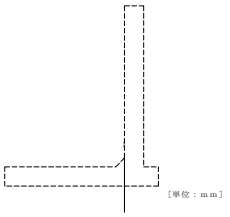
Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)		
			Calculated	Allowable τa1	Allowable τa2
Normal (With Buoyancy)	14.045	56.000	0.025 ≦	0.360	0.360
Seismic 1 (With Buoyancy)	26.565	56.000	0.047 ≦	0.479	0.479
Seismic 2 (With Buoyancy)	-14.719	56.000	0.026 ≦	0.479	0.479
Flood (With Buoyancy)	86.304	56.000	0.154 ≦	0.479	0.479

3.4 Design of Toe Slab

3.4.1 Checking Position

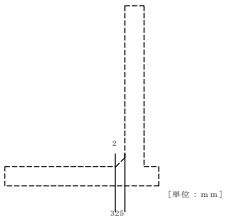
[1]Verification of Bending Stress

Distance from Base = 0.000 m



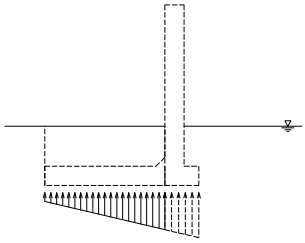
[2]Verification of Shear Stress

Distance from Base = 0.000 m



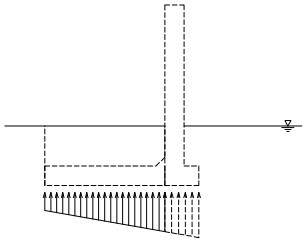
3.4.2 Calculation of Cross-Sectional Force

[1]Normal (With Buoyancy)



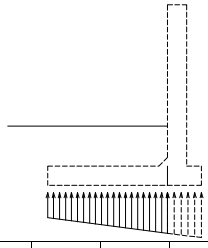
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-174.049	2.023	-352.059
Buoyancy	79.380	2.025	160.745
Subgrade Reaction	129.557	1.609	208.469
Total	34.888	———	17.155

[2]Normal (Without Buoyancy)



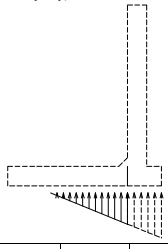
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-174.049	2.023	-352.059
Subgrade Reaction	209.641	1.776	372.313
Total	35.592	———	20.254

[3]Seismic 1 (With Buoyancy)



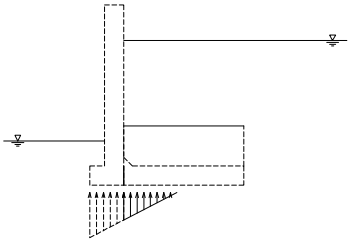
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-174.049	2.023	-352.059
Subgrade Reaction	222.583	1.866	415.406
Total	48.535	———	63.347

[4]Seismic 2 (With Buoyancy)



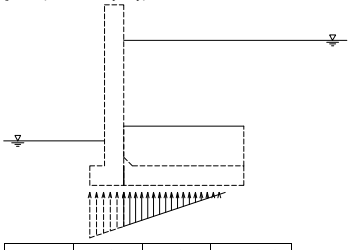
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-65.599	1.993	-130.715
Subgrade Reaction	89.549	0.866	77.520
Total	23.951	———	-53.195

[5]Flood (With Buoyancy)



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	174.049	2.023	352.059
Buoyancy	-79.380	2.025	-160.745
Subgrade Reaction	-64.042	0.600	-38.404
Total	30.627	———	152.910

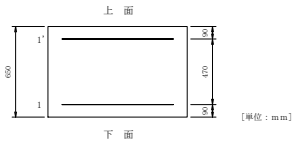
[6]Flood (Without Buoyancy)



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	174.049	2.023	352.059
Subgrade Reaction	-163.858	1.142	-187.071
Total	10.190	———	164.987

3.4.3 Section Calculations (Allowable Stress Method)

(1)Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	9.0	D25	5.067	8.00	40.536
	2'	——	—	——	——	——
Back	1	9.0	D25	5.067	8.00	40.536
	2	——	—	——	——	——

Required Reinforcement in Tension Side 12.755 (cm2)

(2)Verification of Bending Stress

Calculation of the neutral axis

$$x^2+\frac{2\cdot n}{b}\left\{As\cdot(x-d)\right\}=0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c=\frac{M}{\frac{b\cdot x}{2}\cdot\left(\frac{h}{2}-\frac{x}{3}\right)+n\cdot As\cdot\frac{(x-d)\cdot(h/2-d)}{x}}$$

$$\sigma_s=n\cdot\sigma_c\cdot\frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
			Calculated	Allowance	Calculated	Allowance
Normal (Without Buoyancy)	20.254	15.671	0.430 ≦	8.200	9.963 ≦	140.000
Seismic 1 (With Buoyancy)	63.347	15.671	1.345 ≦	10.906	31.161 ≦	186.200
Seismic 2 (With Buoyancy)	-53.195	15.671	1.130 ≦	10.906	26.167 ≦	186.200
Flood (Without Buoyancy)	124.635	15.671	2.647 ≦	10.906	61.308 ≦	186.200

(3)Verification of Shear Stress

$$\tau_m=\frac{S_h}{b\cdot d}\leqq\tau_{a1}$$

Here,

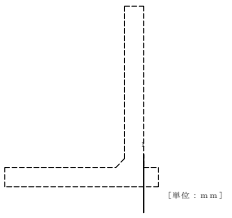
τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)	
			Calculated	Allowable τa2
Normal (With Buoyancy)	27.215	560.000	0.049 ≦	0.360
Seismic 1 (With Buoyancy)	40.966	560.000	0.073 ≦	0.479
Seismic 2 (With Buoyancy)	9.219	560.000	0.016 ≦	0.479
Flood (With Buoyancy)	30.627	560.000	0.055 ≦	0.479

3.5 Design of the Heel Slab

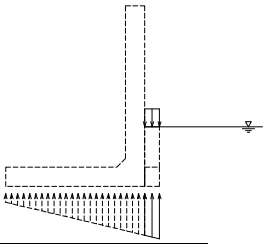
3.5.1 Checking Position

Distance from Base = 0.000 m



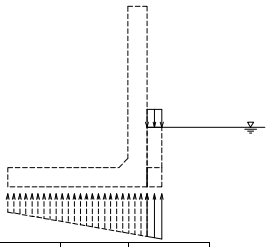
3.5.2 Calculation of Cross-Sectional Force

[1]Normal (With Buoyancy)



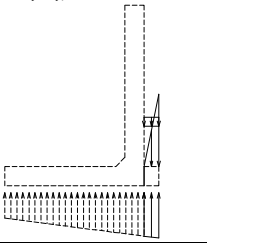
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	21.462	0.250	5.366
Buoyancy	-9.800	0.250	-2.450
Load on Surface	5.000	0.250	1.250
Subgrade Reaction	-30.230	0.253	-7.659
Total	-13.567	———	-3.493

[2]Normal (Without Buoyancy)



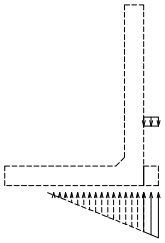
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	21.462	0.250	5.366
Load on Surface	5.000	0.250	1.250
Subgrade Reaction	-39.675	0.252	-10.017
Total	-13.212	———	-3.401

[3]Seismic 1 (With Buoyancy)



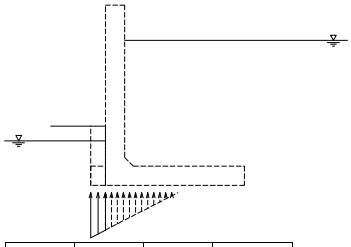
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	21.462	0.250	5.366
Load on Surface	2.500	0.250	0.625
Earth Pressure	10.000	0.333	3.333
Subgrade Reaction	-36.812	0.252	-9.269
Total	-2.849	———	0.054

[4]Seismic 2 (With Buoyancy)



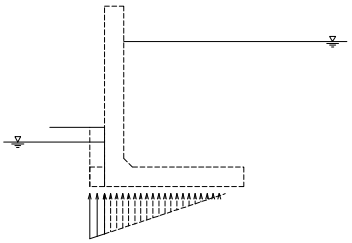
Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	21.462	0.250	5.366
Load on Surface	2.500	0.250	0.625
Subgrade Reaction	-40.408	0.269	-10.881
Total	-16.446	———	-4.890

[5]Flood (With Buoyancy)



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-21.462	0.250	-5.366
Buoyancy	9.800	0.250	2.450
Subgrade Reaction	53.408	0.258	13.764
Total	41.745	———	10.849

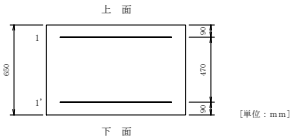
[6]Flood (Without Buoyancy)



Item	Ni (kN)	Xi (m)	M = Ni, Xi (kN.m.)
Body Weight	-21.462	0.250	-5.366
Subgrade Reaction	60.413	0.255	15.394
Total	38.951	———	10.029

3.5.3 Section Calculations (Allowable Stress Method)

(1)Rebar Placement



Single Reinforcement

Position		Cover (cm)	Rebar Diameter	Rebar Area (cm2/pc)	Number	Amount of Reinforcement (cm2)
Front	1'	9.0	D25	5.067	8.00	40.536
	2'	——	–	——	——	——
Back	1	9.0	D25	5.067	8.00	40.536
	2	——	–	——	——	——

Required Reinforcement in Tension Side 0.452 (cm2)

(2)Verification of Bending Stress

Calculation of the neutral axis

$$x^2+\frac{2\cdot n}{b}\left\{As\cdot(x-d)\right\}=0.0$$

From the above, x shall be obtained.

Calculation of Stress Intensity

$$\sigma_c=\frac{M}{\frac{b\cdot x}{2}\cdot\left(\frac{h}{2}-\frac{x}{3}\right)+n\cdot As\cdot\frac{(x-d)\cdot(h/2-d)}{x}}$$

$$\sigma_s=n\cdot\sigma_c\cdot\frac{d-x}{x}$$

Here,

x : Distance from the Concrete Compression Edge to the Neutral Axis (mm)
h : Member Section Height (mm), h = 400.000
b : Member Section Width (mm), b = 1000.000
d : Effective Height of Member (mm)
As: Total Cross-Sectional Area of Rebar in Tension (mm2)
n : Young's Modulus Ratio of Rebar to Concrete, n = 9.00
e : Distance from the Centroid Axis of the Member Section to the Acting Point of Axial Force (mm)
σc: Bending Compressive Stress of Concrete (N/mm2)
σs: Tensile Stress of Rebar (N/mm2)
M : Bending Moment (N.mm)

Load Condition (Water Level)	M (kN.m.)	x (cm)	Compressive Stress (N/mm2)		Tensile Stress (N/mm2)	
			Calculated	Allowance	Calculated	Allowance
Normal (Without Buoyancy)	-3.493	15.671	0.074 ≦	8.200	1.718 ≦	140.000
Seismic 1 (With Buoyancy)	0.054	15.671	0.001 ≦	10.906	0.027 ≦	186.200
Seismic 2 (With Buoyancy)	-4.890	15.671	0.104 ≦	10.906	2.405 ≦	186.200
Flood (Without Buoyancy)	10.849	15.671	0.230 ≦	10.906	5.336 ≦	186.200

(3)Verification of Shear Stress

$$\tau_m=\frac{S_h}{b\cdot d}\leqq\tau_{a1}$$

Here,

τm: Average Shear Stress of Concrete (N/mm2)
Sh : Shear Force (N)
d : Effective Height of Member Section (mm)
b : Member Section Width (mm)

Load Condition (Water Level)	Shear Force Sh (kN)	Effective Height d (cm)	Shear Stress (N/mm2)	
			Calculated	Allowable τa2
Normal (With Buoyancy)	13.567	560.000	0.024 ≦	0.360
Seismic 1 (With Buoyancy)	2.849	560.000	0.005 ≦	0.479
Seismic 2 (With Buoyancy)	16.446	560.000	0.029 ≦	0.479
Flood (With Buoyancy)	15.735	560.000	0.028 ≦	0.479

1.2.5 Consolidation Analysis

The calculation sheets are shown in the following pages.

Left Bank
Station 5+560

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1. Initial Condition

Title :L_7+560

1.1 Initial Condition

1.1.1 Nodal Points Data

Node No	X (m)	Y (m)	Node No	X (m)	Y (m)	Node No	X (m)	Y (m)
1	-64.54	9.87	7	-45.00	-7.38	13	-45.20	14.70
2	-64.54	9.11	8	-45.00	7.44	14	-46.96	18.13
3	-64.54	7.44	9	-45.00	9.11	15	-50.56	18.06
4	-64.54	-7.38	10	-45.00	9.87	16	-52.85	13.48
5	-64.54	-14.47	11	-45.00	13.48	17	-64.54	13.48
6	-45.00	-14.47	12	-45.00	14.70			

1.1.2 Layer Shape Data

Shape Number	Constitution Setting Points						Layer Type	Floor digging / Backfill
1	11	12	13	14	15	16	Embankment	don't
2	11	16	17	1	10		Sand	don't
3	10	1	2	9			Cray	don't
4	9	2	3	8			Sand	don't
5	8	3	4	7			Cray	don't
6	7	4	5	6			Sand	don't

1.1.3 Embankment Condition

Execution Stage	Shape No.	Soil Type	Saturated Unit Weight (kN/m³)	Unit Weight (kN/m³)	Construction Period start	Construction Period Finish	Embankment Removal Date	Construction Period for a second time Start day for a second time	Construction Period for a second time Finish day for a second time	Removal day for a second time
1	1	Embankment	19.5	19.0	0	60	---	---	---	---

1.1.4 Soil Condition

Layer (Shape) No	Layer Name	Calculation Method	Saturated UnitWeight (kN/m³)	Unit Weight (kN/m³)	Layer Type
2	As	B.K.Hough	17.5	17.5	Sand
3	Dc	Delta e method	18.0	18.0	Clay
4	Ds	B.K.Hough	19.0	19.0	Sand
5	Dc	Delta e method	18.0	18.0	Clay
6	Ds	B.K.Hough	19.0	19.0	Sand

Layer (Shape) No	e -logP Curve	logMv -logP Curve	logCv -logP Curve	Water Content (%)	N Value	Compression Index Cc Normal	Compression Index Cc Over	Consolidation Yield Stress Pc (kN/m²)	increase in Preconsolidation qo(kN/m²)	t=(sqr)Tv Replaceable Coefficient (sqr)
2	20	0	0	0	0	0.00	0.00	0.00	0.00	0.00
3	15	0	2	0	0	0.00	0.00	0.00	0.00	0.00
4	22	0	0	0	0	0.00	0.00	0.00	0.00	0.00
5	15	0	2	0	0	0.00	0.00	0.00	0.00	0.00
6	22	0	0	0	0	0.00	0.00	0.00	0.00	0.00

1.1.5 Ground Water Level

Water Unit Weight : 10.0 kN/m³

Ground water influence : There is it. (convergence condition = 1.00cm)

Node No	X (m)	Y (m)
1	-64.54	13.48
2	-45.00	13.48

1.2 Common Item about Calculation

1.2.1 Calculation Condition(Common Item)

Calculation Method : Boussinesq method

Lay No.	Reduction Coefficient of Settlement
2	1.00
3	1.00
4	1.00
5	1.00
6	0.00

1.2.2 Shear Deformation

Calculation Method: Japan Ins of Constraction Eng.
"Flexible Sluiceways"(1998)
Calculation Shape Number: 6433908
Division pitch of Calculation Shape Number: 0.0

Depth which has the influence of shear deformation

Node No	X (m)	Y (m)

layer (Form)	Modulus of deformation (kN/m²)	Load Length (m)
1	0.00	0.00
2	0.00	0.00
3	0.00	0.00
4	0.00	0.00
5	0.00	0.00

Execution	Modulus of deformation (kN/m²)	Load Length (m)
1	0.00	0.00

Poisson's ratio :0.00

1.2.3 Residual Condition

Calculation of Settlement Period length 60 day

1.3 Calculation of Computation Time Condition

1.3.1 Calculation Condition(Settlement Time)

History Condition :Lasped days

Calculation Period :36000 day

Output condition of Cross Section Diagram

Degree of Consolidation :100% Calculation point(X Coodinate) :-55.00m

Creation method of Time-Settlemnt Curve :Parallel Translation Method

1.3.2 Consolidation Condition

Coefficient-of-consolidation calculation method of some layers
Layer Thickness Converting Method : Parallel Translation Method

Drainage Condition

Layer (Form)	Drainage Condition
2	Sand Layer
3	Both Side
4	Sand Layer
5	Both Side
6	Sand Layer

Bedrock Condition :Drained

1.4.1 Curves Record

(1)e-logP Curve
Curve 20 :Loose Sand
Interpolation Method between Data :Curve Line
Layer No. in use : 2

Number	1	2	3	4	5	6	7	8
Consolidation Stress (kN/m²)	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
Void Ratio e	0.780	0.760	0.742	0.714	0.688	0.678	0.662	0.640

Number	9	10	11	12
Consolidation Stress (kN/m²)	20.00	30.00	50.00	100.00
Void Ratio e	0.621	0.611	0.600	0.590

Curve 15 :DD-BH-L01
Interpolation Method between Data :Curve Line
Layer No. in use : 3 5

Number	1	2	3	4	5	6
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	800.00
Void Ratio e	1.960	1.920	1.800	1.650	1.450	1.000

Curve 22 :Compacted Sand
Interpolation Method between Data :Curve Line
Layer No. in use : 4 6

Number	1	2	3	4	5	6	7	8
Consolidation Stress (kN/m²)	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
Void Ratio e	0.490	0.484	0.477	0.467	0.457	0.451	0.443	0.433

Number	9	10	11	12	13	14
Consolidation Stress (kN/m²)	20.00	30.00	50.00	100.00	200.00	1000.00
Void Ratio e	0.423	0.417	0.410	0.400	0.390	0.380

(2)logCv-logP Curve
Curve 2 :DD-BH-L01 (Dc1)
Interpolation Method between Data :Curve Line
Consolidation Stress Calculation Method :Geometrica
Layer No. in use : 3 5

Number	1	2	3	4	5	6	7	8
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00	1600.00
Coefficient of Consolidation Cv(cm²/day)	62.00	87.00	148.00	158.00	55.00	35.00	28.00	23.00

2. Results

2.1 Results of each Points

Calculation Point 1 : Left_Crest
Calculation Depth : -50.563 m
Ground Water Level : 13.477 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	B.K.Hough	3.610	13.57	64.05	0.00	8.423
3	delta e method	0.760	30.14	49.31	0.00	4.996
4	B.K.Hough	1.670	40.70	43.21	0.00	1.201
5	delta e method	14.820	107.49	21.60	0.00	28.107
6	B.K.Hough	7.090	198.68	12.46	0.00	0.000

Sub Total: 42.726(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	0.631	0.593	——	——	——	——	——	——
3	1.894	1.704	——	——	——	48.94	——	145.738
4	0.413	0.403	——	——	——	——	——	——
5	1.632	1.582	——	——	——	117.80	——	129.660
6	0.390	0.389	——	——	——	——	——	——

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point=-55.000m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	8.423	100.000	——	8.423
3	100.000	4.996	99.954	——	4.993
4	100.000	1.201	100.000	——	1.201
5	99.999	28.107	9.497	——	2.669
6	100.000	0.000	100.000	——	0.000

Sub Total: 42.726(cm) Sub Total: 17.286(cm)

Residual Settlement: 25.440(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	3.610	0.000
3	0.760	145.738
4	1.670	0.000
5	14.820	129.660
6	7.090	0.000

Sa = 100.00

ΔS= 25.44

Sa ≧ΔS ・・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)

ΔS : Designing residual settlement(Total settlement) (cm)

Calculation Point 2 : Center_of_Embankment
Calculation Depth : -48.764 m
Ground Water Level : 13.477 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	B.K.Hough	3.610	13.57	76.88	0.00	8.859
3	delta e method	0.760	30.14	57.85	0.00	5.605
4	B.K.Hough	1.670	40.70	49.11	0.00	1.320
5	delta e method	14.820	107.49	22.31	0.00	28.990
6	B.K.Hough	7.090	198.68	12.59	0.00	0.000

Sub Total: 44.774(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	0.631	0.591	——	——	——	——	——	——
3	1.894	1.681	——	——	——	51.50	——	151.103
4	0.413	0.402	——	——	——	——	——	——
5	1.632	1.580	——	——	——	118.12	——	129.141
6	0.390	0.389	——	——	——	——	——	——

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point=-55.000m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	8.859	100.000	——	8.859
3	100.000	5.605	99.965	——	5.603
4	100.000	1.320	100.000	——	1.320
5	99.999	28.989	9.478	——	2.748
6	100.000	0.000	100.000	——	0.000

Sub Total: 44.774(cm) Sub Total: 18.530(cm)

Residual Settlement: 26.244(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	3.610	0.000
3	0.760	151.103
4	1.670	0.000
5	14.820	129.141
6	7.090	0.000

Sa = 100.00

ΔS= 26.24

Sa ≧ΔS ・・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)

ΔS : Designing residual settlement(Total settlement) (cm)

Calculation Point 3 : Right_Side_of_Embank
Calculation Depth : ment -46 m
Ground Water Level : 13.477 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	B.K.Hough	3.610	13.57	65.27	0.00	8.468
3	delta e method	0.760	30.14	49.91	0.00	5.039
4	B.K.Hough	1.670	40.70	43.60	0.00	1.209
5	delta e method	14.820	107.49	21.64	0.00	28.162
6	B.K.Hough	7.090	198.68	12.47	0.00	0.000

Sub Total: 42.878(cm)

Lay No.	eo	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	0.631	0.593	——	——	——	——	——	——
3	1.894	1.702	——	——	——	49.12	——	146.130
4	0.413	0.403	——	——	——	——	——	——
5	1.632	1.582	——	——	——	117.82	——	129.628
6	0.390	0.389	——	——	——	——	——	——

[Immediate Sinkage] "Flexible Sluiceways"(1998)
Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00
Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]
Degree of Consolidation: 100%
(Calculation Point=-55.000m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	8.468	100.000	——	8.468
3	100.000	5.039	99.955	——	5.037
4	100.000	1.209	100.000	——	1.209
5	99.999	28.162	9.496	——	2.674
6	100.000	0.000	100.000	——	0.000

Sub Total: 42.878(cm) Sub Total: 17.388(cm)
Residual Settlement: 25.490(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	3.610	0.000
3	0.760	146.130
4	1.670	0.000
5	14.820	129.628
6	7.090	0.000

Sa = 100.00
ΔS= 25.49
Sa ≧ΔS ・・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Designing residual settlement(Total settlement) (cm)

Calculation Point 4 : Toe_of_Embankment
Calculation Depth : -45.200 m
Ground Water Level : 13.477 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	B.K.Hough	3.610	13.57	27.25	0.00	6.034
3	delta e method	0.760	30.14	31.18	0.00	3.556
4	B.K.Hough	1.670	40.70	30.57	0.00	0.919
5	delta e method	14.820	107.49	19.80	0.00	25.876
6	B.K.Hough	7.090	198.68	12.10	0.00	0.000

Sub Total: 36.385(cm)

Lay No.	eo	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	0.631	0.604	——	——	——	——	——	——
3	1.894	1.759	——	——	——	42.99	——	132.121
4	0.413	0.405	——	——	——	——	——	——
5	1.632	1.586	——	——	——	116.97	——	130.977
6	0.390	0.389	——	——	——	——	——	——

[Immediate Sinkage] "Flexible Sluiceways"(1998)
Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00
Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]
Degree of Consolidation: 100%
(Calculation Point=-55.000m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	6.034	100.000	——	6.034
3	100.000	3.556	99.907	——	3.553
4	100.000	0.919	100.000	——	0.919
5	99.999	25.876	9.545	——	2.470
6	100.000	0.000	100.000	——	0.000

Sub Total: 36.385(cm) Sub Total: 12.976(cm)
Residual Settlement: 23.409(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	3.610	0.000
3	0.760	132.121
4	1.670	0.000
5	14.820	130.977
6	7.090	0.000

Sa = 100.00
ΔS= 23.41
Sa ≧ΔS ・・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Designing residual settlement(Total settlement) (cm)

2.2 Degree of Consolidation - Duration in days

Calculation Point 1 : Left_Crest
Calculation Depth : -50.563 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	17	32	46	60	222	541	1020	1714	2903	---
Settlement	4.273	8.545	12.818	17.091	21.363	25.636	29.908	34.181	38.454	42.726

Layer No. : 2 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.842	1.685	2.527	3.369	4.211	5.054	5.896	6.738	7.580	8.423

Layer No. : 3 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	9	14	20	25	31	37	43	49	55	---
Settlement	0.500	0.999	1.499	1.998	2.498	2.997	3.497	3.997	4.496	4.996

Layer No. : 4 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : Ds

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.120	0.240	0.360	0.480	0.600	0.720	0.841	0.961	1.081	1.201

Layer No. : 5 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	64	164	330	563	864	1243	1736	2432	3622	---
Settlement	2.811	5.621	8.432	11.243	14.054	16.864	19.675	22.486	25.296	28.107

Layer No. : 6 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : Ds

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	1	1	1	1	1	1	1	1	1	---
Settlement	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Calculation Point 2 : Center_of_Embankment
Calculation Depth : -48.764 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	17	31	45	59	204	518	996	1693	2887	---
Settlement	4.477	8.955	13.432	17.910	22.387	26.864	31.342	35.819	40.297	44.774

Layer No. : 2 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.886	1.772	2.658	3.544	4.430	5.315	6.201	7.087	7.973	8.859

Layer No. : 3 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	9	14	20	25	31	37	43	49	55	---
Settlement	0.560	1.121	1.681	2.242	2.802	3.363	3.923	4.484	5.044	5.605

Layer No. : 4 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : Ds

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.132	0.264	0.396	0.528	0.660	0.792	0.924	1.056	1.188	1.320

Layer No. : 5 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	64	164	331	565	867	1248	1743	2442	3636	---
Settlement	2.899	5.798	8.697	11.596	14.495	17.394	20.293	23.192	26.091	28.990

Layer No. : 6 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : Ds

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	1	1	1	1	1	1	1	1	1	---
Settlement	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Calculation Point 3 : Right_Side_of_Embank
Calculation Depth : ment -46 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	17	32	46	60	220	539	1017	1711	2901	---
Settlement	4.288	8.576	12.864	17.151	21.439	25.727	30.015	34.303	38.591	42.878

Layer No. : 2 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.847	1.694	2.540	3.387	4.234	5.081	5.928	6.775	7.621	8.468

Layer No. : 3 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	9	14	20	25	31	37	43	49	55	---
Settlement	0.504	1.008	1.512	2.016	2.520	3.023	3.527	4.031	4.535	5.039

Layer No. : 4 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : Ds

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.121	0.242	0.363	0.484	0.604	0.725	0.846	0.967	1.088	1.209

Layer No. : 5 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	64	164	330	563	864	1244	1737	2433	3623	---
Settlement	2.816	5.632	8.449	11.265	14.081	16.897	19.714	22.530	25.346	28.162

Layer No. : 6 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : Ds

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	1	1	1	1	1	1	1	1	1	---
Settlement	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Calculation Point 4 : Toe_of_Embankment
Calculation Depth : -45.200 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	19	36	52	111	321	661	1141	1829	3007	---
Settlement	3.638	7.277	10.915	14.554	18.192	21.831	25.469	29.108	32.746	36.385

Layer No. : 2 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.603	1.207	1.810	2.414	3.017	3.620	4.224	4.827	5.431	6.034

Layer No. : 3 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	9	15	20	26	31	37	43	49	55	---
Settlement	0.356	0.711	1.067	1.422	1.778	2.134	2.489	2.845	3.200	3.556

Layer No. : 4 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : Ds

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.092	0.184	0.276	0.367	0.459	0.551	0.643	0.735	0.827	0.919

Layer No. : 5 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	63	162	327	557	855	1231	1719	2408	3586	---
Settlement	2.588	5.175	7.763	10.350	12.938	15.526	18.113	20.701	23.289	25.876

Layer No. : 6 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : Ds

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	1	1	1	1	1	1	1	1	1	---
Settlement	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

2.3 Calculation result on the way in each construction stage

Calculation Point 1 : Left_Crest
Calculation Depth : -50.563 m
Ground Water Level : 13.477 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4	5	6		
1	0.000	145.738	0.000	129.660	0.000		

Calculation Point 2 : Center_of_Embankment
Calculation Depth : -48.764 m
Ground Water Level : 13.477 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4	5	6		
1	0.000	151.103	0.000	129.141	0.000		

Calculation Point 3 : Right_Side_of_Embank
Calculation Depth : ment -46 m
Ground Water Level : 13.477 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4	5	6		
1	0.000	146.130	0.000	129.628	0.000		

Calculation Point 4 : Toe_of_Embankment
Calculation Depth : -45.200 m
Ground Water Level : 13.477 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4	5	6		
1	0.000	132.121	0.000	130.977	0.000		

Left Bank
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1. Initial Condition 1

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1. Initial Condition

Title :

1.1 Initial Condition

1.1.1 Nodal Points Data

Node No	X (m)	Y (m)
1	-67.75	-11.41
2	-45.00	-11.41
3	-45.00	1.93
4	-45.00	4.95
5	-45.00	10.96
6	-45.00	11.96
7	-45.00	14.73
8	-45.00	15.10
9	-47.00	15.10

Node No	X (m)	Y (m)
10	-49.11	19.22
11	-59.71	19.01
12	-60.73	16.97
13	-61.74	17.12
14	-67.75	17.12
15	-67.75	16.73
16	-67.75	11.96
17	-67.75	10.96
18	-67.75	4.95

Node No	X (m)	Y (m)
19	-67.75	1.93
20	-59.08	16.74
21	-58.94	16.73
22	-58.90	15.75
23	-58.79	15.71
24	-52.33	14.73
25	-45.71	14.82

1.1.2 Layer Shape Data

Shape Number	Constitution Setting Points										Layer Type	Floor digging / Backfill
1	12	11	10	9	8	7	25	24	23	20	Embankment	don't
2	7	25	24	23	20	12	13	14	15	16	Cray	don't
	6											
3	16	17	5	6							Sand	don't
4	17	18	4	5							Cray	don't
5	18	19	3	4							Cray	don't

1.1.3 Embankment Condition

Execution Stage	Shape No.	Soil Type	Saturated Unit Weight (kN/m³)	Unit Weight (kN/m³)	Construction Period start	Construction Period Finish	Embankment Removal Date	Construction Period for a second time Start day for a second time	Construction Period for a second time Finish day for a second time	Removal day for a second time
1	1	Embankment	19.5	19.0	0	60	---	---	---	---

1.1.4 Soil Condition

Layer (Shape) No	Layer Name	Calculation Method	Saturated Unit Weight (kN/m³)	Unit Weight (kN/m³)	Layer Type
2	Ac	Delta e method	15.5	15.5	Clay
3	As	B.K.Hough	17.5	17.5	Sand
4	Ac	Delta e method	15.5	15.0	Clay
5	Dc	Delta e method	18.0	18.0	Clay

Layer (Shape) No	e -logP Curve	logMv -logP Curve	logCv -logP Curve	Water Content (%)	N Value	Compression Index Cc Normal	Compression Index Cc Over	Consolidation Yield Stress Pc (kN/m²)	Increase in Preconsolidation q0(kN/m²)	t=(sqr)Tv Replaceable Coefficient (sqr)
2	14	0	1	0	0	0.00	0.00	0.00	0.00	0.00
3	20	0	0	0	0	0.00	0.00	0.00	0.00	0.00
4	14	0	1	0	0	0.00	0.00	0.00	0.00	0.00
5	16	0	2	0	0	0.00	0.00	0.00	0.00	0.00

1.1.5 Ground Water Level

Water Unit Weight : 10.0 kN/m³

Ground water influence : There is it. (convergence condition = 1.00cm)

Node No	X (m)	Y (m)
1	-60.70	16.97
2	-45.00	14.80

1.2 Common Item about Calculation

1.2.1 Calculation Condition(Common Item)

Calculation Method : Boussinesq method

Lay No.	Reduction Coefficient of Settlement
2	1.00
3	1.00
4	1.00
5	1.00

1.2.2 Shear Deformation

Calculation Method: Japan Ins of Constraction Eng.
"Flexible Sluiceways"(1998)
Calculation Shape Number: 6433908
Division pitch of Calculation Shape Number: 0.0

Depth which has the influence of shear deformation

Node No	X (m)	Y (m)

layer (Form)	Modulus of deformation (kN/m²)	Load Length (m)
1	0.00	0.00
2	0.00	0.00
3	0.00	0.00
4	0.00	0.00

Execution	Modulus of deformation (kN/m²)	Load Length (m)
1	0.00	0.00

Poisson's ratio :0.00

1.2.3 Residual Condition

Calculation of Settlement Period length 60 day

1.3 Calculation of Computation Time Condition

1.3.1 Calculation Condition(Settlement Time)

History Condition :Lasped days

Calculation Period :36000 day

Output condition of Cross Section Diagram

Degree of Consolidation :100% Calculation point(X Coodinate) :-55.00m

Creation method of Time-Settlemnt Curve :Parallel Translation Method

1.3.2 Consolidation Condition

Coefficient-of-consolidation calculation method of some layers
Layer Thickness Converting Method : Parallel Translation Method

Drainage Condition

Layer (Form)	Drainage Condition
2	Both Side
3	Sand Layer
4	Both Side
5	Both Side

Bedrock Condition :Drained

1.4.1 Curves Record

(1)e-logP Curve
Curve 14 :DD-BH-L10
Interpolation Method between Data :Curve Line
Layer No. in use : 2 4

Number	1	2	3	4	5	6	7
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00
Void Ratio e	1.360	1.350	1.320	1.240	1.120	1.000	0.880

Curve 20 :Loose Sand
Interpolation Method between Data :Curve Line
Layer No. in use : 3

Number	1	2	3	4	5	6	7	8
Consolidation Stress (kN/m²)	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
Void Ratio e	0.780	0.760	0.742	0.714	0.688	0.678	0.662	0.640

Number	9	10	11	12
Consolidation Stress (kN/m²)	20.00	30.00	50.00	100.00
Void Ratio e	0.621	0.611	0.600	0.590

Curve 16 :DD-BH-L13
Interpolation Method between Data :Curve Line
Layer No. in use : 5

Number	1	2	3	4	5	6	7
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00
Void Ratio e	1.370	1.350	1.320	1.240	1.120	1.000	0.880

(2)logCv-logP Curve
Curve 1 :DD-BH-L10 (Ac)
Interpolation Method between Data :Curve Line
Consolidation Stress Calculation Method :Geometrica
Layer No. in use : 2 4

Number	1	2	3	4	5	6	7	8
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00	1600.00
Coefficient of Consolidation Cv(cm²/day)	29.00	98.00	69.00	66.00	24.00	20.00	18.00	16.00

Curve 2 :DD-BH-L01 (Dc1)
Interpolation Method between Data :Curve Line
Consolidation Stress Calculation Method :Geometrica
Layer No. in use : 5

Number	1	2	3	4	5	6	7	8
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00	1600.00
Coefficient of Consolidation Cv(cm²/day)	62.00	87.00	148.00	158.00	55.00	35.00	28.00	23.00

2. Results

2.1 Results of each Points

Calculation Point 1 : Left_Crest
Calculation Depth : -59.709 m
Ground Water Level : 16.833 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	delta e method	4.868	13.39	21.12	0.00	3.778
3	B.K.Hough	1.000	30.52	25.62	0.00	0.783
4	delta e method	6.010	50.80	26.67	0.00	11.179
5	delta e method	3.020	79.41	24.97	0.00	5.222

Sub Total: 20.962(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	1.359	1.341	——	——	——	21.49	——	87.945
3	0.611	0.598	——	——	——	——	——	——
4	1.319	1.276	——	——	——	62.73	——	68.726
5	1.273	1.233	——	——	——	91.04	——	169.290

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point=-55.000m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	3.778	23.814	——	0.900
3	100.000	0.783	100.000	——	0.783
4	100.000	11.179	12.915	↓	1.444
5	100.000	5.222	12.915	12.915	0.674

Sub Total: 20.962(cm) Sub Total: 3.801(cm)

Residual Settlement: 17.162(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	4.868	87.945
3	1.000	0.000
5	12.453	169.290

Calculation Point 2 : Center_of_Embankment
Calculation Depth : -55.000 m
Ground Water Level : 16.182 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	delta e method	3.175	8.73	61.11	0.00	10.098
3	B.K.Hough	1.000	21.21	57.23	0.00	1.631
4	delta e method	6.010	41.49	46.65	0.00	18.961
5	delta e method	3.020	70.10	35.07	0.00	7.360

Sub Total: 38.050(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	1.363	1.288	——	——	——	24.69	——	97.557
3	0.620	0.593	——	——	——	——	——	——
4	1.332	1.258	——	——	——	60.47	——	68.329
5	1.288	1.232	——	——	——	85.86	——	173.874

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point=-55.000m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	10.098	38.452	——	3.883
3	100.000	1.631	100.000	——	1.631
4	100.000	18.961	12.928	↓	2.451
5	100.000	7.360	12.928	12.928	0.952

Sub Total: 38.050(cm) Sub Total: 8.917(cm)

Residual Settlement: 29.134(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	3.175	97.557
3	1.000	0.000
5	12.607	173.874

Sa = 50.00
ΔS= 29.13
Sa ≧ΔS ・・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Desigining residual settlement(Total settlement) (cm)

Calculation Point 3 : Right_Side_of_Embank
Calculation Depth : ment -49 m
Ground Water Level : 15.368 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	delta e method	2.814	7.74	61.24	0.00	8.959
3	B.K.Hough	1.000	19.23	50.62	0.00	1.686
4	delta e method	6.010	39.50	40.22	0.00	16.125
5	delta e method	3.020	68.11	31.45	0.00	6.656

Sub Total: 33.426(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	1.365	1.290	——	——	——	23.10	——	93.903
3	0.622	0.595	——	——	——	——	——	——
4	1.335	1.272	——	——	——	56.12	——	67.916
5	1.291	1.241	——	——	——	82.35	——	175.985

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point=-55.000m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	8.959	42.565	——	3.813
3	100.000	1.686	100.000	——	1.686
4	100.000	16.125	12.917	↓	2.083
5	100.000	6.656	12.917	12.917	0.860

Sub Total: 33.426(cm) Sub Total: 8.442(cm)

Residual Settlement: 24.984(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	2.814	93.903
3	1.000	0.000
5	12.694	175.985

Sa = 50.00
ΔS= 24.98
Sa ≧ΔS ・・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Designing residual settlement(Total settlement) (cm)

Calculation Point 4 : Toe_of_Embankment
Calculation Depth : -47.000 m
Ground Water Level : 15.076 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	delta e method	2.842	7.82	15.80	0.00	1.628
3	B.K.Hough	1.000	19.38	24.89	0.00	1.200
4	delta e method	6.010	39.66	28.19	0.00	11.076
5	delta e method	3.020	68.27	25.87	0.00	5.515

Sub Total: 19.419(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	1.365	1.351	——	——	——	13.59	——	38.604
3	0.622	0.602	——	——	——	——	——	——
4	1.334	1.291	——	——	——	51.87	——	68.364
5	1.291	1.249	——	——	——	80.17	——	176.843

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point=-55.000m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	1.628	27.019	——	0.440
3	100.000	1.200	100.000	——	1.200
4	100.000	11.076	12.957	↓	1.435
5	100.000	5.515	12.957	12.957	0.715

Sub Total: 19.419(cm) Sub Total: 3.790(cm)

Residual Settlement: 15.629(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	2.842	38.604
3	1.000	0.000
5	12.686	176.843

Sa = 10.00
ΔS= 15.63
Sa ≧ΔS ・・・・・・・・・・・・・・・・・・ NG

Sa : Allowance residual settlement(cm)
ΔS : Designing residual settlement(Total settlement) (cm)

2.2 Degree of Consolidation - Duration in days

Calculation Point 1 : Left_Crest
Calculation Depth : -59.709 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	40	69	130	222	347	518	757	1114	1747	---
Settlement	2.096	4.192	6.289	8.385	10.481	12.577	14.674	16.770	18.866	20.962

Layer No. : 2 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	34	54	78	115	163	223	302	412	602	---
Settlement	0.378	0.756	1.133	1.511	1.889	2.267	2.645	3.023	3.400	3.778

Layer No. : 3 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.078	0.157	0.235	0.313	0.391	0.470	0.548	0.626	0.704	0.783

Layer No. : 4 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	51	102	192	318	481	686	953	1329	1972	---
Settlement	1.118	2.236	3.354	4.472	5.590	6.707	7.825	8.943	10.061	11.179

Layer No. : 5 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	51	102	192	318	481	686	953	1329	1972	---
Settlement	0.522	1.044	1.567	2.089	2.611	3.133	3.656	4.178	4.700	5.222

Calculation Point 2 : Center_of_Embankment
Calculation Depth : -55.000 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	33	54	85	138	222	369	613	985	1627	---
Settlement	3.805	7.610	11.415	15.220	19.025	22.830	26.635	30.440	34.245	38.050

Layer No. : 2 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	25	39	51	63	81	104	135	177	250	---
Settlement	1.010	2.020	3.029	4.039	5.049	6.059	7.068	8.078	9.088	10.098

Layer No. : 3 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.163	0.326	0.489	0.652	0.815	0.978	1.142	1.305	1.468	1.631

Layer No. : 4 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	51	102	192	318	480	685	951	1327	1969	---
Settlement	1.896	3.792	5.688	7.585	9.481	11.377	13.273	15.169	17.065	18.961

Layer No. : 5 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	51	102	192	318	480	685	951	1327	1968	---
Settlement	0.736	1.472	2.208	2.944	3.680	4.416	5.152	5.888	6.624	7.360

Calculation Point 3 : Right_Side_of_Embank
Calculation Depth : ment -49 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	31	51	76	123	202	349	599	973	1616	---
Settlement	3.343	6.685	10.028	13.370	16.713	20.056	23.398	26.741	30.083	33.426

Layer No. : 2 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	23	37	48	58	72	91	115	150	209	---
Settlement	0.896	1.792	2.688	3.584	4.480	5.375	6.271	7.167	8.063	8.959

Layer No. : 3 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.169	0.337	0.506	0.674	0.843	1.011	1.180	1.349	1.517	1.686

Layer No. : 4 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	51	102	192	318	481	686	953	1329	1972	---
Settlement	1.612	3.225	4.837	6.450	8.062	9.675	11.287	12.900	14.512	16.125

Layer No. : 5 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	51	102	192	318	481	686	953	1329	1972	---
Settlement	0.666	1.331	1.997	2.663	3.328	3.994	4.659	5.325	5.991	6.656

Calculation Point 4 : Toe_of_Embankment
Calculation Depth : -47.000 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	37	63	126	225	363	551	807	1177	1815	---
Settlement	1.942	3.884	5.826	7.768	9.709	11.651	13.593	15.535	17.477	19.419

Layer No. : 2 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	31	50	67	96	133	180	241	327	474	---
Settlement	0.163	0.326	0.488	0.651	0.814	0.977	1.139	1.302	1.465	1.628

Layer No. : 3 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.120	0.240	0.360	0.480	0.600	0.720	0.840	0.960	1.080	1.200

Layer No. : 4 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	51	102	191	316	478	682	947	1321	1960	---
Settlement	1.108	2.215	3.323	4.431	5.538	6.646	7.753	8.861	9.969	11.076

Layer No. : 5 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	51	102	191	316	478	682	947	1321	1960	---
Settlement	0.551	1.103	1.654	2.206	2.757	3.309	3.860	4.412	4.963	5.515

2.3 Calculation result on the way in each construction stage

Calculation Point 1 : Left_Crest
Calculation Depth : -59.709 m
Ground Water Level : 16.833 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4	5			
1	87.945	0.000	68.726	169.290			

Calculation Point 2 : Center_of_Embankment
Calculation Depth : -55.000 m
Ground Water Level : 16.182 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4	5			
1	97.557	0.000	68.329	173.874			

Calculation Point 3 : Right_Side_of_Embank
Calculation Depth : ment -49 m
Ground Water Level : 15.368 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4	5			
1	93.903	0.000	67.916	175.985			

Calculation Point 4 : Toe_of_Embankment
Calculation Depth : -47.000 m
Ground Water Level : 15.076 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4	5			
1	38.604	0.000	68.364	176.843			

Right Bank
Station. 7+240

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1. Initial Condition

Title :R_7+240

1.1 Initial Condition

1.1.1 Nodal Points Data

Node No	X (m)	Y (m)
1	64.64	15.78
2	64.64	9.11
3	64.64	-1.78
4	64.64	-12.03
5	45.00	-12.03
6	45.00	-1.78
7	45.00	9.11
8	45.00	11.14
9	45.00	14.60
10	45.20	14.60
11	46.62	17.43
12	46.92	17.93
13	50.52	17.86
14	51.71	15.48
15	52.46	15.48
16	53.61	15.48
17	54.22	15.78
18	50.35	14.81
19	47.07	12.97

1.1.2 Layer Shape Data

Shape Number	Constitution Setting Points									Layer Type	Floor digging / Backfill
1	8	9	10	11	12	13	14	18	19	Embankment	don't
2	8	19	18	14	15	16	17	1	2	7	Sand	don't
3	7	2	3	6							Cray	don't

1.1.3 Embankment Condition

Execution Stage	Shape No.	Soil Type	Saturated Unit Weight (kN/m³)	Unit Weight (kN/m³)	Construction Period start	Construction Period Finish	Embankment Removal Date	Construction Period for a second time Start day for a second time	Construction Period for a second time Finish day for a second time	Removal day for a second time
1	1	Embankment	19.5	19.0	0	60	---	---	---	---

1.1.4 Soil Condition

Layer (Shape) No	Layer Name	Calculation Method	Saturated Unit Weight (kN/m³)	Unit Weight (kN/m³)	Layer Type
2	As	B.K.Hough	17.5	17.5	Sand
3	Dc	Delta e method	18.0	18.0	Clay

Layer (Shape) No	e -logP Curve	logMv -logP Curve	logCv -logP Curve	Water Content (%)	N Value	Compression Index Cc Normal	Compression Index Cc Over	Consolidation Yield in Stress Pc (kN/m²)	Increase in Preconsolidation q0(kN/m²)	t=(sqr)Tv Replaceable Coefficient (sqr)
2	20	0	0	0	0	0.00	0.00	0.00	0.00	0.00
3	17	0	4	0	0	0.00	0.00	0.00	0.00	0.00

1.1.5 Ground Water Level

Water Unit Weight : 10.0 kN/m³

Ground water influence : There is it. (convergence condition = 1.00cm)

Node No	X (m)	Y (m)
1	45.00	14.60
2	45.20	14.60
3	51.71	15.48
4	52.46	15.48
5	53.61	15.48
5	54.22	15.78
5	64.64	15.78

1.2 Common Item about Calculation

1.2.1 Calculation Condition(Common Item)

Calculation Method : Boussinesq method

Lay No.	Reduction Coefficient of Settlement
2	1.00
3	1.00

1.2.2 Shear Deformation

Calculation Method: Japan Ins of Construction Eng.
"Flexible Sluiceways"(1998)
Calculation Shape Number: 6433908
Division pitch of Calculation Shape Number: 0.0

Depth which has the influence of shear deformation

Node No	X (m)	Y (m)

layer (Form)	Modulus of deformation (kN/m²)	Load Length (m)
1	0.00	0.00
2	0.00	0.00

Execution	Modulus of deformation (kN/m²)	Load Length (m)
1	0.00	0.00

Poisson's ratio :0.00

1.2.3 Residual Condition

Calculation of Settlement Period length 60 day

1.3 Calculation of Computation Time Condition

1.3.1 Calculation Condition(Settlement Time)

History Condition :Lasped days

Calculation Period :36000 day

Output condition of Cross Section Diagram

Degree of Consolidation :100% Calculation point(X Coodinate) : 48.71m

Creation method of Time-Settlemnt Curve :Parallel Translation Method

1.3.2 Consolidation Condition

Coefficient-of-consolidation calculation method of some layers
Layer Thickness Converting Method : Parallel Translation Method

Drainage Condition

Layer (Form)	Drainage Condition
2	Sand Layer
3	Both Side

Bedrock Condition :Drained

1.4.1 Curves Record

(1)e-logP Curve
Curve 20 :Loose Sand
Interpolation Method between Data :Curve Line
Layer No. in use : 2

Number	1	2	3	4	5	6	7	8
Consolidation Stress (kN/m²)	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
Void Ratio e	0.780	0.760	0.742	0.714	0.688	0.678	0.662	0.640

Number	9	10	11	12
Consolidation Stress (kN/m²)	20.00	30.00	50.00	100.00
Void Ratio e	0.621	0.611	0.600	0.590

Curve 17 :DD-BH-R03
Interpolation Method between Data :Curve Line
Layer No. in use : 3

Number	1	2	3	4	5	6	7
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00
Void Ratio e	1.860	1.800	1.660	1.520	1.360	1.000	0.960

(2)logCv-logP Curve
Curve 4 :DD-BH-R03 (Dc3)
Interpolation Method between Data :Curve Line
Consolidation Stress Calculation Method :Geometrica
Layer No. in use : 3

Number	1	2	3	4	5	6	7
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00
Coefficient of Consolidation Cv(cm²/day)	123.00	97.00	103.00	47.00	61.00	71.00	40.00

2. Results

2.1 Results of each Points

Calculation Point 1 : Toe_of_Embankment
Calculation Depth : 45.200 m
Ground Water Level : 14.600 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	B.K.Hough	2.207	8.28	36.58	0.00	5.853
3	delta e method	10.890	60.11	19.60	0.00	24.391

Sub Total: 30.245(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	0.646	0.602	――	――	――	――	――	――
3	1.619	1.560	――	――	――	69.22	――	70.982

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point= 48.710m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	5.853	100.000	――	5.853
3	100.000	24.391	9.563	――	2.333

Sub Total: 30.245(cm) Sub Total: 8.186(cm)

Residual Settlement: 22.059(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement, it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	2.207	0.000
3	10.890	70.982

Sa = 100.00
ΔS= 22.06
Sa ≧ΔS ・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Desigining residual settlement(Total settlement) (cm)

Calculation Point 2 : Left_Crest
Calculation Depth : 46.916 m
Ground Water Level : 14.832 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	B.K.Hough	3.724	13.97	58.13	0.00	8.283
3	delta e method	10.890	71.49	21.64	0.00	21.127

Sub Total: 29.410(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	0.630	0.594	――	――	――	――	――	――
3	1.582	1.532	――	――	――	81.60	――	56.948

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point= 48.710m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	8.283	100.000	――	8.283
3	100.000	21.127	8.566	――	1.810

Sub Total: 29.410(cm) Sub Total: 10.093(cm)

Residual Settlement: 19.317(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement, it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	3.724	0.000
3	10.890	56.948

Sa = 100.00
ΔS= 19.32
Sa ≧ΔS ・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Desigining residual settlement(Total settlement) (cm)

Calculation Point 3 : Center_of_Embankment
Calculation Depth : 48.717 m
Ground Water Level : 15.076 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	B.K.Hough	4.784	17.94	48.47	0.00	8.371
3	delta e method	10.890	79.44	21.34	0.00	17.856

Sub Total: 26.227(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	0.624	0.595	----	----	----	----	----	----
3	1.561	1.519	----	----	----	89.47	----	51.345

[Immediate Sinkage] "Flexible Sluiceways"(1998)
Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00
Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]
Degree of Consolidation: 100%
(Calculation Point= 48.710m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	8.371	100.000	----	8.371
3	99.999	17.856	8.133	----	1.452

Sub Total: 26.227(cm) Sub Total: 9.824(cm)
Residual Settlement: 16.404(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	4.784	0.000
3	10.890	51.345

Sa = 100.00
ΔS= 16.40
Sa ≧ΔS ・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Desigining residual settlement(Total settlement) (cm)

Calculation Point 4 : Right_Crest
Calculation Depth : 50.517 m
Ground Water Level : 15.319 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	B.K.Hough	5.782	21.68	28.36	0.00	6.773
3	delta e method	10.890	86.93	18.90	0.00	13.964

Sub Total: 20.737(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	0.619	0.600	----	----	----	----	----	----
3	1.544	1.511	----	----	----	95.91	----	48.311

[Immediate Sinkage] "Flexible Sluiceways"(1998)
Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00
Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]
Degree of Consolidation: 100%
(Calculation Point= 48.710m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	6.773	100.000	----	6.773
3	99.999	13.964	7.889	----	1.102

Sub Total: 20.737(cm) Sub Total: 7.875(cm)
Residual Settlement: 12.862(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	5.782	0.000
3	10.890	48.311

Sa = 100.00
ΔS= 12.86
Sa ≧ΔS ・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Desigining residual settlement(Total settlement) (cm)

2.2 Degree of Consolidation - Duration in days

Calculation Point 1 : Toe_of_Embankment
Calculation Depth : 45.200 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	25	46	88	246	504	866	1349	2035	3209	---
Settlement	3.024	6.049	9.073	12.098	15.122	18.147	21.171	24.196	27.220	30.245

Layer No. : 2 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.585	1.171	1.756	2.341	2.927	3.512	4.097	4.683	5.268	5.853

Layer No. : 3 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	63	162	326	555	852	1227	1713	2399	3573	---
Settlement	2.439	4.878	7.317	9.757	12.196	14.635	17.074	19.513	21.952	24.391

Calculation Point 2 : Left_Crest
Calculation Depth : 46.916 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	19	37	54	142	408	834	1431	2285	3748	---
Settlement	2.941	5.882	8.823	11.764	14.705	17.646	20.587	23.528	26.469	29.410

Layer No. : 2 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.828	1.657	2.485	3.313	4.141	4.970	5.798	6.626	7.455	8.283

Layer No. : 3 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	71	194	398	685	1055	1522	2128	2983	4446	---
Settlement	2.113	4.225	6.338	8.451	10.564	12.676	14.789	16.902	19.014	21.127

Calculation Point 3 : Center_of_Embankment
Calculation Depth : 48.717 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	18	34	49	94	350	802	1459	2406	4028	---
Settlement	2.623	5.245	7.868	10.491	13.114	15.736	18.359	20.982	23.605	26.227

Layer No. : 2 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.837	1.674	2.511	3.348	4.186	5.023	5.860	6.697	7.534	8.371

Layer No. : 3 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	76	212	439	756	1166	1684	2357	3305	4927	---
Settlement	1.786	3.571	5.357	7.143	8.928	10.714	12.499	14.285	16.071	17.856

Calculation Point 4 : Right_Crest
Calculation Depth : 50.517 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	17	33	49	88	350	825	1521	2528	4251	---
Settlement	2.074	4.147	6.221	8.295	10.368	12.442	14.516	16.589	18.663	20.737

Layer No. : 2 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	---
Settlement	0.677	1.355	2.032	2.709	3.386	4.064	4.741	5.418	6.096	6.773

Layer No. : 3 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	79	223	464	802	1238	1788	2503	3511	5235	---
Settlement	1.396	2.793	4.189	5.586	6.982	8.378	9.775	11.171	12.567	13.964

2.3 Calculation result on the way in each construction stage

Calculation Point 1 : Toe_of_Embankment
Calculation Depth : 45.200 m
Ground Water Level : 14.600 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3					
1	0.000	70.982					

Calculation Point 2 : Left_Crest
Calculation Depth : 46.916 m
Ground Water Level : 14.832 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3					
1	0.000	56.948					

Calculation Point 3 : Center_of_Embankment
Calculation Depth : 48.717 m
Ground Water Level : 15.076 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3					
1	0.000	51.345					

Calculation Point 4 : Right_Crest
Calculation Depth : 50.517 m
Ground Water Level : 15.319 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3					
1	0.000	48.311					

Right Bank
Station. 8+600

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1. Initial Condition

Title : R_8+600

1.1 Initial Condition

1.1.1 Nodal Points Data

Node No	X (m)	Y (m)	Node No	X (m)	Y (m)	Node No	X (m)	Y (m)
1	65.30	19.87	10	45.00	14.90	19	65.30	11.77
2	58.34	19.87	11	45.00	11.77	20	47.83	9.30
3	54.38	17.89	12	45.00	9.98	21	48.54	9.98
4	53.61	17.89	13	45.00	8.97	22	50.42	11.77
5	52.98	17.89	14	45.00	4.75	23	50.45	11.80
6	52.58	18.69	15	45.00	0.00	24	51.22	12.36
7	49.08	18.76	16	65.30	0.00	25	51.76	12.68
8	48.68	18.26	17	65.30	4.75	26	52.61	13.03
9	47.00	14.90	18	65.30	9.98			

1.1.2 Layer Shape Data

Shape Number	Constitution Setting Points										Layer Type	Floor digging / Backfill
1	4	5	6	7	8	9	10	11	12	13	Embankment	don't
	20	21	22	23	24	25	26					
2	22	23	24	25	26	4	3	2	1	19	Cray	don't
3	21	22	19	18							Sand	don't
4	14	13	20	21	18	17					Cray	don't

1.1.3 Embankment Condition

Execution Stage	Shape No.	Soil Type	Saturated Unit Weight (kN/m³)	Unit Weight (kN/m³)	Construction Period start	Construction Period Finish	Embankment Removal Date	Construction Period for a second time Start day for a second time	Construction Period for a second time Finish day for a second time	Removal day for a second time
1	1	Embankment	19.5	19.0	0	60	---	---	---	---

1.1.4 Soil Condition

Layer (Shape) No	Layer Name	Calculation Method	Saturated Unit Weight (kN/m³)	Unit Weight (kN/m³)	Layer Type
2	Ac	Delta e method	15.5	15.5	Clay
3	As	B.K.Hough	17.5	17.5	Sand
4	Dc	Delta e method	18.0	18.0	Clay

Layer (Shape) No	e -logP Curve	logMv -logP Curve	logCv -logP Curve	Water Content (%)	N Value	Compression Index Cc Normal	Compression Index Cc Over	Consolidation Yield Stress Pc (kN/m²)	Increase in Preconsolidation qo(kN/m²)	t=(sqr)Tv Replaceable Coefficient (sqr)
2	14	0	1	0	0	0.00	0.00	0.00	0.00	0.00
3	20	0	0	0	0	0.00	0.00	0.00	0.00	0.00
4	18	0	5	0	0	0.00	0.00	0.00	0.00	0.00

1.1.5 Ground Water Level

Water Unit Weight : 10.0 kN/m³

Ground water influence : There is it. (convergence condition = 1.00cm)

Node No	X (m)	Y (m)
1	45.00	14.90
2	47.00	14.90
3	53.61	17.89
4	54.38	17.89
5	58.34	19.87
5	65.30	19.87

1.2 Common Item about Calculation

1.2.1 Calculation Condition(Common Item)

Calculation Method : Boussinesq method

Lay No.	Reduction Coefficient of Settlement
2	1.00
3	1.00
4	1.00

1.2.2 Shear Deformation

Calculation Method: Japan Ins of Construction Eng. "Flexible Sluiceways"(1998)
Calculation Shape Number: 6433908
Division pitch of Calculation Shape Number: 0.0

Depth which has the influence of shear deformation

Node No	X (m)	Y (m)

layer (Form)	Modulus of deformation (kN/m²)	Load Length (m)
1	0.00	0.00
2	0.00	0.00
3	0.00	0.00

Execution	Modulus of deformation (kN/m²)	Load Length (m)
1	0.00	0.00

Poisson's ratio :0.00

1.2.3 Residual Condition

Calculation of Settlement Period length 60 day

1.3 Calculation of Computation Time Condition

1.3.1 Calculation Condition(Settlement Time)

History Condition :Lasped days

Calculation Period :36000 day

Output condition of Cross Section Diagram

Degree of Consolidation :100% Calculation point(X Coodinate) : 48.71m

Creation method of Time-Settlemnt Curve :Parallel Translation Method

1.3.2 Consolidation Condition

Coefficient-of-consolidation calculation method of some layers
Layer Thickness Converting Method : Parallel Translation Method

Drainage Condition

Layer (Form)	Drainage Condition
2	Both Side
3	Sand Layer
4	Both Side

Bedrock Condition :Drained

1.4.1 Curves Record

(1)e-logP Curve
Curve 14 :DD-BH-L10
Interpolation Method between Data :Curve Line
Layer No. in use : 2

Number	1	2	3	4	5	6	7
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00
Void Ratio e	1.360	1.350	1.320	1.240	1.120	1.000	0.880

Curve 20 :Loose Sand
Interpolation Method between Data :Curve Line
Layer No. in use : 3

Number	1	2	3	4	5	6	7	8
Consolidation Stress (kN/m²)	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
Void Ratio e	0.780	0.760	0.742	0.714	0.688	0.678	0.662	0.640

Number	9	10	11	12	13
Consolidation Stress (kN/m²)	20.00	30.00	50.00	100.00	1000.00
Void Ratio e	0.621	0.611	0.600	0.590	0.580

Curve 18 :DD-BH-R13
Interpolation Method between Data :Curve Line
Layer No. in use : 4

Number	1	2	3	4	5	6	7
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00
Void Ratio e	1.860	1.800	1.660	1.520	1.360	1.000	0.960

(2)logCv-logP Curve
Curve 1 :DD-BH-L10 (Ac)
Interpolation Method between Data :Curve Line
Consolidation Stress Calculation Method :Geometrica
Layer No. in use : 2

Number	1	2	3	4	5	6	7	8
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00	800.00	1600.00
Coefficient of Consolidation Cv(cm²/day)	29.00	98.00	69.00	66.00	24.00	20.00	18.00	16.00

Curve 5 :DD-BH-R13 (Dc4)
Interpolation Method between Data :Curve Line
Consolidation Stress Calculation Method :Geometrica
Layer No. in use : 4

Number	1	2	3	4	5	6
Consolidation Stress (kN/m²)	12.00	25.00	50.00	100.00	200.00	400.00
Coefficient of Consolidation Cv(cm²/day)	580.00	110.00	55.00	120.00	80.00	60.00

2. Results

2.1 Results of each Points

Calculation Point 1 : Toe_of_Embankment
Calculation Depth : 47.000 m
Ground Water Level : 14.900 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
4	delta e method	4.453	17.81	68.32	0.00	45.687

Sub Total: 45.687(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
4	1.837	1.546	——	——	——	39.17	——	57.347

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point= 48.710m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
4	100.000	45.687	21.020	——	9.603

Sub Total: 45.687(cm) Sub Total: 9.603(cm)

Residual Settlement: 36.083(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
4	4.453	57.347

Sa = 100.00
ΔS= 36.08
Sa ≧ΔS ・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Desigining residual settlement(Total settlement) (cm)

Calculation Point 2 : Left_Crest
Calculation Depth : 49.079 m
Ground Water Level : 15.840 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
3	B.K.Hough	0.513	1.93	106.54	0.00	3.038
4	delta e method	5.230	24.77	67.47	0.00	50.027

Sub Total: 53.065(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
3	0.689	0.589	——	——	——	——	——	——
4	1.801	1.533	——	——	——	47.80	——	54.184

[Immediate Sinkage] "Flexible Sluiceways"(1998)

Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00

Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]

Degree of Consolidation: 100%

(Calculation Point= 48.710m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
3	100.000	3.038	100.000	——	3.038
4	100.000	50.027	17.397	——	8.703

Sub Total: 53.065(cm) Sub Total: 11.742(cm)

Residual Settlement: 41.324(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
3	0.513	0.000
4	5.230	54.184

Sa = 100.00
ΔS= 41.32
Sa ≧ΔS ・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Desigining residual settlement(Total settlement) (cm)

Calculation Point 3 : Center_of_Embankment
Calculation Depth : 50.829 m
Ground Water Level : 16.630 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	delta e method	0.306	0.84	90.59	0.00	3.284
3	B.K.Hough	1.790	8.39	56.97	0.00	5.419
4	delta e method	5.230	36.03	48.50	0.00	35.242

Sub Total: 43.945(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	1.524	1.253	——	——	——	8.77	——	14.546
3	0.645	0.595	——	——	——	——	——	——
4	1.733	1.549	——	——	——	55.19	——	58.999

[Immediate Sinkage] "Flexible Sluiceways"(1998)
Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00
Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]
Degree of Consolidation: 100%
(Calculation Point= 48.710m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	3.284	99.188	——	3.258
3	100.000	5.419	100.000	——	5.419
4	100.000	35.242	18.154	——	6.398

Sub Total: 43.945(cm) Sub Total: 15.075(cm)
Residual Settlement: 28.871(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	0.306	14.546
3	1.790	0.000
4	5.230	58.999

Sa = 100.00
ΔS= 28.87
Sa ≧ΔS・・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Desigining residual settlement(Total settlement) (cm)

Calculation Point 4 : Right_Crest
Calculation Depth : 52.579 m
Ground Water Level : 17.421 m

Lay No.	Calculation Method	Thickness of the Layer (m)	Effective Pressure po (kN/m²)	Stress Increment Dp (kN/m²)	Increase in Preconsolidation Loading qo(kN/m²)	Total Settlement (cm)
2	delta e method	1.247	3.43	40.68	0.00	3.035
3	B.K.Hough	1.790	13.57	31.74	0.00	3.224
4	delta e method	5.230	41.21	31.02	0.00	24.006

Sub Total: 30.264(cm)

Lay No.	e0	e1	Mv (cm²/kN)	Cc1	Cc2	SQRT(po(po+Dp)) (kN/m²)	po+Dp/2 (kN/m²)	Cv (cm²/day)
2	1.387	1.329	——	——	——	12.30	——	30.715
3	0.631	0.602	——	——	——	——	——	——
4	1.704	1.580	——	——	——	54.55	——	58.380

[Immediate Sinkage] "Flexible Sluiceways"(1998)
Sub Total(Immediate Sinkage) : 0.000(cm)

[Side Sinkage] "Flexible Sluiceways"(1998) Poisson's ratio : 0.00
Sub Total(Side Sinkage) : 0.000(cm)

[Cross Section Diagram] [Residual Settlement]
Degree of Consolidation: 100%
(Calculation Point= 48.710m) Duration of a period: 60days

Lay No.	Degree of Consolidation (%)	Settlement (cm)	Degree of Consolidation of the period(%) Settlement	Unit Layer	Settlement of the period (cm)
2	100.000	3.035	54.774	——	1.662
3	100.000	3.224	100.000	——	3.224
4	100.000	24.006	18.058	——	4.335

Sub Total: 30.264(cm) Sub Total: 9.221(cm)
Residual Settlement: 21.043(cm)

※When the amount of the immediate sinkage is included in the amount of the total settlement,it doesn't become output (consolidation × total settlement = settlement).

Thinkness of the combined clay layers

Lay No.	Thinkness of the combined clay layers	Cv of the combined layer
2	1.247	30.715
3	1.790	0.000
4	5.230	58.380

Sa = 100.00
ΔS= 21.04
Sa ≧ΔS・・・・・・・・・・・・・・・・・・ OK

Sa : Allowance residual settlement(cm)
ΔS : Desigining residual settlement(Total settlement) (cm)

2.2 Degree of Consolidation - Duration in days

Calculation Point 1 : Toe_of_Embankment
Calculation Depth : 47.000 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	37	59	92	139	201	278	379	521	764	----
Settlement	4.569	9.137	13.706	18.275	22.843	27.412	31.981	36.549	41.118	45.687

Layer No. : 4 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	37	59	92	139	201	278	379	521	764	----
Settlement	4.569	9.137	13.706	18.275	22.843	27.412	31.981	36.549	41.118	45.687

Calculation Point 2 : Left_Crest
Calculation Depth : 49.079 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	34	56	96	162	249	362	509	716	1071	----
Settlement	5.307	10.613	15.920	21.226	26.533	31.839	37.146	42.452	47.759	53.065

Layer No. : 3 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	----
Settlement	0.304	0.608	0.911	1.215	1.519	1.823	2.127	2.431	2.734	3.038

Layer No. : 4 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	42	70	120	189	279	392	539	746	1101	----
Settlement	5.003	10.005	15.008	20.011	25.014	30.016	35.019	40.022	45.024	50.027

Calculation Point 3 : Center_of_Embankment
Calculation Depth : 50.829 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	22	39	54	88	160	260	394	584	910	----
Settlement	4.395	8.789	13.184	17.578	21.973	26.367	30.762	35.156	39.551	43.945

Layer No. : 2 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	10	16	22	27	33	38	44	49	55	----
Settlement	0.328	0.657	0.985	1.314	1.642	1.971	2.299	2.628	2.956	3.284

Layer No. : 3 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	----
Settlement	0.542	1.084	1.626	2.168	2.710	3.252	3.793	4.335	4.877	5.419

Layer No. : 4 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	41	67	112	176	259	362	497	688	1013	----
Settlement	3.524	7.048	10.573	14.097	17.621	21.145	24.669	28.193	31.718	35.242

Calculation Point 4 : Right_Crest
Calculation Depth : 52.579 m
Overall Degree of Consolidation

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	26	44	60	98	162	258	393	585	914	----
Settlement	3.026	6.053	9.079	12.105	15.132	18.158	21.185	24.211	27.237	30.264

Layer No. : 2 soil name : Ac

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	20	31	41	49	57	67	82	102	138	----
Settlement	0.303	0.607	0.910	1.214	1.517	1.821	2.124	2.428	2.731	3.035

Layer No. : 3 Immediate Sinkage(calculated by B.K.Hough or DeBeer), soil name : As

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	6	12	18	24	30	36	42	48	54	----
Settlement	0.322	0.645	0.967	1.289	1.612	1.934	2.256	2.579	2.901	3.224

Layer No. : 4 soil name : Dc

Deg. of Consolidation	10	20	30	40	50	60	70	80	90	100
Duration	41	67	113	178	261	366	502	695	1024	----
Settlement	2.401	4.801	7.202	9.602	12.003	14.403	16.804	19.205	21.605	24.006

2.3 Calculation result on the way in each construction stage

Calculation Point 1 : Toe_of_Embankment
Calculation Depth : 47.000 m
Ground Water Level : 14.900 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	4						
1	57.347						

Calculation Point 2 : Left_Crest
Calculation Depth : 49.079 m
Ground Water Level : 15.840 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	3	4					
1	0.000	54.184					

Calculation Point 3 : Center_of_Embankment
Calculation Depth : 50.829 m
Ground Water Level : 16.630 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4				
1	14.546	0.000	58.999				

Calculation Point 4 : Right_Crest
Calculation Depth : 52.579 m
Ground Water Level : 17.421 m

Cv value of each construction stage in each layer (cm2/day)

	Layer No.						
Loading	2	3	4				
1	30.715	0.000	58.380				

CHAPTER 2 Drainage Structure

2.1 Manhole

2.1.1 Conditions and Outline of Structural Analysis of Manhole

(1) Conditions for Structural Calculation

Conditions for structural calculation are as follows.

(a) Condition

Materials	f'_{ck} (N/mm^2)	E_c 10^4 (N/mm^2)
20.7	20.7	2.380

Unit weight (Reinforced concrete) γc = 24.50 (kN/m^3)
Unit weight (Reinforced concrete (submerged)) $\gamma c'$ = 14.50 (kN/m^3)

(b) Specification of Reinforcing Bar

Grade	F_{yk} (N/mm^2)	$E_s \times 10^5$ (N/mm^2)
275	275	2.000

(c) Groundwater Level

Depth (H): 0.0 (m) from ground surface
Unit weight of water: 10.0 (kN/m^3)

(d) Conditions for Earth Pressure

Depth Z (m)	Unit weight (Wet) γ (kN/m^3)	Unit weight (saturated) γ_{sat} (kN/m^3)	Coefficient for earth pressure at rest K	Coefficient for vertical pressure α
10.000	18.000	20.000	0.5000	1.0000

(e) Live Load

Considering the usage of normal vehicles, following conditions are applied as live load.

Vehicle: T-14, 55.0 (kN)

Impact Coefficient: 0.300

Uniform Load: 10.0 (kN/m^2)

(2) Categorizing and Selection of Calculation Model Type

Manholes designed in this project can be categorized into several types of calculation models based on similarity in proportion, as all manholes have no soil coverage so that difference of load conditions is ignorable. Following tables explain categorization of all manholes and determination of dimensions of each calculation model in consideration of maximum sizes of manholes categorized.

Table 2.1.1 Grouping of Manholes and Selection of Calculation Model Type (1/2)

Name of MH	Values from Drawings				Dimensions of Calc. Model				Model Type
	Vd1 (mm)	Vd2 (mm)	H (mm)	Opening w (mm)	Vd1 (mm)	Vd2 (mm)	H (mm)	w (mm)	
MR141	1200	1200	1470	300	1500	2400	2000	300	a
MR124A	2000	1400	1650	900	1500	2400	2000	900	a
MR147A	1200	1200	1971	300	1500	2400	2000	300	a
ML104.5	1500	2350	2000	900	1500	2400	2000	900	a
MR015A	1200	1400	2248	900	1200	1400	3000	900	b
ML058.2	1200	1400	2300	900	1200	1400	3000	900	b
ML018	1200	1400	2300	900	1200	1400	3000	900	b
ML015	1200	1400	2300	900	1200	1400	3000	900	b
ML013	1200	1400	2300	900	1200	1400	3000	900	b
ML012.2	1200	1400	2300	900	1200	1400	3000	900	b
ML012	1200	1400	2300	900	1200	1400	3000	900	b
ML011.1	1200	1400	2300	900	1200	1400	3000	900	b
MR151C	1200	1400	2300	900	1200	1400	3000	900	b
ML017.2	1200	1400	2400	900	1200	1400	3000	900	b
ML016	1200	1400	2400	900	1200	1400	3000	900	b
ML012.201	1200	1400	2488	900	1200	1400	3000	900	b
MR003.10	1200	1400	2493	900	1200	1400	3000	900	b
ML017	1200	1400	2545	900	1200	1400	3000	900	b
ML050.2	1200	1400	2674	900	1200	1400	3000	900	b
MR136	1200	1400	2700	900	1200	1400	3000	900	b
ML004	1200	1400	2774	900	1200	1400	3000	900	b
MR137 & MR138	1200	1435	2782	900	1200	1400	3000	900	b
ML012.3	1200	1400	2801	900	1200	1400	3000	900	b
MR021.302	1200	1400	2948	900	1200	1400	3000	900	b
MR003.1	1200	1400	2976	900	1200	1400	3000	900	b
MR021.3	1200	1400	3080	900	1200	1400	3000	900	b
ML097A	1200	2300	2751	1000	1200	2600	3000	1000	c
ML022A	1200	2580	2967	1050	1200	2600	3000	1050	c
MR021.1	1200	1580	2915	1050	1500	2100	3000	1050	d
ML005	1200	1700	2740	1000	1500	2100	3000	1000	d
MR144	1200	1825	2320	900	1500	2100	3000	900	d
ML104.2	1500	2050	2891	900	1500	2100	3000	900	d
ML104.3	1500	2050	2968	900	1500	2100	3000	900	d
ML104.4	1500	2050	2993	900	1500	2100	3000	900	d
MR023	1200	1400	3134	900	1200	1400	4000	900	e
MR004.3	1200	1400	3239	900	1200	1400	4000	900	e
MR002A	1200	1400	3272	900	1200	1400	4000	900	e
MR021.2	1200	1400	3309	900	1200	1400	4000	900	e
MR022	1200	1400	3413	900	1200	1400	4000	900	e
MR003	1200	1400	3591	900	1200	1400	4000	900	e
ML100	1200	1400	3643	900	1200	1400	4000	900	e
MR001A	1200	1400	3794	900	1200	1400	4000	900	e
ML103	1200	1400	3817	900	1200	1400	4000	900	e
ML101	1200	1400	3817	900	1200	1400	4000	900	e
ML064.1	1200	1400	3959	900	1200	1400	4000	900	e
MR090	1000	1580	3203	1050	1200	2000	4000	1050	f
ML065A	1200	1580	3779	1050	1200	2000	4000	1050	f
ML062.3D	1200	1750	3122	1200	1200	2000	4000	1200	f
ML061.2	1200	2000	3700	900	1200	2000	4000	900	f
ML087.1	1200	2300	3256	1000	2000	2500	4000	1000	g
MR009.1	1200	2450	3600	1800	2000	2500	4000	1800	g
MR025.1	1200	2450	3715	1800	2000	2500	4000	1800	g
ML087.2	1200	2500	3649	1000	2000	2500	4000	1000	g
ML087A	1200	2500	3717	1000	2000	2500	4000	1000	g
ML087C	1200	2500	3717	1000	2000	2500	4000	1000	g
ML087D	1200	2500	3773	1000	2000	2500	4000	1000	g
MR125A	1400	2200	3525	1000	2000	2500	4000	1000	g
ML104.1	1500	2050	3182	900	2000	2500	4000	900	g
ML009	1500	2100	3115	1500	2000	2500	4000	1500	g
MR024	2000	2000	3857	1400	2000	2500	4000	1400	g

Source: JICA Study Team

Table 2.1.2 Grouping of Manholes and Selection of Calculation Model Type (2/2)

Name of MH	Values from Drawings				Dimensions of Calc. Model			
	Vd1 (mm)	Vd2 (mm)	H (mm)	Opening w (mm)	Vd1 (mm)	Vd2 (mm)	H (mm)	w (mm)
MR003.5	1200	1200	4103	300	1200	1400	5000	300
MR003.105	1200	1200	4189	300	1200	1400	5000	300
MR004.1	1200	1200	4341	300	1200	1400	5000	300
MR151D	1200	1400	4415	900	1200	1400	5000	900
ML064.2	1200	1400	4418	900	1200	1400	5000	900
MR021.301	1200	1400	4596	900	1200	1400	5000	900
MR020	1200	1400	4637	900	1200	1400	5000	900
MR015.2	1200	1400	4886	900	1200	1400	5000	900
ML012.1	1200	1750	4138	1200	1200	2100	5000	1200
MR004A	1200	1750	4265	1200	1200	2100	5000	1200
MR059	1200	2130	4947	900	1200	2100	5000	900
MR073	1200	2340	4322	1000	2000	2700	5000	1000
MR072.1	1200	2340	4482	1000	2000	2700	5000	1000
ML099	1200	2450	4970	1800	2000	2700	5000	1800
ML087B	1200	2500	4298	1000	2000	2700	5000	1000
MR074	1200	2500	4877	1000	2000	2700	5000	1000
MR047	1200	2600	4977	900	2000	2700	5000	900
MR047.1	1200	2600	4977	900	2000	2700	5000	900
ML091.1	1200	2700	4211	1200	2000	2700	5000	1200
MR067A	1200	2700	4400	1200	2000	2700	5000	1200
ML017.1	2000	2500	4917	2000	2000	2700	5000	2000
MR025	2000	2700	4894	2000	2000	2700	5000	2000
ML061.3	900	1400	5979	900	1200	1400	6000	900
MR014	1000	1400	5663	900	1200	1400	6000	900
MR115	1200	1200	5230	300	1200	1400	6000	300
MR015.101	1200	1400	5040	900	1200	1400	6000	900
ML066.101	1200	1730	5106	900	2000	1400	6000	900
MR048	1200	2550	5011	900	2000	1400	6000	900
MR021	2000	1400	5188	900	2000	1400	6000	900
MR151	2000	1400	5290	900	2000	1400	6000	900
MR019	2000	1400	5315	900	2000	1400	6000	900
MR058.1	2000	1400	5788	900	2000	1400	6000	900
MR071	2000	1400	5905	900	2000	1400	6000	900
MR056	2000	1400	5979	900	2000	1400	6000	900
ML102	2000	1400	5994	900	2000	1400	6000	900
MR053	2000	1400	6001	900	2000	1400	6000	900
MR072	2000	2300	5385	1000	2100	2600	6000	1000
MR057	2000	2600	5464	900	2100	2600	6000	900
MR054	2100	1400	5568	900	2100	2600	6000	900
ML066.4	2100	1580	5528	1050	2100	2600	6000	1050
MR122	2100	1700	5916	900	2100	2600	6000	900
MR009A	2100	2300	5813	1000	2100	2600	6000	1000
MR069	2000	1400	6274	900	2100	1800	7000	900
MR116	2100	1750	6239	1200	2100	1800	7000	1200
MR043.39	2100	1750	6398	1200	2100	1800	7000	1200
MR032.501	2100	1750	6511	1200	2100	1800	7000	1200
ML068B	2000	2300	6384	1000	2100	2300	7000	1000
ML068A	2000	2300	6823	1000	2100	2300	7000	1000
ML068D	2000	2300	6905	1000	2100	2300	7000	1000
ML068C	2000	2300	6944	1000	2100	2300	7000	1000
MR120	2100	2050	6239	1200	2100	2300	7000	1200
ML068	2100	2300	6905	1000	2100	2300	7000	1000
ML072A	2100	2500	6100	900	1200	3000	7000	900
MR055	2100	2700	6268	1500	1200	3000	7000	1500
ML061.4	2100	2800	6505	900	1200	3000	7000	900
ML097.3	1200	2950	6393	1200	1200	3000	7000	1200
MR067.1	2000	1400	7306	900	2100	1400	8000	900
MR030	2000	1400	7634	900	2100	1400	8000	900
MR027	2000	1400	7646	900	2100	1400	8000	900
MR029	2100	1400	7646	900	2100	1400	8000	900
MR028	2100	1400	7646	900	2100	1400	8000	900
ML073.3	2100	3130	7123	1800	2100	3200	8000	1800
ML098	2100	3220	7687	1500	2100	3200	8000	1500
ML097.4	2100	2800	7945	1200	2100	3200	8000	1200
ML020 & ML021	1200	3200	2552	2x900	1200	2600	3000	2x900
ML019 & ML019.1	1200	3800	4697	2X1200	2000	4150	6000	2X1200
MR007 & MR008	2000	4150	5362	2x1200	2000	4150	6000	2x1200
ML062A ML062.1 M	1200	5850	4785	3X1200	1200	5850	5000	3X1200

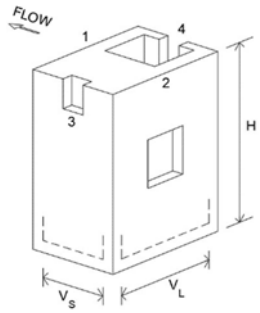
Source: JICA Study Team

(3) Analysis Method of Manholes

In structural analysis, each member of manholes, namely top slab, bottom slab and side walls, can be calculated as an independent slab element. Slab analysis method can be selected considering proportion and support conditions of each member.

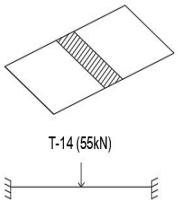
Table 2.1.3 Adopted Slab Analysis Method by Members

Calc. Type	Dimension of Calculation Model						Calculation Method by Member											
	Vd(1)	Vd(2)	H	Opening		GL-WL	Top Slab			Bottom Slab			Side Slab (Short Side)			Side Slab (Long Side)		
	(mm)	(mm)	(mm)	width (mm)	height (mm)	(mm)	Short side	Long side	Method	Short side	Long side	Method	B	H	Method	B	H	Method
a	1,500	2,400	2000	300	300	1,162	1500	2400	2 side	1500	2400	4 side	1500	2000	4 side	2400	2000	4 side
b	1,200	1,400	3000	900	900	757	1200	1400	2 side	1200	1400	4 side	1200	3000	2 side	1400	3000	2 side
c	1,200	2,600	3000	1000	1000	616	1200	2600	2 side	1200	2600	4 side	1200	3000	2 side	2600	3000	4 side
d	1,500	2,100	3000	1050	1050	933	1500	2100	2 side	1500	2100	4 side	1500	3000	4 side	2100	3000	4 side
e	1,200	1,400	4000	900	900	1,141	1200	1400	2 side	1200	1400	4 side	1200	4000	2 side	1400	4000	2 side
f	1,200	2,000	4000	1050	1050	1,214	1200	2000	2 side	1200	2000	4 side	1200	4000	2 side	2000	4000	2 side
g	2,000	2,500	4000	1000	1000	616	2000	2500	2 side	2000	2500	4 side	2000	4000	4 side	2500	4000	4 side
h	1,200	1,400	5000	300	300	986	1200	1400	2 side	1200	1400	4 side	1200	5000	2 side	1400	5000	2 side
i	1,200	2,100	5000	1200	1200	1,274	1200	2100	2 side	1200	2100	4 side	1200	5000	2 side	2100	5000	2 side
j	2,000	2,700	5000	1000	1000	800	2000	2700	2 side	2000	2700	4 side	2000	5000	2 side	2700	5000	4 side
k	1,200	1,400	6000	900	900	1,744	1200	1400	2 side	1200	1400	4 side	1200	6000	2 side	1400	6000	2 side
l	2,000	1,400	6000	900	900	1,508	1400	2000	2 side	1400	2000	4 side	2000	6000	2 side	1400	6000	2 side
m	2,100	2,600	6000	1000	1000	1,700	2100	2600	2 side	2100	2600	4 side	2100	6000	2 side	2600	6000	2 side
n	2,100	1,800	7000	900	900	2,005	1800	2100	2 side	1800	2100	4 side	2100	7000	2 side	1800	7000	2 side
o	2,100	2,300	7000	1000	1000	1,382	2100	2300	2 side	2100	2300	4 side	2100	7000	2 side	2300	7000	2 side
p	1,200	3,000	7000	900	900	884	1200	3000	2 side	1200	3000	2 side	1200	7000	2 side	3000	7000	2 side
q	2,100	1,400	8000	900	900	2,012	1400	2100	2 side	1400	2100	4 side	2100	8000	2 side	1400	8000	2 side
r	2,100	3,200	8000	1800	1800	945	2100	3200	2 side	2100	3200	4 side	2100	8000	2 side	3200	8000	2 side
s	1,200	2,600	3000	2x900	2x900	1,685	1200	2600	2 side	1200	2600	4 side	1200	3000	2 side	2600	3000	4 side
t	2,000	4,150	6000	2X1200	2X1200	1,301	2000	4150	2 side	2000	4150	4 side	2000	6000	2 side	4150	6000	4 side
u	1,200	5,850	5000	3X1200	3X1200	1,478	1200	5850	2 side	1200	5850	2 side	1200	5000	2 side	5850	5000	4 side



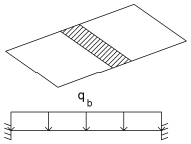
Top Slab

[1way slab]



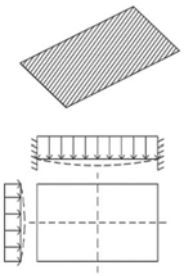
Bottom Slab

[1way slab]



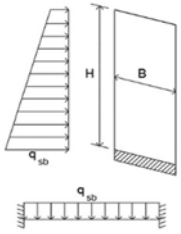
[2way slab]

(V_L/V_S < 2.5)



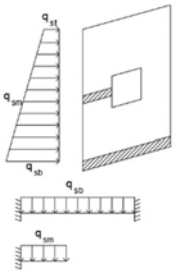
Side Slab (3,4)

[1way slab]



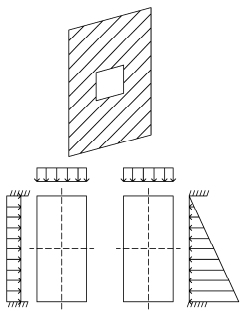
Side Slab (1,2)

[1way slab]



[2way slab]

(V_L/H < 2.5 and 0.4*V_L>Opening)



Source: JICA Study Team

(4) Summary of Load Calculation

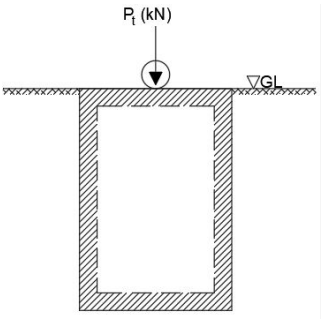
1) Top Slab

Rear wheel load charged to manhole top slabs is considered as uniform load with soil coverage. However, in this project all manhole top slabs are exposed to road surface so that point load P can be loaded directly as rear wheel load.

Rear wheel Load :

$$P = \frac{(2 \text{ x Rear wheel (kN)})}{\text{Width of vehicle x } (1 + \text{Impact factor})}$$

$$= (2 \text{ x } 55) / 2.75 \text{ x } (1+0.30) = 52.0 \text{ kN}$$



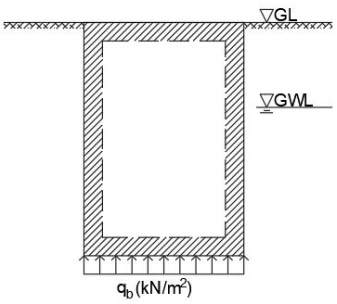
2) Bottom Slab

For bottom slab, uniform load of ground reaction force shall be applied while sidewalls are functioned as perimeter support. Ground reaction force is obtained by summation of self-weight, soil coverage and live load at top slab by following equation.

$Wb = (W+Ws)/A+Pv1$

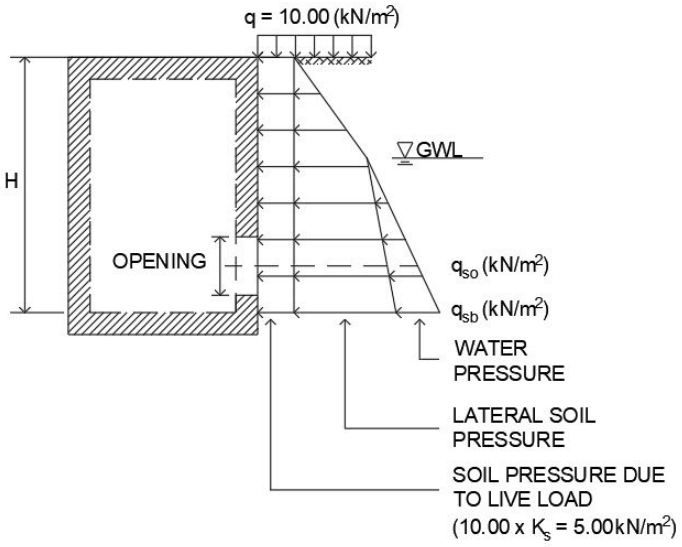
Where,

W : Self-Weight
Ws : Weight of Soil Coverage (=0.0(kN/m^2))
A : Area of Bottom Slab (m)
Pv1 : Live Load at Ground Surface(=10.0(kN/m^2)



3) Side Wall

Lateral soil pressure and ground water pressure shall be considered for side walls. Effect of traffic load at ground surface shall be added to lateral soil pressure as shown in Figure 7.2.3. Since manholes are located at back of river dike, residual water level (RWL) is applied as ground water level.



Source: JICA Study Team

Figure 2.1.1 Live load charged to Side Wall

4) Middle Slab

Middle slab, or platform is constructed for maintenance staff to access safely to bottom floor of manhole. Thus, pedestrian Load of 5kN/m^2 shall be considered for middle slab.

(5) Summary of Calculation Results and Bar Arrangement

Summerly of calculation results are shown in the table below. Details of structural calculations of each calculation model type are shown in Appendix.

Table 2.1.4 Summary of Bar Schedule

Calc. Type	Thickness			Bar Schedule								
	Top Slab	Bottom Slab	Side Wall	Top Slab		Bottom Slab		Side Wall				
								Horizontal		Vertical		Shear
	ts (mm)	tb (mm)	tw (mm)	Top Bar	Bottom Bar	Top Bar	Bottom Bar	Outer Bar	Inner Bar	Outer Bar	Inner Bar	Reinforcing Bar
a	250	300	300	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	-
b	250	300	300	D12 @250	D12 @250	D12 @250	D12 @250	D12 @250	D12 @250	D12 @250	D12 @250	-
c	250	300	300	D12 @250	D12 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-
d	250	300	300	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	-
e	250	300	300	D12 @250	D12 @250	D12 @250	D12 @250	D12 @250	D12 @250	D12 @250	D12 @250	-
f	250	300	300	D12 @250	D12 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	-
g	250	350	350	D16 @250	D16 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-
h	250	300	300	D12 @250	D12 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	-
i	250	350	350	D12 @250	D12 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-
j	250	400	400	D16 @250	D16 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-
k	250	300	300	D12 @250	D12 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	-
l	250	400	400	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	-
m	250	450	450	D16 @250	D16 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-
n	250	400	400	D16 @250	D16 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-
o	250	450	400	D16 @250	D16 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-
p	250	500	500	D16 @250	D16 @250	D25 @250	D25 @250	D25 @250	D25 @250	D25 @250	D25 @250	-
q	250	400	400	D16 @250	D16 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-
r	250	600	600	D16 @250	D16 @250	D25 @250	D25 @250	D25 @250	D25 @250	D25 @250	D25 @250	-
s	250	300	300	D12 @250	D12 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	D16 @250	-
t	250	550	550	D16 @250	D16 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-
u	250	550	550	D16 @250	D16 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	D20 @250	-

Source: JICA Study Team

2.1.2 Calculation Details by Manhole Type

The calculation sheets of each manhole type are shown from next page by following order.

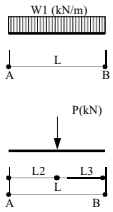
2.1.2.1 MANHOLE TYPE A
2.1.2.2 MANHOLE TYPE B
2.1.2.3 MANHOLE TYPE C
2.1.2.4 MANHOLE TYPE D
2.1.2.5 MANHOLE TYPE E
2.1.2.6 MANHOLE TYPE F
2.1.2.7 MANHOLE TYPE H
2.1.2.8 MANHOLE TYPE I
2.1.2.9 MANHOLE TYPE J
2.1.2.10 MANHOLE TYPE K
2.1.2.11 MANHOLE TYPE L
2.1.2.12 MANHOLE TYPE M
2.1.2.13 MANHOLE TYPE N
2.1.2.14 MANHOLE TYPE O
2.1.2.15 MANHOLE TYPE P
2.1.2.16 MANHOLE TYPE Q
2.1.2.17 MANHOLE TYPE R
2.1.2.18 MANHOLE TYPE S
2.1.2.19 MANHOLE TYPE T
2.1.2.21 MANHOLE TYPE U

2.1.2.1 MANHOLE TYPE A

Type a

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.500 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

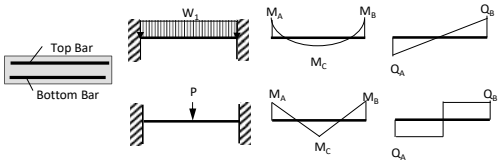
P = 52.000 kN : Point Load

L2 = 0.750 m L3 = 0.750 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN･m) for top bars	M(kN･m) for bottom bars	Q(kN)
W1+w	2.25	1.13	8.00
P	9.75	9.75	26.00
Total	12.00	10.88	34.00



1

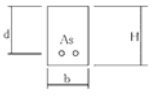
Type a

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm



Bending Moment	M =	12.00	kN・m
Shear Force	S =	34.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.136	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	87.756	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.200	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 313.59854

σ s = (M*10^5)/(b*d^2*p*j)

= 8775.60927

τ= (S*10^3)/(b*j*d)

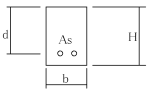
= 20.00078

2

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm



Bending Moment	M =	10.88	kN・m
Shear Force	S =	34.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.843	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	79.566	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.200	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 284.32934

σ s = (M*10^5)/(b*d^2*p*j)

= 7956.55240

τ= (S*10^3)/(b*j*d)

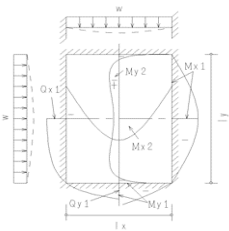
= 20.00078

3

Type a

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.500 m

ly = 2.400 m

B×D = 100 × 30 cm

②Load Conditions

w = 41.200 kN/m : Uniform Load

ΣW = 41.20 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.6

α for Mx2 = 0.036

α for Mx1 = 0.078

α for Qx1 = 0.520

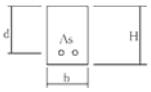
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	3.34	7.24	32.14

Type a

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter 16 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 3.34 kN・m

Shear Force S = 32.14 kN

Width of Member b = 100.0 cm

Height of Member H = 30.0 cm

Equivalent Height (Tensile Side) d = 20.000 cm

Total Cross-Sectional (Tensile Side) A_s = 8.044 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 0.770 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 22.528 N/mm^2 ○

Shearing Stress of Concrete τ = 0.174 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 77.01635

σ s = (M*10^5)/(b*d^2*p*j)

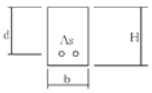
= 2252.76683

τ= (S*10^3)/(b*j*d)

= 17.43764

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter 16 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 7.24 kN・m

Shear Force S = 32.14 kN

Width of Member b = 100.0 cm

Height of Member H = 30.0 cm

Equivalent Height (Tensile Side) d = 20.000 cm

Total Cross-Sectional (Tensile Side) A_s = 8.044 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 1.669 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 48.832 N/mm^2 ○

Shearing Stress of Concrete τ = 0.174 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 166.94562

σ s = (M*10^5)/(b*d^2*p*j)

= 4883.24307

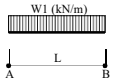
τ= (S*10^3)/(b*j*d)

= 17.43764

Type a

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.500 m

B×D = 100 × 30 cm

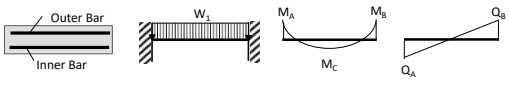
②Load Conditions

W1 = 28.609 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 28.61 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	5.37	2.69	18.00
Total	5.37	2.69	18.00

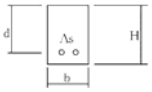


Type a

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	5.37	kN・m
Shear Force	S =	18.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.238	N/mm^2 ○
Tensile Stress of Reinforcing Bar	σs=	36.220	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.098	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Reinforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) = 0.00402

k = √(2*n*p+(n*p)^2)-n*p = 0.2352910

j = 1-(k/3) = 0.92157

σc = (2*M*10^5)/(b*d^2*k*j) = 123.82569

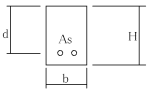
σs = (M*10^5)/(b*d^2*p*j) = 3621.96344

τ = (S*10^3)/(b*j*d) = 9.76595

x = k*d = 4.706

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	2.69	kN・m
Shear Force	S =	18.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.620	N/mm^2 ○
Tensile Stress of Reinforcing Bar	σs=	18.144	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.098	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Reinforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) = 0.00402

k = √(2*n*p+(n*p)^2)-n*p = 0.23529

j = 1-(k/3) = 0.92157

σc = (2*M*10^5)/(b*d^2*k*j) = 62.02814

σs = (M*10^5)/(b*d^2*p*j) = 1814.35412

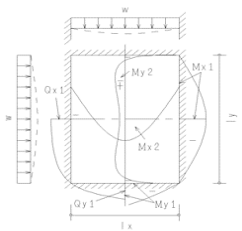
τ = (S*10^3)/(b*j*d) = 9.76595

x = k*d = 4.706

Type a

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q by Uniform Load】



①Dimensional Conditions

lx = 1.750 m

ly = 2.400 m

B×D = 100 × 30 cm

②Load Conditions

w = 6.250 kN/m : Uniform Load

ΣW = 6.25 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

ly/lx	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.4

α for Mx1 = 0.072

α for My1 = 0.056

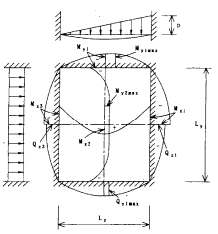
α for Qy1 = 0.460

Load	Mx1 (kN・m)	My1 (kN・m)	Q(kN)
Uniform	1.38	1.08	5.04

Type a

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.750 m

ly = 2.400 m

B×D = 100 × 30 cm

②Load Conditions

p = 22.359 kN/m : Triangle Load

(= 28.61 - 6.25)

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Ly/Lx	Mx1	Mx1max	My1	Qx1	Qy1
1.0	0.034			0.33	
1.1	0.037			0.34	
1.2	0.04			0.35	
1.3	0.043			0.35	
1.4	0.045			0.35	
1.5	0.046			0.35	
1.6	0.046			0.35	
1.7	0.047			0.35	
1.8	0.048			0.35	
1.9	0.049			0.35	
2.0	0.049			0.35	

Iy/Ix = 1.4

α for Mx1max = 0.045

α for My1 = 0.000

α for Qy1 = 0.350

Load	Mx1max (kN・m)	My1 (kN・m)	Q(kN)
Triangle	3.09	0.00	13.70

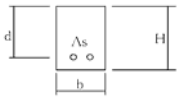
Load	M@side center (kN・m)	M@bottom end (kN・m)	Q(kN)
Uniform	1.38	1.08	5.04
Triangle	3.09	0.00	13.70
Total	4.47	1.08	18.74

Type a

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	4.47	kN・m	
Shear Force	S =	18.74	kN	
Width of Member	b =	100.0	cm	
Height of Member	H =	30.0	cm	
Equivalent Height （Tensile Side）	d =	20.000	cm	
Total Cross-Sectional （Tensile Side）	A_s =	8.044	cm^2	
Modulous of Elasticity	n =	9.000		
Compressive Stress of Concrete	σc=	1.031	N/mm^2	○
Tensile Stress of Rainforcing Bar	σs=	30.149	N/mm^2	○
Shearing Stress of Concrete	τ =	0.102	N/mm^2	○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d)
= 0.00402

x = k*d
= 4.706

k = √(2*n*p+(n*p)^2)-n*p
= 0.23529

j = 1-(k/3)
= 0.92157

σc = (2*M*10^5)/(b*d^2*k*j)
= 103.07278

σs = (M*10^5)/(b*d^2*p*j)
= 3014.93046

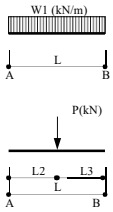
τ= (S*10^3)/(b*j*d)
= 10.16744

2.1.2.2 MANHOLE TYPE B

Type b

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

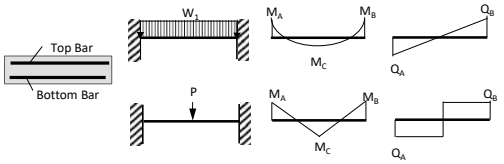
P = 52.000 kN : Point Load

L2 = 0.600 m L3 = 0.600 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN･m) for top bars	M(kN･m) for bottom bars	Q(kN)
W1+w	1.44	0.72	6.00
P	7.80	7.80	26.00
Total	9.24	8.52	32.00



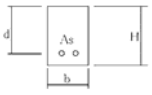
1

Type b

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	9.24	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.050	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	117.823	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 304.98173

σ s = (M*10^5)/(b*d^2*p*j)

= ##########

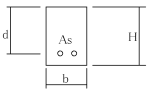
τ= (S*10^3)/(b*j*d)

= 18.45994

2

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	8.52	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.812	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	108.642	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 281.21692

σ s = (M*10^5)/(b*d^2*p*j)

= ##########

τ= (S*10^3)/(b*j*d)

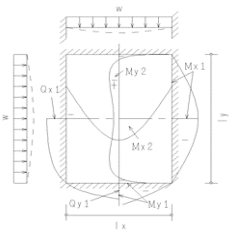
= 18.45994

3

Type b

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.200 m

ly = 1.400 m

B×D = 100 × 30 cm

②Load Conditions

w = 58.400 kN/m : Uniform Load

ΣW = 58.40 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.2

α for Mx2 = 0.025

α for Mx1 = 0.064

α for Qx1 = 0.490

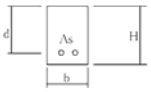
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	2.11	5.39	34.34

Type b

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter 12 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 2.11 kN・m

Shear Force S = 34.34 kN

Width of Member b = 100.0 cm

Height of Member H = 30.0 cm

Equivalent Height (Tensile Side) d = 20.000 cm

Total Cross-Sectional (Tensile Side) A_s = 4.524 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 0.616 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 24.830 N/mm^2 ○

Shearing Stress of Concrete τ = 0.183 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00226 = 3.649

k = √(2*n*p+(n*p)^2)-n*p

= 0.18245

j = 1-(k/3)

= 0.93918

σ c = (2*M*10^5)/(b*d^2*k*j)

= 61.56894

σ s = (M*10^5)/(b*d^2*p*j)

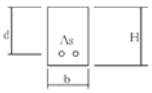
= 2483.01444

τ= (S*10^3)/(b*j*d)

= 18.28183

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter 12 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 5.39 kN・m

Shear Force S = 34.34 kN

Width of Member b = 100.0 cm

Height of Member H = 30.0 cm

Equivalent Height (Tensile Side) d = 20.000 cm

Total Cross-Sectional (Tensile Side) A_s = 4.524 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 1.573 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 63.429 N/mm^2 ○

Shearing Stress of Concrete τ = 0.183 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00226 = 3.649

k = √(2*n*p+(n*p)^2)-n*p

= 0.18245

j = 1-(k/3)

= 0.93918

σ c = (2*M*10^5)/(b*d^2*k*j)

= 157.27802

σ s = (M*10^5)/(b*d^2*p*j)

= 6342.86626

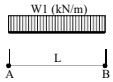
τ= (S*10^3)/(b*j*d)

= 18.28183

Type b

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 30 cm

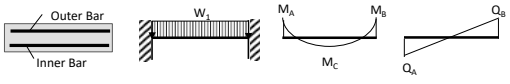
②Load Conditions

W1 = 52.520 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 52.52 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	6.31	3.16	24.00
Total	6.31	3.16	24.00

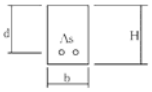


Type b

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	6.31	kN・m
Shear Force	S =	24.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.841	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	74.255	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.128	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

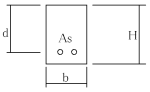
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00226 = 3.649
k = √(2*n*p+(n*p)^2)-n*p
= 0.1824484
j = 1-(k/3)
= 0.93918
σc = (2*M*10^5)/(b*d^2*k*j)
= 184.12324
σs = (M*10^5)/(b*d^2*p*j)
= 7425.50762
τ = (S*10^3)/(b*j*d)
= 12.77705

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	3.16	kN・m
Shear Force	S =	24.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.922	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	37.186	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.128	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

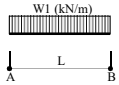
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00226 = 3.649
k = √(2*n*p+(n*p)^2)-n*p
= 0.18245
j = 1-(k/3)
= 0.93918
σc = (2*M*10^5)/(b*d^2*k*j)
= 92.20752
σs = (M*10^5)/(b*d^2*p*j)
= 3718.63773
τ = (S*10^3)/(b*j*d)
= 12.77705

Type b

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.400 m

B×D = 100 × 30 cm

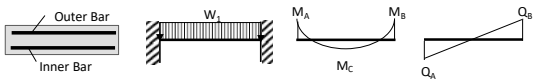
②Load Conditions

W1 = 52.520 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 52.52 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	8.58	4.29	29.00
Total	8.58	4.29	29.00

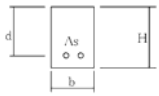


Type b

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	8.58	kN・m
Shear Force	S =	29.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.504	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	100.968	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.154	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

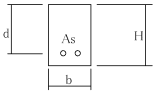
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00226 = 3.649
k = √(2*n*p+(n*p)^2)-n*p
= 0.1824484
j = 1-(k/3)
= 0.93918
σc = (2*M*10^5)/(b*d^2*k*j)
= 250.36092
σs = (M*10^5)/(b*d^2*p*j)
= 10096.8075
τ = (S*10^3)/(b*j*d)
= 15.43894

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	4.29	kN・m
Shear Force	S =	29.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height （Tensile Side)	d =	20.000	cm
Total Cross-Sectional （Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.252	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	50.484	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.154	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d)
= 0.00226

x = k*d
= 3.649

k = √(2*n*p+(n*p)^2)-n*p
= 0.18245

j = 1-(k/3)
= 0.93918

σ c = (2*M*10^5)/(b*d^2*k*j)
= 125.18046

σ s = (M*10^5)/(b*d^2*p*j)
= 5048.40376

τ= (S*10^3)/(b*j*d)
= 15.43894

【Study on Shear Force Reinforcement】

Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Cross Sectional Area of Shear Reinforcing Bar	Aw =	113.10	mm^2 ○
Required Cross Sectional Area of Shear Reinforcing Bar	Aw =	-39.66	mm^2

$$Aw = \frac{1.15*Sh*s}{\sigma sa*d}$$

Sh = Q - Sca

Sca =b*d*τa

where,

Sca : Shear force beared by concrete

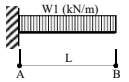
Sh : Shear force beared by stirrup reinforcement bars

Sca =	67.62	kN
Sh =	-38.62	kN

Type b

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.250 m

B×D = 100 × 30 cm

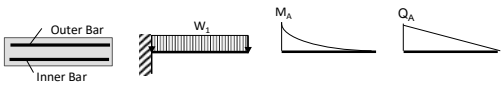
②Load Conditions

W1 = 23.920 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 23.92 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	0.75		3.00
Total	0.75		3.00

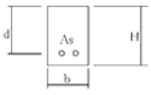


Type b

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	0.75	kN・m
Shear Force	S =	3.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height （Tensile Side)	d =	20.000	cm
Total Cross-Sectional （Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.219	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	8.826	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.016	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d)
= 0.00226

x = k*d
= 3.649

k = √(2*n*p+(n*p)^2)-n*p
= 0.1824484

j = 1-(k/3)
= 0.93918

σ c = (2*M*10^5)/(b*d^2*k*j)
= 21.88470

σ s = (M*10^5)/(b*d^2*p*j)
= 882.588069

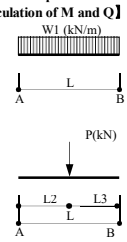
τ= (S*10^3)/(b*j*d)
= 1.59713

2.1.2.3 MANHOLE TYPE C

Type c

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

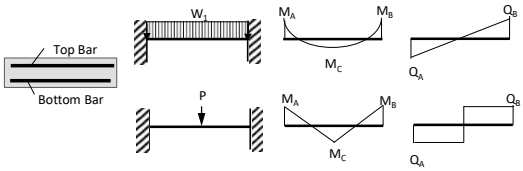
P = 52.000 kN : Point Load

L2 = 0.600 m L3 = 0.600 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	1.44	0.72	6.00
P	7.80	7.80	26.00
Total	9.24	8.52	32.00

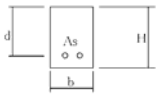


Type c

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	9.24	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.050	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	117.823	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 304.98173

σ s = (M*10^5)/(b*d^2*p*j)

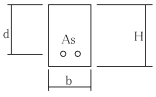
= 11782.28829

τ= (S*10^3)/(b*j*d)

= 18.45994

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	8.52	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.812	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	108.642	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 281.21692

σ s = (M*10^5)/(b*d^2*p*j)

= 10864.18790

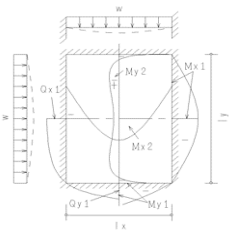
τ= (S*10^3)/(b*j*d)

= 18.45994

Type c

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.200 m

ly = 2.600 m

B×D = 100 × 30 cm

②Load Conditions

w = 53.450 kN/m : Uniform Load

ΣW = 53.45 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 2.2

α for Mx2 = 0.040

α for Mx1 = 0.083

α for Qx1 = 0.520

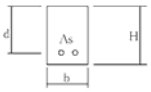
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	3.08	6.39	33.36

Type c

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	3.08	kN・m
Shear Force	S =	33.36	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.598	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	13.537	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.184	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00628 = 5.690

k = √(2*n*p+(n*p)^2)-n*p

= 0.28449

j = 1-(k/3)

= 0.90517

σ c = (2*M*10^5)/(b*d^2*k*j)

= 59.80358

σ s = (M*10^5)/(b*d^2*p*j)

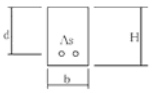
= 1353.70482

τ= (S*10^3)/(b*j*d)

= 18.42746

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	6.39	kN・m
Shear Force	S =	33.36	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.241	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	28.085	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.184	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00628 = 5.690

k = √(2*n*p+(n*p)^2)-n*p

= 0.28449

j = 1-(k/3)

= 0.90517

σ c = (2*M*10^5)/(b*d^2*k*j)

= 124.07300

σ s = (M*10^5)/(b*d^2*p*j)

= 2808.49800

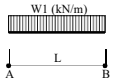
τ= (S*10^3)/(b*j*d)

= 18.42746

Type c

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 30 cm

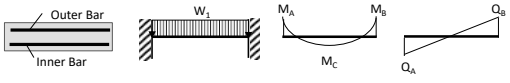
②Load Conditions

W1 = 46.612 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 46.61 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	5.60	2.80	21.00
Total	5.60	2.80	21.00



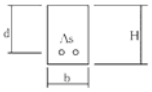
Type c

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Reinforcing Bar

Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



Bending Moment	M =	5.60	kN・m
Shear Force	S =	21.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.087	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	24.613	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.116	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00628 = 5.690

k = √(2*n*p+(n*p)^2)-n*p

= 0.2844874

j = 1-(k/3)

= 0.90517

σc = (2*M*10^5)/(b*d^2*k*j)

= 108.73378

σs = (M*10^5)/(b*d^2*p*j)

= 2461.2815

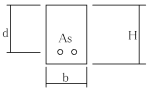
τ= (S*10^3)/(b*j*d)

= 11.60002

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar

Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



Bending Moment	M =	2.80	kN・m
Shear Force	S =	21.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.544	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	12.306	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.116	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00628 = 5.690

k = √(2*n*p+(n*p)^2)-n*p

= 0.28449

j = 1-(k/3)

= 0.90517

σc = (2*M*10^5)/(b*d^2*k*j)

= 54.36689

σs = (M*10^5)/(b*d^2*p*j)

= 1230.64075

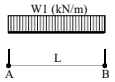
τ= (S*10^3)/(b*j*d)

= 11.60002

Type c

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.600 m

B×D = 100 × 30 cm

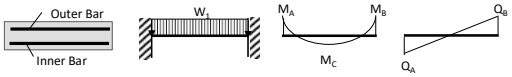
②Load Conditions

W1 = 46.612 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 46.61 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	26.26	13.13	54.00
Total	26.26	13.13	54.00



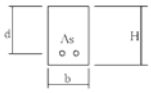
Type c

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar

Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



Bending Moment	M =	26.26	kN・m
Shear Force	S =	54.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	5.099	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	115.417	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.298	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00628 = 5.690

k = √(2*n*p+(n*p)^2)-n*p

= 0.2844874

j = 1-(k/3)

= 0.90517

σc = (2*M*10^5)/(b*d^2*k*j)

= 509.88374

σs = (M*10^5)/(b*d^2*p*j)

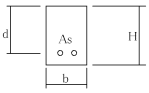
= 11541.6522

τ= (S*10^3)/(b*j*d)

= 29.82862

【Stress Intensity Calcularion】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	13.13	kN・m
Shear Force	S =	54.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.549	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	57.708	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.298	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) = 0.00628
k = √(2*n*p+(n*p)^2)-n*p = 0.28449
j = 1-(k/3) = 0.90517
σ c = (2*M*10^5)/(b*d^2*k*j) = 254.94187
σ s = (M*10^5)/(b*d^2*p*j) = 5770.82609
τ = (S*10^3)/(b*j*d) = 29.82862
x = k*d = 5.690

【Study on Shear Force Reinforcement】

Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Cross Sectional Area of Shear Reinforcing Bar	Aw =	113.10	mm^2 ○
Required Cross Sectional Area of Shear Reinforcing Bar	Aw =	-11.47	mm^2

$$Aw = \frac{1.15*Sh*s}{\sigma sa*d}$$

Sh = Q - Sca
Sca =b*d*τa

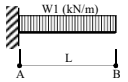
where,
Sca : Shear force beared by concrete
Sh : Shear force beared by stirrup reinforcement bars

Sca =	65.17	kN	
Sh =	-11.17	kN	

Type c

Analysis of Side Slab (Vd2 Opening)

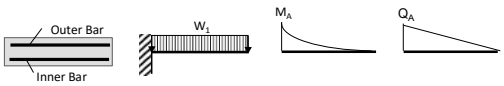
【Calculation of M and Q】



①Dimensional Conditions
L = 0.800 m
B×D = 100 × 30 cm

②Load Conditions
W1 = 35.737 kN/m : Uniform Load
w = kN/m : Self Weight
ΣW = 35.74 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	11.44		24.00
Total	11.44		24.00

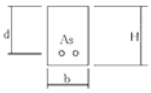


Type c

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calcularion】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	11.44	kN・m
Shear Force	S =	24.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.221	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	50.280	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.133	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

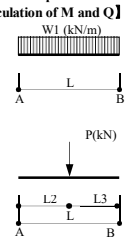
p = As/(b*d) = 0.00628
k = √(2*n*p+(n*p)^2)-n*p = 0.2844874
j = 1-(k/3) = 0.90517
σ c = (2*M*10^5)/(b*d^2*k*j) = 222.12757
σ s = (M*10^5)/(b*d^2*p*j) = 5028.04649
τ = (S*10^3)/(b*j*d) = 13.25717
x = k*d = 5.690

2.1.2.4 MANHOLE TYPE D

Type d

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.500 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

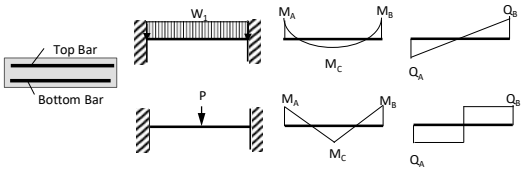
P = 52.000 kN : Point Load

L2 = 0.750 m L3 = 0.750 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	2.25	1.13	8.00
P	9.75	9.75	26.00
Total	12.00	10.88	34.00

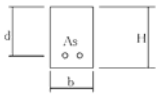


Type d

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	12.00	kN・m
Shear Force	S =	34.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.136	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	87.756	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.200	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 313.59854

σ s = (M*10^5)/(b*d^2*p*j)

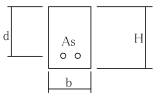
= 8775.60927

τ= (S*10^3)/(b*j*d)

= 20.00078

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	10.88	kN・m
Shear Force	S =	34.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.843	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	79.566	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.200	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 284.32934

σ s = (M*10^5)/(b*d^2*p*j)

= 7956.55240

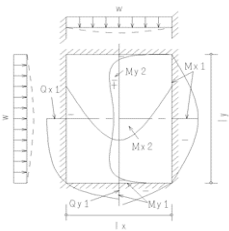
τ= (S*10^3)/(b*j*d)

= 20.00078

Type d

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.500 m

ly = 2.100 m

B×D = 100 × 30 cm

②Load Conditions

w = 52.540 kN/m : Uniform Load

ΣW = 52.54 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.4

α for Mx2 = 0.031

α for Mx1 = 0.072

α for Qx1 = 0.510

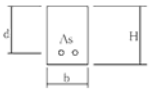
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	3.67	8.52	40.20

Type d

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	3.67	kN・m
Shear Force	S =	40.20	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.846	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	24.753	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.218	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 84.62575

σ s = (M*10^5)/(b*d^2*p*j)

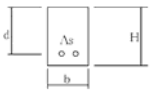
= 2475.34559

τ= (S*10^3)/(b*j*d)

= 21.81061

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	8.52	kN・m
Shear Force	S =	40.20	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.965	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	57.466	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.218	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 196.46087

σ s = (M*10^5)/(b*d^2*p*j)

= 5746.57886

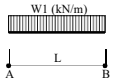
τ= (S*10^3)/(b*j*d)

= 21.81061

Type d

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.500 m

B×D = 100 × 30 cm

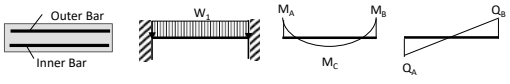
②Load Conditions

W1 = 44.869 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 44.87 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	8.42	4.21	27.00
Total	8.42	4.21	27.00

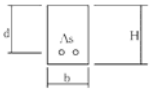


Type d

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	8.42	kN・m
Shear Force	S =	27.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.942	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	56.791	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.146	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.2352910

j = 1-(k/3)

= 0.92157

σc = (2*M*10^5)/(b*d^2*k*j)

= 194.15499

σs = (M*10^5)/(b*d^2*p*j)

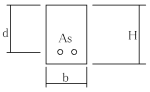
= 5679.13075

τ= (S*10^3)/(b*j*d)

= 14.64892

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	4.21	kN・m
Shear Force	S =	27.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.971	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	28.396	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.146	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σc = (2*M*10^5)/(b*d^2*k*j)

= 97.07749

σs = (M*10^5)/(b*d^2*p*j)

= 2839.56538

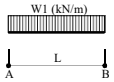
τ= (S*10^3)/(b*j*d)

= 14.64892

Type d

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 30 cm

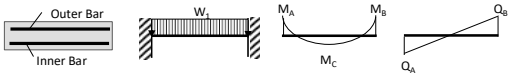
②Load Conditions

W1 = 44.869 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 44.87 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	16.49	8.25	41.00
Total	16.49	8.25	41.00

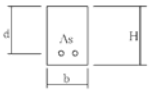


Type d

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	16.49	kN・m
Shear Force	S =	41.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.802	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	111.222	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.222	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.2352910

j = 1-(k/3)

= 0.92157

σc = (2*M*10^5)/(b*d^2*k*j)

= 380.23940

σs = (M*10^5)/(b*d^2*p*j)

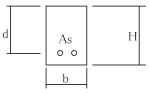
= 11122.1931

τ= (S*10^3)/(b*j*d)

= 22.24466

【Stress Intensity Calcularion】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	8.25	kN・m
Shear Force	S =	41.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.902	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	55.645	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.222	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.23529
j = 1-(k/3)
= 0.92157
σ c = (2*M*10^5)/(b*d^2*k*j)
= 190.23499
σ s = (M*10^5)/(b*d^2*p*j)
= 5564.46897
τ= (S*10^3)/(b*j*d)
= 22.24466

【Study on Shear Force Reinforcement】

Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Cross Sectional Area of Shear Reinforcing Bar	Aw =	113.10	mm^2 ○
Required Cross Sectional Area of Shear Reinforcing Bar	Aw =	-26.03	mm^2

$$Aw = \frac{1.15*Sh*s}{\sigma sa*d}$$

Sh = Q - Sca
Sca =b*d*τa

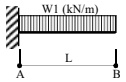
where,
Sca : Shear force beared by concrete
Sh : Shear force beared by stirrup reinforcement bars

Sca =	66.35	kN
Sh =	-25.35	kN

Type d

Analysis of Side Slab (Vd2 Opening)

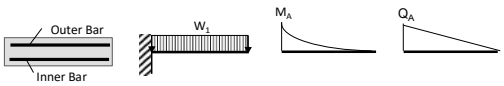
【Calculation of M and Q】



①Dimensional Conditions
L = 0.525 m
B×D = 100 × 30 cm

②Load Conditions
W1 = 33.994 kN/m : Uniform Load
w = kN/m : Self Weight
ΣW = 33.99 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	4.69		13.00
Total	4.69		13.00

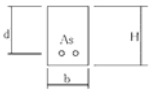


Type d

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calcularion】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	4.69	kN・m
Shear Force	S =	13.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.081	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	31.633	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.071	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

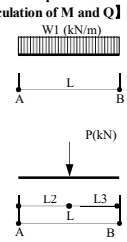
p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.2352910
j = 1-(k/3)
= 0.92157
σ c = (2*M*10^5)/(b*d^2*k*j)
= 108.14571
σ s = (M*10^5)/(b*d^2*p*j)
= 3163.3163
τ= (S*10^3)/(b*j*d)
= 7.05318

2.1.2.5 MANHOLE TYPE E

Type e

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

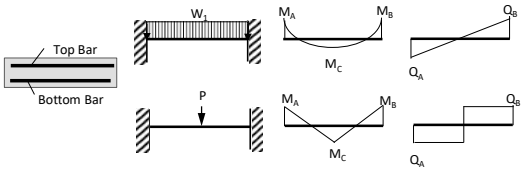
P = 52.000 kN : Point Load

L2 = 0.600 m L3 = 0.600 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	1.44	0.72	6.00
P	7.80	7.80	26.00
Total	9.24	8.52	32.00

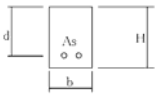


Type e

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	9.24	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.050	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	117.823	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 304.98173

σ s = (M*10^5)/(b*d^2*p*j)

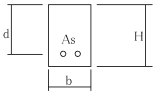
= 11782.28829

τ= (S*10^3)/(b*j*d)

= 18.45994

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	8.52	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.812	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	108.642	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 281.21692

σ s = (M*10^5)/(b*d^2*p*j)

= 10864.18790

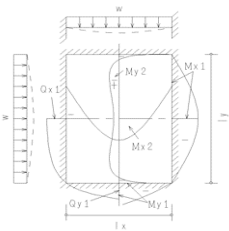
τ= (S*10^3)/(b*j*d)

= 18.45994

Type e

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.200 m

ly = 1.400 m

B×D = 100 × 30 cm

②Load Conditions

w = 71.200 kN/m : Uniform Load

ΣW = 71.20 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.2

α for Mx2 = 0.025

α for Mx1 = 0.064

α for Qx1 = 0.490

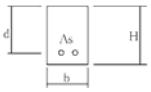
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	2.57	6.57	41.87

Type e

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	2.57	kN・m
Shear Force	S =	41.87	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.750	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	30.243	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.223	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00226 = 3.649

k = √(2*n*p+(n*p)^2)-n*p

= 0.18245

j = 1-(k/3)

= 0.93918

σ c = (2*M*10^5)/(b*d^2*k*j)

= 74.99156

σ s = (M*10^5)/(b*d^2*p*j)

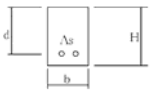
= 3024.33512

τ= (S*10^3)/(b*j*d)

= 22.29063

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	6.57	kN・m
Shear Force	S =	41.87	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.917	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	77.315	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.223	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00226 = 3.649

k = √(2*n*p+(n*p)^2)-n*p

= 0.18245

j = 1-(k/3)

= 0.93918

σ c = (2*M*10^5)/(b*d^2*k*j)

= 191.70994

σ s = (M*10^5)/(b*d^2*p*j)

= 7731.47149

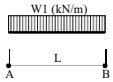
τ= (S*10^3)/(b*j*d)

= 22.29063

Type e

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 30 cm

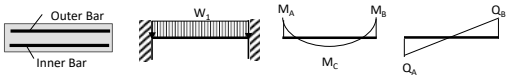
②Load Conditions

W1 = 58.725 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 58.73 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	7.05	3.53	27.00
Total	7.05	3.53	27.00

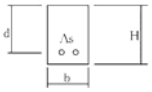


Type e

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	7.05	kN・m
Shear Force	S =	27.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.057	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	82.963	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.144	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00226 = 3.649

k = √(2*n*p+(n*p)^2)-n*p

= 0.1824484

j = 1-(k/3)

= 0.93918

σ c = (2*M*10^5)/(b*d^2*k*j)

= 205.71614

σ s = (M*10^5)/(b*d^2*p*j)

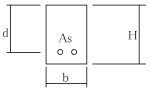
= 8296.32785

τ= (S*10^3)/(b*j*d)

= 14.37418

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	3.53	kN・m
Shear Force	S =	27.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.030	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	41.540	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.144	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00226 = 3.649

k = √(2*n*p+(n*p)^2)-n*p

= 0.18245

j = 1-(k/3)

= 0.93918

σ c = (2*M*10^5)/(b*d^2*k*j)

= 103.00397

σ s = (M*10^5)/(b*d^2*p*j)

= 4154.04785

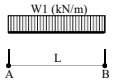
τ= (S*10^3)/(b*j*d)

= 14.37418

Type e

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.400 m

B×D = 100 × 30 cm

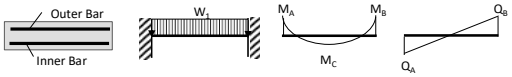
②Load Conditions

W1 = 58.725 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 58.73 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	9.60	4.80	33.00
Total	9.60	4.80	33.00

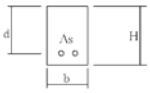


Type e

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	9.60	kN・m
Shear Force	S =	33.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.801	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	112.971	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.176	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00226 = 3.649

k = √(2*n*p+(n*p)^2)-n*p

= 0.1824484

j = 1-(k/3)

= 0.93918

σ c = (2*M*10^5)/(b*d^2*k*j)

= 280.12411

σ s = (M*10^5)/(b*d^2*p*j)

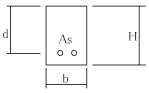
= 11297.1273

τ= (S*10^3)/(b*j*d)

= 17.56845

【Stress Intensity Calcularion】 For Inner Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	4.80	kN・m
Shear Force	S =	33.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.401	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	56.486	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.176	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00226 = 3.649
k = √(2*n*p+(n*p)^2)-n*p
= 0.18245
j = 1-(k/3)
= 0.93918
σ c = (2*M*10^5)/(b*d^2*k*j)
= 140.06205
σ s = (M*10^5)/(b*d^2*p*j)
= 5648.56364
τ= (S*10^3)/(b*j*d)
= 17.56845

【Study on Shear Force Reinforcement】

Diameter	12	mm
Interval of Reinforcing Bar	250	mm

Cross Sectional Area of Shear Reinforcing Bar	Aw =	113.10	mm^2 ○
Required Cross Sectional Area of Shear Reinforcing Bar	Aw =	-35.55	mm^2

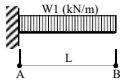
$$Aw = \frac{1.15*Sh*s}{\sigma sa*d}$$

Sh = Q - Sca
Sca =b*d*τa

where,
Sca : Shear force beared by concrete
Sh : Shear force beared by stirrup reinforcement bars

Sca =	67.62	kN
Sh =	-34.62	kN

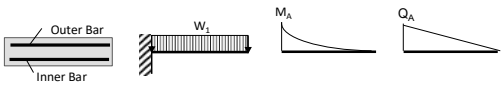
Type e
Analysis of Side Slab (Vd2 Opening)
【Calculation of M and Q】



①Dimensional Conditions
L = 0.250 m
B×D = 100 × 30 cm

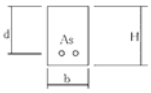
②Load Conditions
W1 = 48.975 kN/m : Uniform Load
w = kN/m : Self Weight
ΣW = 48.97 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	1.54		5.00
Total	1.54		5.00



Type e
Analysis of Side Slab (Vd2 Opening)
【Stress Intensity Calcularion】 For Outer Bars

Position of Rainforcing Bar



Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	1.54	kN・m
Shear Force	S =	5.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.449	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	18.122	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.027	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

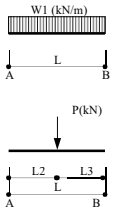
p = As/(b*d) x = k*d
= 0.00226 = 3.649
k = √(2*n*p+(n*p)^2)-n*p
= 0.1824484
j = 1-(k/3)
= 0.93918
σ c = (2*M*10^5)/(b*d^2*k*j)
= 44.93658
σ s = (M*10^5)/(b*d^2*p*j)
= 1812.2475
τ= (S*10^3)/(b*j*d)
= 2.66189

2.1.2.6 MANHOLE TYPE F

Type f

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

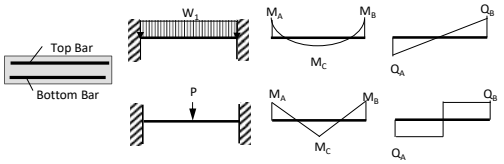
P = 52.000 kN : Point Load

L2 = 0.600 m L3 = 0.600 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN･m) for top bars	M(kN･m) for bottom bars	Q(kN)
W1+w	1.44	0.72	6.00
P	7.80	7.80	26.00
Total	9.24	8.52	32.00



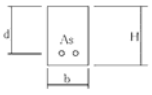
1

Type f

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	9.24	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.050	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	117.823	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 304.98173

σ s = (M*10^5)/(b*d^2*p*j)

= 11782.28829

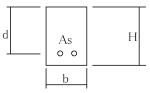
τ= (S*10^3)/(b*j*d)

= 18.45994

2

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	8.52	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.812	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	108.642	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 281.21692

σ s = (M*10^5)/(b*d^2*p*j)

= 10864.18790

τ= (S*10^3)/(b*j*d)

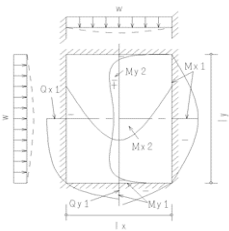
= 18.45994

3

Type f

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.200 m

ly = 2.000 m

B×D = 100 × 30 cm

②Load Conditions

w = 67.050 kN/m : Uniform Load

ΣW = 67.05 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.7

α for Mx2 = 0.037

α for Mx1 = 0.079

α for Qx1 = 0.520

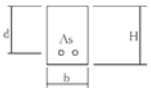
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	3.58	7.63	41.84

Type f

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	3.58	kN・m
Shear Force	S =	41.84	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.826	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	24.146	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.227	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 82.55046

σ s = (M*10^5)/(b*d^2*p*j)

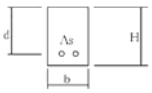
= 2414.64229

τ = (S*10^3)/(b*j*d)

= 22.70040

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	7.63	kN・m
Shear Force	S =	41.84	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.759	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	51.463	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.227	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 175.93855

σ s = (M*10^5)/(b*d^2*p*j)

= 5146.29069

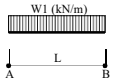
τ = (S*10^3)/(b*j*d)

= 22.70040

Type f

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 30 cm

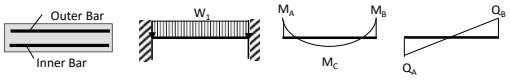
②Load Conditions

W1 = 58.323 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 58.32 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	7.00	3.50	27.00
Total	7.00	3.50	27.00

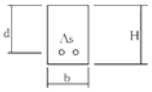


Type f

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	7.00	kN・m
Shear Force	S =	27.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.614	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	47.214	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.146	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

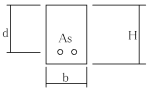
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.2352910
j = 1-(k/3)
= 0.92157
σc = (2*M*10^5)/(b*d^2*k*j)
= 161.41151
σs = (M*10^5)/(b*d^2*p*j)
= 4721.36761
τ= (S*10^3)/(b*j*d)
= 14.64892

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	3.50	kN・m
Shear Force	S =	27.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.807	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	23.607	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.146	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

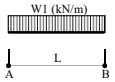
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.23529
j = 1-(k/3)
= 0.92157
σc = (2*M*10^5)/(b*d^2*k*j)
= 80.70576
σs = (M*10^5)/(b*d^2*p*j)
= 2360.68380
τ= (S*10^3)/(b*j*d)
= 14.64892

Type f

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.000 m

B×D = 100 × 30 cm

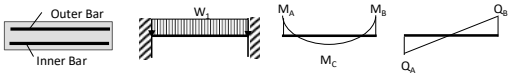
②Load Conditions

W1 = 58.323 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 58.32 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	19.45	9.73	50.00
Total	19.45	9.73	50.00

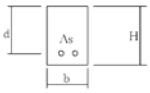


Type f

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	19.45	kN・m
Shear Force	S =	50.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.485	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	131.187	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.271	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

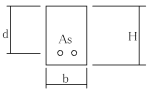
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.2352910
j = 1-(k/3)
= 0.92157
σc = (2*M*10^5)/(b*d^2*k*j)
= 448.49341
σs = (M*10^5)/(b*d^2*p*j)
= 13118.6571
τ= (S*10^3)/(b*j*d)
= 27.12763

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	9.73	kN・m	
Shear Force	S =	50.00	kN	
Width of Member	b =	100.0	cm	
Height of Member	H =	30.0	cm	
Equivalent Height (Tensile Side)	d =	20.000	cm	
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2	
Modulous of Elasticity	n =	9.000		
Compressive Stress of Concrete	σc=	2.244	N/mm^2	○
Tensile Stress of Rainforcing Bar	σs=	65.627	N/mm^2	○
Shearing Stress of Concrete	τ =	0.271	N/mm^2	○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

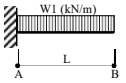
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.23529
j = 1-(k/3)
= 0.92157
σ c = (2*M*10^5)/(b*d^2*k*j)
= 224.36200
σ s = (M*10^5)/(b*d^2*p*j)
= 6562.70097
τ = (S*10^3)/(b*j*d)
= 27.12763

Type f

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.475 m

B×D = 100 × 30 cm

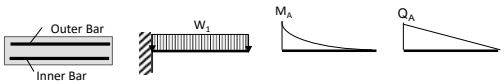
②Load Conditions

W1 = 46.323 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 46.32 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	5.23		16.00
Total	5.23		16.00

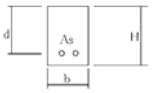


Type f

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	5.23	kN・m	
Shear Force	S =	16.00	kN	
Width of Member	b =	100.0	cm	
Height of Member	H =	30.0	cm	
Equivalent Height (Tensile Side)	d =	20.000	cm	
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2	
Modulous of Elasticity	n =	9.000		
Compressive Stress of Concrete	σc=	1.015	N/mm^2	○
Tensile Stress of Rainforcing Bar	σs=	22.987	N/mm^2	○
Shearing Stress of Concrete	τ =	0.088	N/mm^2	○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

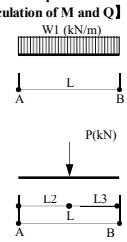
p = As/(b*d) x = k*d
= 0.00628 = 5.690
k = √(2*n*p+(n*p)^2)-n*p
= 0.2844874
j = 1-(k/3)
= 0.90517
σ c = (2*M*10^5)/(b*d^2*k*j)
= 101.54958
σ s = (M*10^5)/(b*d^2*p*j)
= 2298.66111
τ = (S*10^3)/(b*j*d)
= 8.83811

2.1.2.7 MANHOLE TYPE G

Type g

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 2.000 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

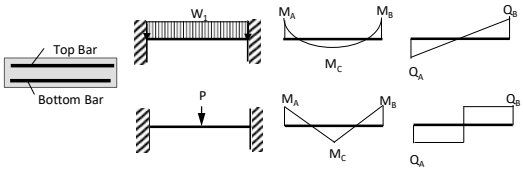
P = 52.000 kN : Point Load

L2 = 1.000 m L3 = 1.000 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	4.00	2.00	11.00
P	13.00	13.00	26.00
Total	17.00	15.00	37.00

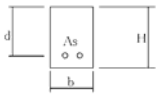


Type g

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	17.00	kN・m
Shear Force	S =	37.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.443	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	124.321	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.218	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 444.26459

σ s = (M*10^5)/(b*d^2*p*j)

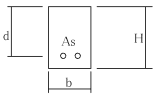
= 12432.11313

τ= (S*10^3)/(b*j*d)

= 21.76556

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	15.00	kN・m
Shear Force	S =	37.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.920	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	109.695	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.218	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 391.99817

σ s = (M*10^5)/(b*d^2*p*j)

= 10969.51158

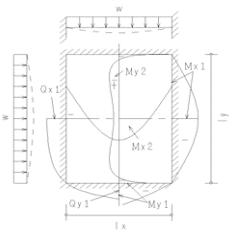
τ= (S*10^3)/(b*j*d)

= 21.76556

Type g

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 2.000 m

ly = 2.500 m

B×D = 100 × 35 cm

②Load Conditions

w = 74.070 kN/m : Uniform Load

ΣW = 74.07 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.3

α for Mx2 = 0.029

α for Mx1 = 0.068

α for Qx1 = 0.500

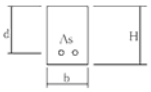
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	8.60	20.15	74.07

Type g

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	8.60	kN・m
Shear Force	S =	74.07	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.163	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	29.957	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.324	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.25895

j = 1-(k/3)

= 0.91368

σ c = (2*M*10^5)/(b*d^2*k*j)

= 116.31381

σ s = (M*10^5)/(b*d^2*p*j)

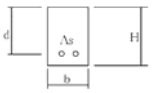
= 2995.69190

τ = (S*10^3)/(b*j*d)

= 32.42703

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	20.15	kN・m
Shear Force	S =	74.07	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.725	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	70.190	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.324	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.25895

j = 1-(k/3)

= 0.91368

σ c = (2*M*10^5)/(b*d^2*k*j)

= 272.52596

σ s = (M*10^5)/(b*d^2*p*j)

= 7018.97578

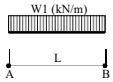
τ = (S*10^3)/(b*j*d)

= 32.42703

Type g

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.000 m

B×D = 100 × 35 cm

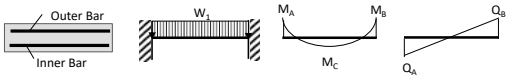
②Load Conditions

W1 = 74.070 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 74.07 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	24.69	12.35	62.00
Total	24.69	12.35	62.00

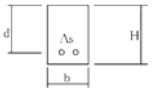


Type g

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	24.69	kN・m
Shear Force	S =	62.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.339	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	86.004	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.271	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.2589536

j = 1-(k/3)

= 0.91368

σc = (2*M*10^5)/(b*d^2*k*j)

= 333.92883

σs = (M*10^5)/(b*d^2*p*j)

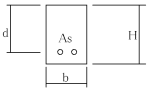
= 8600.42243

τ= (S*10^3)/(b*j*d)

= 27.14292

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	12.35	kN・m
Shear Force	S =	62.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.670	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	43.020	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.271	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.25895

j = 1-(k/3)

= 0.91368

σc = (2*M*10^5)/(b*d^2*k*j)

= 167.03204

σs = (M*10^5)/(b*d^2*p*j)

= 4301.95290

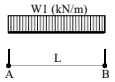
τ= (S*10^3)/(b*j*d)

= 27.14292

Type g

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.500 m

B×D = 100 × 35 cm

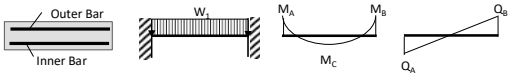
②Load Conditions

W1 = 74.070 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 74.07 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	38.58	19.29	80.00
Total	38.58	19.29	80.00

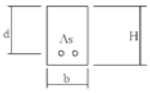


Type g

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	38.58	kN・m
Shear Force	S =	80.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	5.218	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	134.388	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.350	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.2589536

j = 1-(k/3)

= 0.91368

σc = (2*M*10^5)/(b*d^2*k*j)

= 521.78916

σs = (M*10^5)/(b*d^2*p*j)

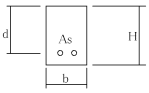
= 13438.8132

τ= (S*10^3)/(b*j*d)

= 35.02312

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	19.29	kN・m
Shear Force	S =	80.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.609	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	67.194	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.350	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p
= 0.25895

j = 1-(k/3)
= 0.91368

σ c = (2*M*10^5)/(b*d^2*k*j)
= 260.89458

σ s = (M*10^5)/(b*d^2*p*j)
= 6719.40659

τ= (S*10^3)/(b*j*d)
= 35.02312

【Study on Shear Force Reinforcement】

Diameter	12	mm
Interval of Reinforcing Bar	250	mm

Cross Sectional Area of Shear Reinforcing Bar	Aw =	113.10	mm^2 ○
Required Cross Sectional Area of Shear Reinforcing Bar	Aw =	-1.83	mm^2

$$Aw = \frac{1.15*Sh*s}{\sigma sa*d}$$

Sh = Q - Sca

Sca =b*d*τa

where,

Sca : Shear force beared by concrete

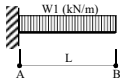
Sh : Shear force beared by stirrup reinforcement bars

Sca =	82.23	kN
Sh =	-2.23	kN

Type g

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.750 m

B×D = 100 × 35 cm

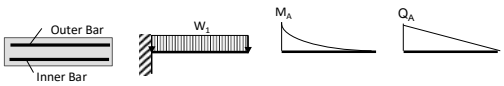
②Load Conditions

W1 = 60.420 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 60.42 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	17.00		35.00
Total	17.00		35.00

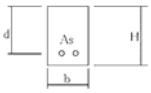


Type g

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	17.00	kN・m
Shear Force	S =	35.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.299	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	59.217	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.153	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p
= 0.2589536

j = 1-(k/3)
= 0.91368

σ c = (2*M*10^5)/(b*d^2*k*j)
= 229.92265

σ s = (M*10^5)/(b*d^2*p*j)
= 5921.71654

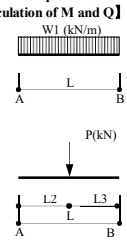
τ= (S*10^3)/(b*j*d)
= 15.32262

2.1.2.8 MANHOLE TYPE H

Type h

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

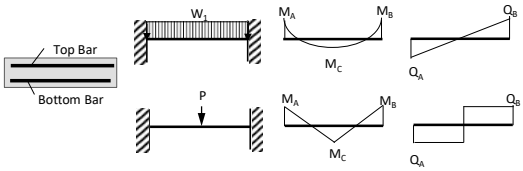
P = 52.000 kN : Point Load

L2 = 0.600 m L3 = 0.600 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	1.44	0.72	6.00
P	7.80	7.80	26.00
Total	9.24	8.52	32.00

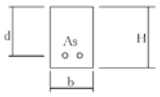


Type h

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	9.24	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.050	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	117.823	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 304.98173

σ s = (M*10^5)/(b*d^2*p*j)

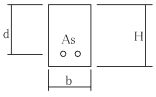
= 11782.28829

τ= (S*10^3)/(b*j*d)

= 18.45994

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	8.52	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.812	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	108.642	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 281.21692

σ s = (M*10^5)/(b*d^2*p*j)

= 10864.18790

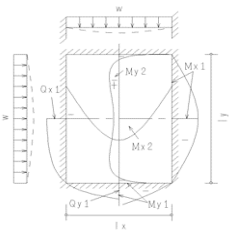
τ= (S*10^3)/(b*j*d)

= 18.45994

Type h

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.200 m

ly = 1.400 m

B×D = 100 × 30 cm

②Load Conditions

w = 84.000 kN/m : Uniform Load

ΣW = 84.00 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.2

α for Mx2 = 0.025

α for Mx1 = 0.064

α for Qx1 = 0.490

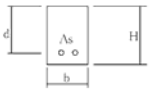
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	3.03	7.75	49.40

Type h

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	3.03	kN・m
Shear Force	S =	49.40	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.699	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	20.437	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.268	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 69.86813

σ s = (M*10^5)/(b*d^2*p*j)

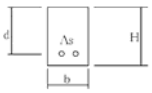
= 2043.67769

τ= (S*10^3)/(b*j*d)

= 26.80210

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	7.75	kN・m
Shear Force	S =	49.40	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.787	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	52.272	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.268	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 178.70560

σ s = (M*10^5)/(b*d^2*p*j)

= 5227.22842

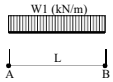
τ= (S*10^3)/(b*j*d)

= 26.80210

Type h

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 30 cm

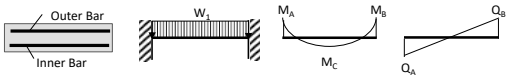
②Load Conditions

W1 = 74.577 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 74.58 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	8.95	4.48	34.00
Total	8.95	4.48	34.00

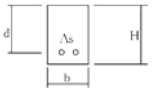


Type h

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	8.95	kN・m
Shear Force	S =	34.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.064	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	60.366	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.184	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

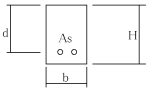
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.2352910
j = 1-(k/3)
= 0.92157
σc = (2*M*10^5)/(b*d^2*k*j)
= 206.37615
σs = (M*10^5)/(b*d^2*p*j)
= 6036.60573
τ= (S*10^3)/(b*j*d)
= 18.44679

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	4.48	kN・m
Shear Force	S =	34.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.033	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	30.217	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.184	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

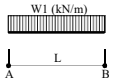
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.23529
j = 1-(k/3)
= 0.92157
σc = (2*M*10^5)/(b*d^2*k*j)
= 103.30337
σs = (M*10^5)/(b*d^2*p*j)
= 3021.67527
τ= (S*10^3)/(b*j*d)
= 18.44679

Type h

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.400 m

B×D = 100 × 30 cm

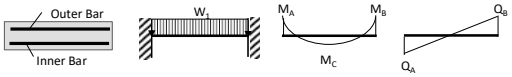
②Load Conditions

W1 = 74.577 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 74.58 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	12.19	6.10	42.00
Total	12.19	6.10	42.00

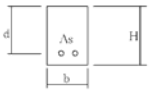


Type h

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	12.19	kN・m
Shear Force	S =	42.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.811	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	82.219	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.228	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

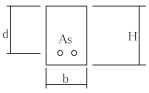
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.2352910
j = 1-(k/3)
= 0.92157
σc = (2*M*10^5)/(b*d^2*k*j)
= 281.08662
σs = (M*10^5)/(b*d^2*p*j)
= 8221.92445
τ= (S*10^3)/(b*j*d)
= 22.78721

【Stress Intensity Calcularion】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	6.10	kN・m
Shear Force	S =	42.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.407	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	41.143	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.228	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.23529
j = 1-(k/3)
= 0.92157
σ c = (2*M*10^5)/(b*d^2*k*j)
= 140.65860
σ s = (M*10^5)/(b*d^2*p*j)
= 4114.33463
τ= (S*10^3)/(b*j*d)
= 22.78721

【Study on Shear Force Reinforcement】

Diameter	12	mm
Interval of Reinforcing Bar	250	mm

Cross Sectional Area of Shear Reinforcing Bar	Aw =	113.10	mm^2 ○
Required Cross Sectional Area of Shear Reinforcing Bar	Aw =	-25.01	mm^2

$$Aw = \frac{1.15*Sh*s}{\sigma sa*d}$$

Sh = Q - Sca
Sca =b*d*τa

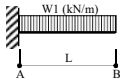
where,
Sca : Shear force beared by concrete
Sh : Shear force beared by stirrup reinforcement bars

Sca =	66.35	kN
Sh =	-24.35	kN

Type h

Analysis of Side Slab (Vd2 Opening)

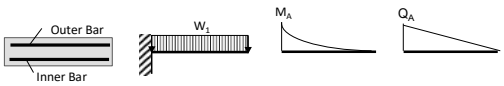
【Calculation of M and Q】



①Dimensional Conditions
L = 0.550 m
B×D = 100 × 30 cm

②Load Conditions
W1 = 64.827 kN/m : Uniform Load
w = kN/m : Self Weight
ΣW = 64.83 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	9.81		26.00
Total	9.81		26.00

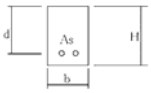


Type h

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calcularion】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	9.81	kN・m
Shear Force	S =	26.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.262	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	66.167	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.141	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

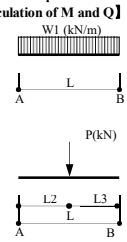
p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.2352910
j = 1-(k/3)
= 0.92157
σ c = (2*M*10^5)/(b*d^2*k*j)
= 226.20670
σ s = (M*10^5)/(b*d^2*p*j)
= 6616.65946
τ= (S*10^3)/(b*j*d)
= 14.10637

2.1.2.9 MANHOLE TYPE I

Type i

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

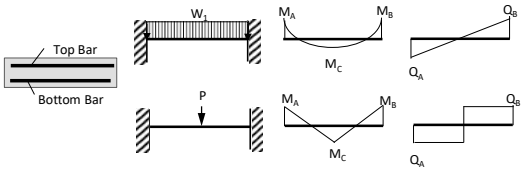
P = 52.000 kN : Point Load

L2 = 0.600 m L3 = 0.600 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	1.44	0.72	6.00
P	7.80	7.80	26.00
Total	9.24	8.52	32.00

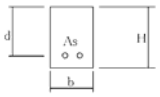


Type i

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	9.24	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.050	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	117.823	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 304.98173

σ s = (M*10^5)/(b*d^2*p*j)

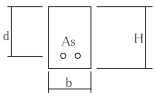
= 11782.28829

τ= (S*10^3)/(b*j*d)

= 18.45994

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	8.52	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.812	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	108.642	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 281.21692

σ s = (M*10^5)/(b*d^2*p*j)

= 10864.18790

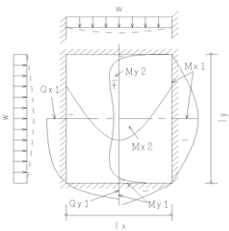
τ= (S*10^3)/(b*j*d)

= 18.45994

Type i

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.200 m

ly = 2.100 m

B×D = 100 × 35 cm

②Load Conditions

w = 84.400 kN/m : Uniform Load

ΣW = 84.40 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.8

α for Mx2 = 0.038

α for Mx1 = 0.081

α for Qx1 = 0.520

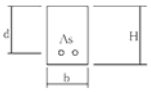
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	4.62	9.85	52.67

Type i

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter 20 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 4.62 kN・m

Shear Force S = 52.67 kN

Width of Member b = 100.0 cm

Height of Member H = 35.0 cm

Equivalent Height (Tensile Side) d = 25.000 cm

Total Cross-Sectional (Tensile Side) A_s = 12.568 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 0.625 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 16.093 N/mm^2 ○

Shearing Stress of Concrete τ = 0.231 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.25895

j = 1-(k/3)

= 0.91368

σ c = (2*M*10^5)/(b*d^2*k*j)

= 62.48486

σ s = (M*10^5)/(b*d^2*p*j)

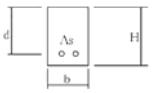
= 1609.31355

τ= (S*10^3)/(b*j*d)

= 23.05835

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter 20 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 9.85 kN・m

Shear Force S = 52.67 kN

Width of Member b = 100.0 cm

Height of Member H = 35.0 cm

Equivalent Height (Tensile Side) d = 25.000 cm

Total Cross-Sectional (Tensile Side) A_s = 12.568 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 1.332 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 34.311 N/mm^2 ○

Shearing Stress of Concrete τ = 0.231 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.25895

j = 1-(k/3)

= 0.91368

σ c = (2*M*10^5)/(b*d^2*k*j)

= 133.21989

σ s = (M*10^5)/(b*d^2*p*j)

= 3431.11223

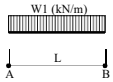
τ= (S*10^3)/(b*j*d)

= 23.05835

Type i

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 35 cm

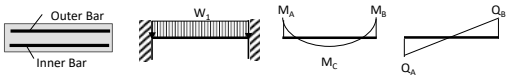
②Load Conditions

W1 = 72.993 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 72.99 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	8.76	4.38	32.00
Total	8.76	4.38	32.00

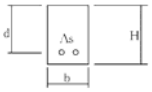


Type i

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	8.76	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.185	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	30.514	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.140	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.2589536

j = 1-(k/3)

= 0.91368

σc = (2*M*10^5)/(b*d^2*k*j)

= 118.47779

σs = (M*10^5)/(b*d^2*p*j)

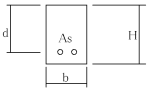
= 3051.4257

τ= (S*10^3)/(b*j*d)

= 14.00925

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	4.38	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.592	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	15.257	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.140	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.25895

j = 1-(k/3)

= 0.91368

σc = (2*M*10^5)/(b*d^2*k*j)

= 59.23889

σs = (M*10^5)/(b*d^2*p*j)

= 1525.71285

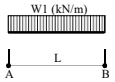
τ= (S*10^3)/(b*j*d)

= 14.00925

Type i

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 35 cm

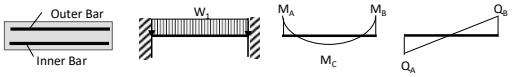
②Load Conditions

W1 = 72.993 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 72.99 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	26.83	13.42	64.00
Total	26.83	13.42	64.00

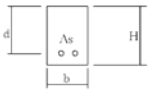


Type i

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	26.83	kN・m
Shear Force	S =	64.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.629	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	93.459	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.280	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00503 = 6.474

k = √(2*n*p+(n*p)^2)-n*p

= 0.2589536

j = 1-(k/3)

= 0.91368

σc = (2*M*10^5)/(b*d^2*k*j)

= 362.87204

σs = (M*10^5)/(b*d^2*p*j)

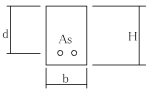
= 9345.86204

τ= (S*10^3)/(b*j*d)

= 28.01850

【Stress Intensity Calcularion】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	
Bending Moment	M =	13.42	kN・m
Shear Force	S =	64.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.815	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	46.747	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.280	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00503 = 6.474
k = √(2*n*p+(n*p)^2)-n*p
= 0.25895
j = 1-(k/3)
= 0.91368
σ c = (2*M*10^5)/(b*d^2*k*j)
= 181.50364
σ s = (M*10^5)/(b*d^2*p*j)
= 4674.67270
τ = (S*10^3)/(b*j*d)
= 28.01850

【Study on Shear Force Reinforcement】

Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Cross Sectional Area of Shear Reinforcing Bar	Aw =	113.10	mm^2 ○
Required Cross Sectional Area of Shear Reinforcing Bar	Aw =	-14.98	mm^2

$$Aw = \frac{1.15*Sh*s}{\sigma sa*d}$$

Sh = Q - Sca
Sca =b*d*τa

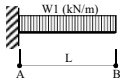
where,
Sca : Shear force beared by concrete
Sh : Shear force beared by stirrup reinforcement bars

Sca =	82.23	kN	
Sh =	-18.23	kN	

Type i

Analysis of Side Slab (Vd2 Opening)

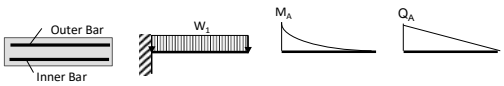
【Calculation of M and Q】



①Dimensional Conditions
L = 0.450 m
B×D = 100 × 35 cm

②Load Conditions
W1 = 60.993 kN/m : Uniform Load
w = kN/m : Self Weight
ΣW = 60.99 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	6.18		17.00
Total	6.18		17.00

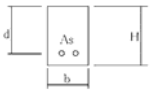


Type i

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calcularion】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	
Bending Moment	M =	6.18	kN・m
Shear Force	S =	17.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	35.0	cm
Equivalent Height (Tensile Side)	d =	25.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.836	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	21.527	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.074	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

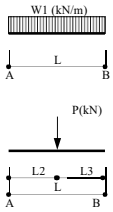
p = As/(b*d) x = k*d
= 0.00503 = 6.474
k = √(2*n*p+(n*p)^2)-n*p
= 0.2589536
j = 1-(k/3)
= 0.91368
σ c = (2*M*10^5)/(b*d^2*k*j)
= 83.58364
σ s = (M*10^5)/(b*d^2*p*j)
= 2152.71813
τ = (S*10^3)/(b*j*d)
= 7.44241

2.1.2.10 MANHOLE TYPE J

Type j

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 2.000 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

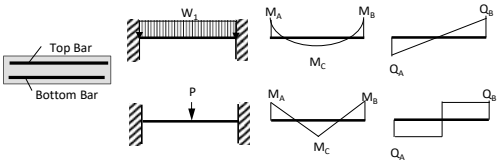
P = 52.000 kN : Point Load

L2 = 1.000 m L3 = 1.000 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN･m) for top bars	M(kN･m) for bottom bars	Q(kN)
W1+w	4.00	2.00	11.00
P	13.00	13.00	26.00
Total	17.00	15.00	37.00

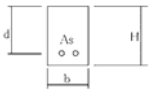


Type j

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	17.00	kN・m
Shear Force	S =	37.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.443	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	124.321	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.218	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 444.26459

σ s = (M*10^5)/(b*d^2*p*j)

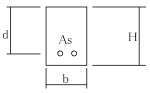
= 12432.11313

τ= (S*10^3)/(b*j*d)

= 21.76556

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	15.00	kN・m
Shear Force	S =	37.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.920	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	109.695	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.218	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 391.99817

σ s = (M*10^5)/(b*d^2*p*j)

= 10969.51158

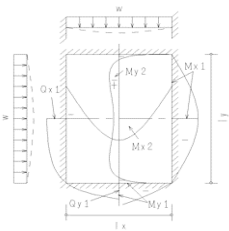
τ= (S*10^3)/(b*j*d)

= 21.76556

Type j

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 2.000 m

ly = 2.700 m

B×D = 100 × 40 cm

②Load Conditions

w = 81.840 kN/m : Uniform Load

ΣW = 81.84 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.4

α for Mx2 = 0.031

α for Mx1 = 0.072

α for Qx1 = 0.510

Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	10.15	23.57	83.48

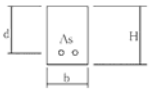
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Type j

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	10.15	kN・m
Shear Force	S =	83.48	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.024	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	29.256	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.302	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p

= 0.23948

j = 1-(k/3)

= 0.92017

σ c = (2*M*10^5)/(b*d^2*k*j)

= 102.35728

σ s = (M*10^5)/(b*d^2*p*j)

= 2925.55711

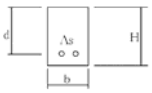
τ = (S*10^3)/(b*j*d)

= 30.24065

5

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	23.57	kN・m
Shear Force	S =	83.48	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.377	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	67.936	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.302	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p

= 0.23948

j = 1-(k/3)

= 0.92017

σ c = (2*M*10^5)/(b*d^2*k*j)

= 237.69076

σ s = (M*10^5)/(b*d^2*p*j)

= 6793.63362

τ = (S*10^3)/(b*j*d)

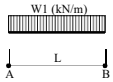
= 30.24065

6

Type j

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.000 m

B×D = 100 × 40 cm

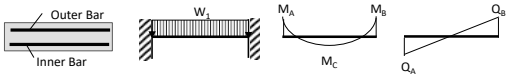
②Load Conditions

W1 = 75.600 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 75.60 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	25.20	12.60	61.00
Total	25.20	12.60	61.00



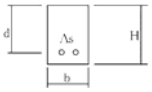
7

Type j

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	25.20	kN・m
Shear Force	S =	61.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.541	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	72.635	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.221	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

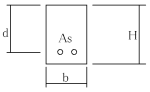
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.2394775
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 254.12843
σs = (M*10^5)/(b*d^2*p*j)
= 7263.45215
τ= (S*10^3)/(b*j*d)
= 22.09727

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	12.60	kN・m
Shear Force	S =	61.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.271	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	36.317	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.221	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

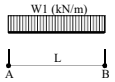
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.23948
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 127.06421
σs = (M*10^5)/(b*d^2*p*j)
= 3631.72607
τ= (S*10^3)/(b*j*d)
= 22.09727

Type j

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.700 m

B×D = 100 × 40 cm

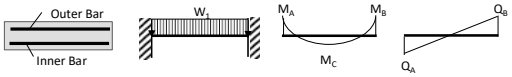
②Load Conditions

W1 = 75.600 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 75.60 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	45.93	22.97	87.00
Total	45.93	22.97	87.00

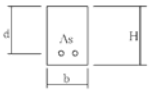


Type j

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	45.93	kN・m
Shear Force	S =	87.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.632	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	132.385	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.315	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

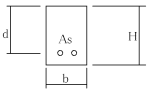
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.2394775
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 463.17932
σs = (M*10^5)/(b*d^2*p*j)
= 13238.5062
τ= (S*10^3)/(b*j*d)
= 31.51577

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	22.97	kN・m
Shear Force	S =	87.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.316	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	66.207	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.315	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p
= 0.23948

j = 1-(k/3)
= 0.92017

σ c = (2*M*10^5)/(b*d^2*k*j)
= 231.64008

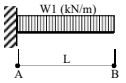
σ s = (M*10^5)/(b*d^2*p*j)
= 6620.69428

τ= (S*10^3)/(b*j*d)
= 31.51577

Type j

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.850 m

B×D = 100 × 45 cm

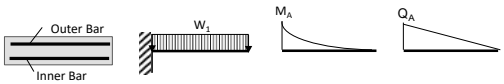
②Load Conditions

W1 = 57.600 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 57.60 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	20.81		36.00
Total	20.81		36.00

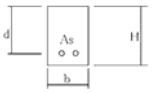


Type j

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	20.81	kN・m
Shear Force	S =	36.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.639	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	51.125	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.111	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p
= 0.2239631

j = 1-(k/3)
= 0.92535

σ c = (2*M*10^5)/(b*d^2*k*j)
= 163.94022

σ s = (M*10^5)/(b*d^2*p*j)
= 5112.50665

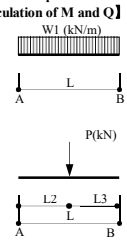
τ= (S*10^3)/(b*j*d)
= 11.11554

2.1.2.11 MANHOLE TYPE K

Type k

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

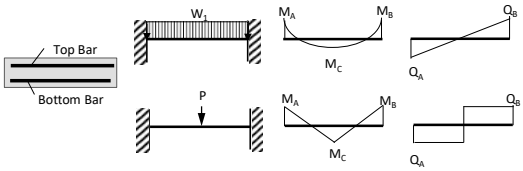
P = 52.000 kN : Point Load

L2 = 0.600 m L3 = 0.600 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	1.44	0.72	6.00
P	7.80	7.80	26.00
Total	9.24	8.52	32.00

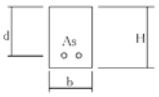


Type k

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	9.24	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.050	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	117.823	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 304.98173

σ s = (M*10^5)/(b*d^2*p*j)

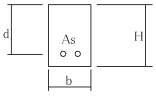
= 11782.28829

τ= (S*10^3)/(b*j*d)

= 18.45994

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	8.52	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.812	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	108.642	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 281.21692

σ s = (M*10^5)/(b*d^2*p*j)

= 10864.18790

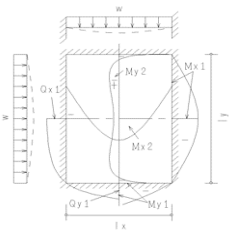
τ= (S*10^3)/(b*j*d)

= 18.45994

Type k

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.200 m

ly = 1.400 m

B×D = 100 × 30 cm

②Load Conditions

w = 96.800 kN/m : Uniform Load

ΣW = 96.80 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.2

α for Mx2 = 0.025

α for Mx1 = 0.064

α for Qx1 = 0.490

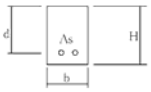
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	3.49	8.93	56.92

Type k

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	3.49	kN・m
Shear Force	S =	56.92	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.805	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	23.539	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.309	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 80.47517

σ s = (M*10^5)/(b*d^2*p*j)

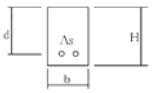
= 2353.93899

τ= (S*10^3)/(b*j*d)

= 30.88209

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	8.93	kN・m
Shear Force	S =	56.92	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.059	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	60.231	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.309	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 205.91497

σ s = (M*10^5)/(b*d^2*p*j)

= 6023.11610

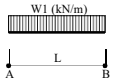
τ= (S*10^3)/(b*j*d)

= 30.88209

Type k

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 30 cm

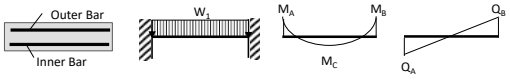
②Load Conditions

W1 = 85.408 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 85.41 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	10.25	5.13	39.00
Total	10.25	5.13	39.00

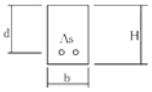


Type k

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	10.25	kN・m
Shear Force	S =	39.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.364	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	69.134	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.212	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

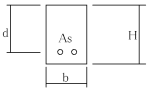
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.2352910
j = 1-(k/3)
= 0.92157
σc = (2*M*10^5)/(b*d^2*k*j)
= 236.35257
σs = (M*10^5)/(b*d^2*p*j)
= 6913.43114
τ= (S*10^3)/(b*j*d)
= 21.15955

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	5.13	kN・m
Shear Force	S =	39.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.183	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	34.601	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.212	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

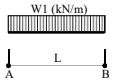
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.23529
j = 1-(k/3)
= 0.92157
σc = (2*M*10^5)/(b*d^2*k*j)
= 118.29158
σs = (M*10^5)/(b*d^2*p*j)
= 3460.08798
τ= (S*10^3)/(b*j*d)
= 21.15955

Type k

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.400 m

B×D = 100 × 30 cm

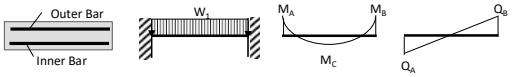
②Load Conditions

W1 = 85.408 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 85.41 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	13.95	6.98	47.00
Total	13.95	6.98	47.00

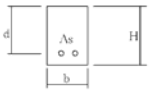


Type k

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	13.95	kN・m
Shear Force	S =	47.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.217	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	94.090	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.255	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

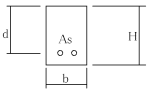
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706
k = √(2*n*p+(n*p)^2)-n*p
= 0.2352910
j = 1-(k/3)
= 0.92157
σc = (2*M*10^5)/(b*d^2*k*j)
= 321.67008
σs = (M*10^5)/(b*d^2*p*j)
= 9409.01116
τ= (S*10^3)/(b*j*d)
= 25.49997

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	6.98	kN・m	
Shear Force	S =	47.00	kN	
Width of Member	b =	100.0	cm	
Height of Member	H =	30.0	cm	
Equivalent Height (Tensile Side)	d =	20.000	cm	
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2	
Modulous of Elasticity	n =	9.000		
Compressive Stress of Concrete	σc=	1.610	N/mm^2	○
Tensile Stress of Rainforcing Bar	σs=	47.079	N/mm^2	○
Shearing Stress of Concrete	τ =	0.255	N/mm^2	○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p
= 0.23529

j = 1-(k/3)
= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)
= 160.95033

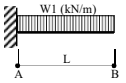
σ s = (M*10^5)/(b*d^2*p*j)
= 4707.87799

τ= (S*10^3)/(b*j*d)
= 25.49997

Type k

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.250 m

B×D = 100 × 30 cm

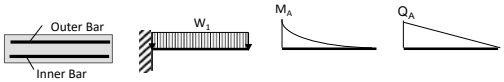
②Load Conditions

W1 = 75.658 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 75.66 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	2.37		8.00
Total	2.37		8.00

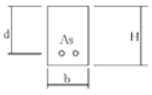


Type k

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	2.37	kN・m	
Shear Force	S =	8.00	kN	
Width of Member	b =	100.0	cm	
Height of Member	H =	30.0	cm	
Equivalent Height (Tensile Side)	d =	20.000	cm	
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2	
Modulous of Elasticity	n =	9.000		
Compressive Stress of Concrete	σc=	0.546	N/mm^2	○
Tensile Stress of Rainforcing Bar	σs=	15.985	N/mm^2	○
Shearing Stress of Concrete	τ =	0.043	N/mm^2	○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p
= 0.2352910

j = 1-(k/3)
= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)
= 54.64933

σ s = (M*10^5)/(b*d^2*p*j)
= 1598.52018

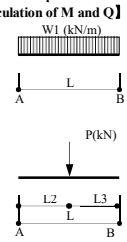
τ= (S*10^3)/(b*j*d)
= 4.34042

2.1.2.12 MANHOLE TYPE L

Type 1

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.400 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

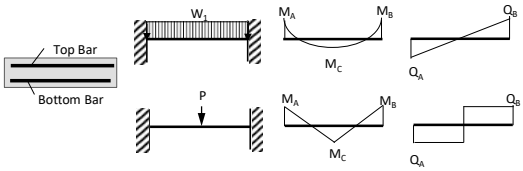
P = 52.000 kN : Point Load

L2 = 0.700 m L3 = 0.700 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	1.96	0.98	7.00
P	9.10	9.10	26.00
Total	11.06	10.08	33.00



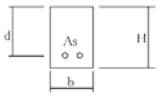
1

Type 1

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	11.06	kN・m
Shear Force	S =	33.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.890	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	80.882	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.194	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 289.03332

σ s = (M*10^5)/(b*d^2*p*j)

= 8088.18654

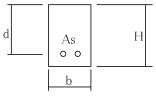
τ= (S*10^3)/(b*j*d)

= 19.41253

2

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	10.08	kN・m
Shear Force	S =	33.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.634	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	73.715	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.194	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 263.42277

σ s = (M*10^5)/(b*d^2*p*j)

= 7371.51178

τ= (S*10^3)/(b*j*d)

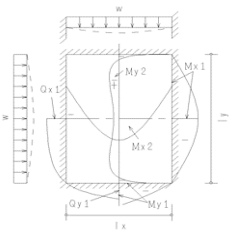
= 19.41253

3

Type 1

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.400 m

ly = 2.000 m

B×D = 100 × 40 cm

②Load Conditions

w = 100.880 kN/m : Uniform Load

ΣW = 100.88 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.5

α for Mx2 = 0.034

α for Mx1 = 0.076

α for Qx1 = 0.510

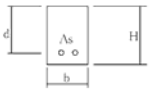
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	6.73	15.03	72.03

Type 1

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	6.73	kN・m
Shear Force	S =	72.03	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.813	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	29.847	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.257	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00268 = 5.906

k = √(2*n*p+(n*p)^2)-n*p

= 0.19688

j = 1-(k/3)

= 0.93437

σ c = (2*M*10^5)/(b*d^2*k*j)

= 81.29808

σ s = (M*10^5)/(b*d^2*p*j)

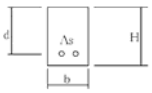
= 2984.70443

τ= (S*10^3)/(b*j*d)

= 25.69637

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	15.03	kN・m
Shear Force	S =	72.03	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.816	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	66.657	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.257	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00268 = 5.906

k = √(2*n*p+(n*p)^2)-n*p

= 0.19688

j = 1-(k/3)

= 0.93437

σ c = (2*M*10^5)/(b*d^2*k*j)

= 181.56168

σ s = (M*10^5)/(b*d^2*p*j)

= 6665.69205

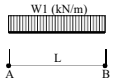
τ= (S*10^3)/(b*j*d)

= 25.69637

Type 1

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.000 m

B×D = 100 × 40 cm

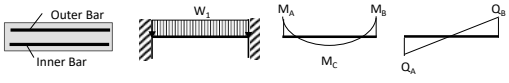
②Load Conditions

W1 = 86.706 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 86.71 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	28.91	14.46	70.00
Total	28.91	14.46	70.00

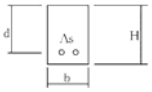


Type 1

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	28.91	kN・m
Shear Force	S =	70.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.492	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	128.214	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.250	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

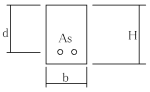
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00268 = 5.906
k = √(2*n*p+(n*p)^2)-n*p
= 0.1968801
j = 1-(k/3)
= 0.93437
σc = (2*M*10^5)/(b*d^2*k*j)
= 349.23142
σs = (M*10^5)/(b*d^2*p*j)
= 12821.3677
τ= (S*10^3)/(b*j*d)
= 24.97217

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	14.46	kN・m
Shear Force	S =	70.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.747	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	64.129	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.250	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

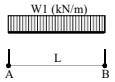
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00268 = 5.906
k = √(2*n*p+(n*p)^2)-n*p
= 0.19688
j = 1-(k/3)
= 0.93437
σc = (2*M*10^5)/(b*d^2*k*j)
= 174.67611
σs = (M*10^5)/(b*d^2*p*j)
= 6412.90134
τ= (S*10^3)/(b*j*d)
= 24.97217

Type 1

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.400 m

B×D = 100 × 40 cm

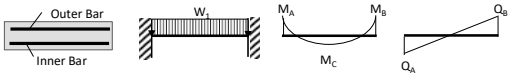
②Load Conditions

W1 = 86.706 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 86.71 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	14.17	7.09	44.00
Total	14.17	7.09	44.00

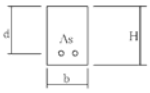


Type 1

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	14.17	kN・m
Shear Force	S =	44.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.712	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	62.843	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.157	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

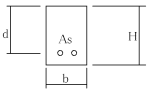
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00268 = 5.906
k = √(2*n*p+(n*p)^2)-n*p
= 0.1968801
j = 1-(k/3)
= 0.93437
σc = (2*M*10^5)/(b*d^2*k*j)
= 171.17292
σs = (M*10^5)/(b*d^2*p*j)
= 6284.28852
τ= (S*10^3)/(b*j*d)
= 15.69680

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	7.09	kN・m
Shear Force	S =	44.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.856	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	31.444	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.157	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00268 = 5.906

k = √(2*n*p+(n*p)^2)-n*p
= 0.19688

j = 1-(k/3)
= 0.93437

σ c = (2*M*10^5)/(b*d^2*k*j)
= 85.64686

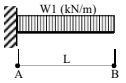
σ s = (M*10^5)/(b*d^2*p*j)
= 3144.36172

τ = (S*10^3)/(b*j*d)
= 15.69680

Type 1

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.250 m

B×D = 100 × 40 cm

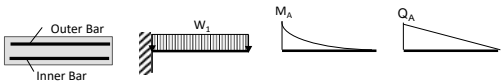
②Load Conditions

W1 = 76.956 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 76.96 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	2.41		4.00
Total	2.41		4.00

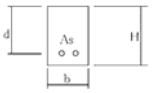


Type 1

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	2.41	kN・m
Shear Force	S =	4.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.243	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	6.946	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.014	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p
= 0.2394775

j = 1-(k/3)
= 0.92017

σ c = (2*M*10^5)/(b*d^2*k*j)
= 24.30355

σ s = (M*10^5)/(b*d^2*p*j)
= 694.63967

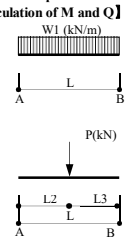
τ = (S*10^3)/(b*j*d)
= 1.44900

2.1.2.13 MANHOLE TYPE M

Type m

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

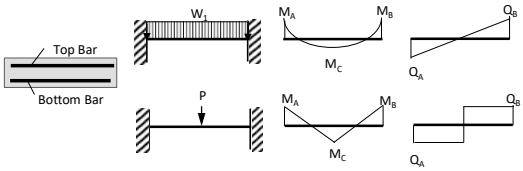
P = 52.000 kN : Point Load

L2 = 1.050 m L3 = 1.050 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	4.41	2.21	12.00
P	13.65	13.65	26.00
Total	18.06	15.86	38.00



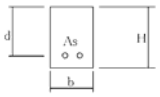
1

Type m

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	18.06	kN・m
Shear Force	S =	38.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.720	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	132.073	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.224	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 471.96580

σ s = (M*10^5)/(b*d^2*p*j)

= 13207.29195

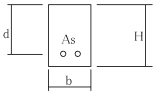
τ= (S*10^3)/(b*j*d)

= 22.35382

2

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	15.86	kN・m
Shear Force	S =	38.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.145	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	115.984	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.224	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 414.47273

σ s = (M*10^5)/(b*d^2*p*j)

= 11598.43025

τ= (S*10^3)/(b*j*d)

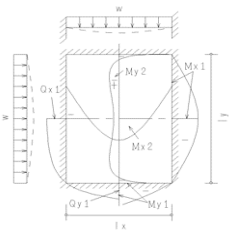
= 22.35382

3

Type m

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 2.100 m

ly = 2.600 m

B×D = 100 × 45 cm

②Load Conditions

w = 93.040 kN/m : Uniform Load

ΣW = 93.04 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.3

α for Mx2 = 0.029

α for Mx1 = 0.068

α for Qx1 = 0.500

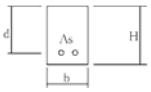
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	11.90	27.91	97.70

Type m

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	11.90	kN・m
Shear Force	S =	97.70	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.937	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	29.235	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.302	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p

= 0.22396

j = 1-(k/3)

= 0.92535

σ c = (2*M*10^5)/(b*d^2*k*j)

= 93.74765

σ s = (M*10^5)/(b*d^2*p*j)

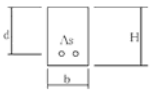
= 2923.53816

τ= (S*10^3)/(b*j*d)

= 30.16633

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	27.91	kN・m
Shear Force	S =	97.70	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.199	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	68.568	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.302	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p

= 0.22396

j = 1-(k/3)

= 0.92535

σ c = (2*M*10^5)/(b*d^2*k*j)

= 219.87369

σ s = (M*10^5)/(b*d^2*p*j)

= 6856.80253

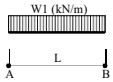
τ= (S*10^3)/(b*j*d)

= 30.16633

Type m

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 45 cm

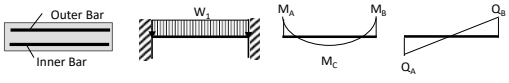
②Load Conditions

W1 = 85.650 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 85.65 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	31.48	15.74	71.00
Total	31.48	15.74	71.00

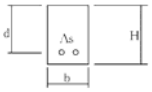


Type m

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	31.48	kN・m
Shear Force	S =	71.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.480	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	77.339	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.219	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p

= 0.2239631

j = 1-(k/3)

= 0.92535

σc = (2*M*10^5)/(b*d^2*k*j)

= 247.99799

σs = (M*10^5)/(b*d^2*p*j)

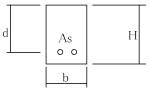
= 7733.86398

τ= (S*10^3)/(b*j*d)

= 21.92231

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	15.74	kN・m
Shear Force	S =	71.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.240	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	38.669	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.219	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p

= 0.22396

j = 1-(k/3)

= 0.92535

σc = (2*M*10^5)/(b*d^2*k*j)

= 123.99899

σs = (M*10^5)/(b*d^2*p*j)

= 3866.93199

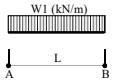
τ= (S*10^3)/(b*j*d)

= 21.92231

Type m

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.600 m

B×D = 100 × 45 cm

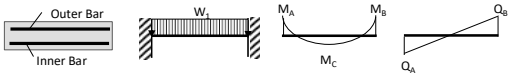
②Load Conditions

W1 = 85.650 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 85.65 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	48.25	24.13	93.00
Total	48.25	24.13	93.00

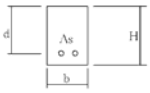


Type m

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	48.25	kN・m
Shear Force	S =	93.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.801	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	118.538	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.287	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p

= 0.2239631

j = 1-(k/3)

= 0.92535

σc = (2*M*10^5)/(b*d^2*k*j)

= 380.11127

σs = (M*10^5)/(b*d^2*p*j)

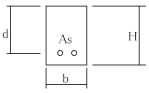
= 11853.8417

τ= (S*10^3)/(b*j*d)

= 28.71514

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	24.13	kN・m
Shear Force	S =	93.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.901	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	59.281	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.287	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p
= 0.22396

j = 1-(k/3)
= 0.92535

σ c = (2*M*10^5)/(b*d^2*k*j)
= 190.09503

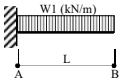
σ s = (M*10^5)/(b*d^2*p*j)
= 5928.14923

τ = (S*10^3)/(b*j*d)
= 28.71514

Type m

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.800 m

B×D = 100 × 45 cm

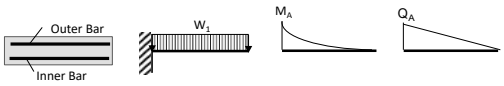
②Load Conditions

W1 = 74.775 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 74.78 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	23.93		43.00
Total	23.93		43.00

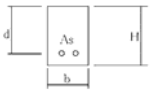


Type m

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	23.93	kN・m
Shear Force	S =	43.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.885	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	58.790	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.133	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p
= 0.2239631

j = 1-(k/3)
= 0.92535

σ c = (2*M*10^5)/(b*d^2*k*j)
= 188.51944

σ s = (M*10^5)/(b*d^2*p*j)
= 5879.01414

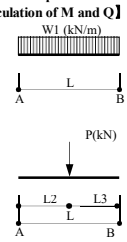
τ = (S*10^3)/(b*j*d)
= 13.27689

2.1.2.14 MANHOLE TYPE N

Type n

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.800 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

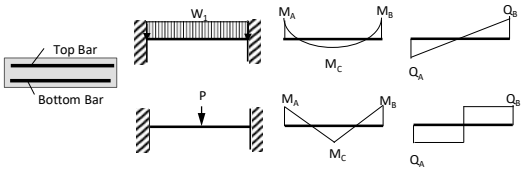
P = 52.000 kN : Point Load

L2 = 0.900 m L3 = 0.900 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	3.24	1.62	10.00
P	11.70	11.70	26.00
Total	14.94	13.32	36.00



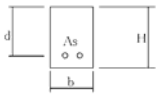
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Type n

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	14.94	kN・m
Shear Force	S =	36.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.904	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	109.256	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.212	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 390.43018

σ s = (M*10^5)/(b*d^2*p*j)

= 10925.63354

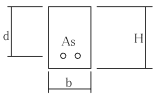
τ= (S*10^3)/(b*j*d)

= 21.17730

2

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	13.32	kN・m
Shear Force	S =	36.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.481	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	97.409	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.212	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 348.09438

σ s = (M*10^5)/(b*d^2*p*j)

= 9740.92629

τ= (S*10^3)/(b*j*d)

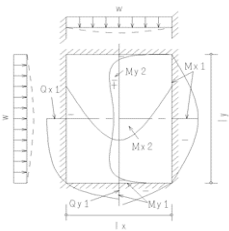
= 21.17730

3

Type n

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.800 m

ly = 2.100 m

B×D = 100 × 40 cm

②Load Conditions

w = 108.200 kN/m : Uniform Load

ΣW = 108.20 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.2

α for Mx2 = 0.025

α for Mx1 = 0.064

α for Qx1 = 0.490

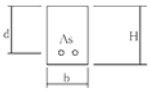
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	8.77	22.44	95.44

Type n

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	
Bending Moment	M =	8.77	kN・m
Shear Force	S =	95.44	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.884	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	25.278	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.346	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p

= 0.23948

j = 1-(k/3)

= 0.92017

σ c = (2*M*10^5)/(b*d^2*k*j)

= 88.44073

σ s = (M*10^5)/(b*d^2*p*j)

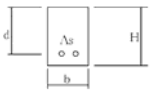
= 2527.79664

τ= (S*10^3)/(b*j*d)

= 34.57317

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	
Bending Moment	M =	22.44	kN・m
Shear Force	S =	95.44	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.263	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	64.679	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.346	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p

= 0.23948

j = 1-(k/3)

= 0.92017

σ c = (2*M*10^5)/(b*d^2*k*j)

= 226.29532

σ s = (M*10^5)/(b*d^2*p*j)

= 6467.93120

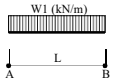
τ= (S*10^3)/(b*j*d)

= 34.57317

Type n

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 40 cm

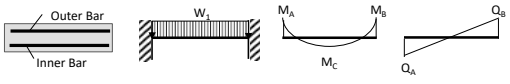
②Load Conditions

W1 = 98.973 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 98.97 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	36.38	18.19	85.00
Total	36.38	18.19	85.00

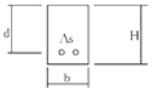


Type n

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Reinforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	36.38	kN・m
Shear Force	S =	85.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.669	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	104.859	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.308	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p

= 0.2394775

j = 1-(k/3)

= 0.92017

σc = (2*M*10^5)/(b*d^2*k*j)

= 366.87271

σs = (M*10^5)/(b*d^2*p*j)

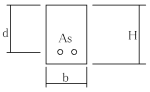
= 10485.8885

τ= (S*10^3)/(b*j*d)

= 30.79127

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	18.19	kN・m
Shear Force	S =	85.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.834	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	52.429	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.308	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p

= 0.23948

j = 1-(k/3)

= 0.92017

σc = (2*M*10^5)/(b*d^2*k*j)

= 183.43635

σs = (M*10^5)/(b*d^2*p*j)

= 5242.94423

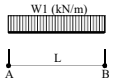
τ= (S*10^3)/(b*j*d)

= 30.79127

Type n

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.800 m

B×D = 100 × 40 cm

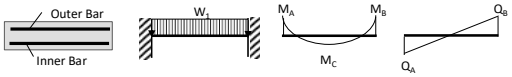
②Load Conditions

W1 = 98.973 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 98.97 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	26.73	13.37	70.00
Total	26.73	13.37	70.00

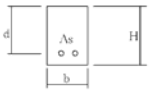


Type n

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	26.73	kN・m
Shear Force	S =	70.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.696	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	77.044	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.254	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p

= 0.2394775

j = 1-(k/3)

= 0.92017

σc = (2*M*10^5)/(b*d^2*k*j)

= 269.55766

σs = (M*10^5)/(b*d^2*p*j)

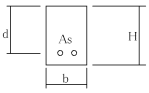
= 7704.44746

τ= (S*10^3)/(b*j*d)

= 25.35752

【Stress Intensity Calcularion】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	13.37	kN・m
Shear Force	S =	70.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.348	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	38.537	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.254	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.23948
j = 1-(k/3)
= 0.92017
σ c = (2*M*10^5)/(b*d^2*k*j)
= 134.82925
σ s = (M*10^5)/(b*d^2*p*j)
= 3853.66489
τ= (S*10^3)/(b*j*d)
= 25.35752

【Study on Shear Force Reinforcement】

Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Cross Sectional Area of Shear Reinforcing Bar	Aw =	113.10	mm^2 ○
Required Cross Sectional Area of Shear Reinforcing Bar	Aw =	-20.11	mm^2

$$Aw = \frac{1.15*Sh*s}{\sigma sa*d}$$

Sh = Q - Sca
Sca =b*d*τa

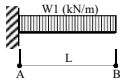
where,
Sca : Shear force beared by concrete
Sh : Shear force beared by stirrup reinforcement bars

Sca =	99.38	kN	
Sh =	-29.38	kN	

Type n

Analysis of Side Slab (Vd2 Opening)

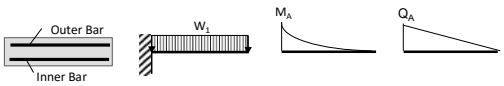
【Calculation of M and Q】



①Dimensional Conditions
L = 0.450 m
B×D = 100 × 40 cm

②Load Conditions
W1 = 86.973 kN/m : Uniform Load
w = kN/m : Self Weight
ΣW = 86.97 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	8.81		22.00
Total	8.81		22.00

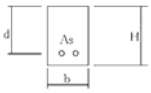


Type n

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calcularion】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	8.81	kN・m
Shear Force	S =	22.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.888	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	25.393	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.080	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

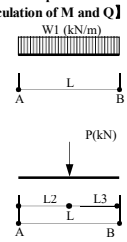
p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.2394775
j = 1-(k/3)
= 0.92017
σ c = (2*M*10^5)/(b*d^2*k*j)
= 88.84411
σ s = (M*10^5)/(b*d^2*p*j)
= 2539.32593
τ= (S*10^3)/(b*j*d)
= 7.96951

2.1.2.15 MANHOLE TYPE O

Type o

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

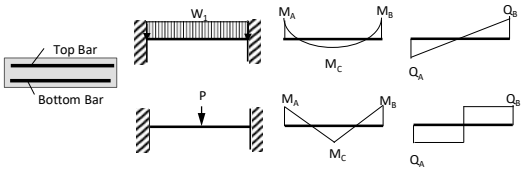
P = 52.000 kN : Point Load

L2 = 1.050 m L3 = 1.050 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	4.41	2.21	12.00
P	13.65	13.65	26.00
Total	18.06	15.86	38.00

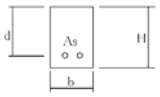


Type o

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	18.06	kN・m
Shear Force	S =	38.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.720	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	132.073	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.224	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 471.96580

σ s = (M*10^5)/(b*d^2*p*j)

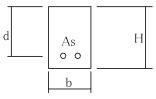
= 13207.29195

τ= (S*10^3)/(b*j*d)

= 22.35382

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	15.86	kN・m
Shear Force	S =	38.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.145	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	115.984	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.224	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 414.47273

σ s = (M*10^5)/(b*d^2*p*j)

= 11598.43025

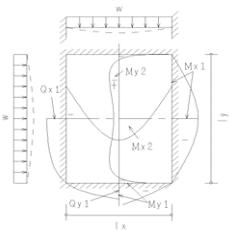
τ= (S*10^3)/(b*j*d)

= 22.35382

Type o

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 2.100 m

ly = 2.300 m

B×D = 100 × 45 cm

②Load Conditions

w = 103.550 kN/m : Uniform Load

ΣW = 103.55 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.1

α for Mx2 = 0.022

α for Mx1 = 0.058

α for Qx1 = 0.470

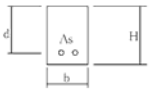
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	10.05	26.49	102.21

Type o

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	10.05	kN・m
Shear Force	S =	102.21	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.792	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	24.690	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.316	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p

= 0.22396

j = 1-(k/3)

= 0.92535

σ c = (2*M*10^5)/(b*d^2*k*j)

= 79.17344

σ s = (M*10^5)/(b*d^2*p*j)

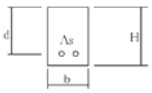
= 2469.03853

τ= (S*10^3)/(b*j*d)

= 31.55886

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	26.49	kN・m
Shear Force	S =	102.21	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.087	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	65.079	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.316	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00359 = 7.839

k = √(2*n*p+(n*p)^2)-n*p

= 0.22396

j = 1-(k/3)

= 0.92535

σ c = (2*M*10^5)/(b*d^2*k*j)

= 208.68700

σ s = (M*10^5)/(b*d^2*p*j)

= 6507.94336

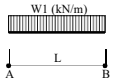
τ= (S*10^3)/(b*j*d)

= 31.55886

Type o

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 40 cm

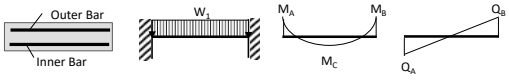
②Load Conditions

W1 = 102.300 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 102.30 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	37.60	18.80	87.00
Total	37.60	18.80	87.00

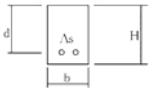


Type o

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	37.60	kN・m
Shear Force	S =	87.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.792	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	108.375	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.315	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

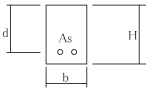
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.2394775
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 379.17575
σs = (M*10^5)/(b*d^2*p*j)
= 10837.5318
τ= (S*10^3)/(b*j*d)
= 31.51577

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	18.80	kN・m
Shear Force	S =	87.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.896	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	54.188	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.315	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.23948
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 189.58788
σs = (M*10^5)/(b*d^2*p*j)
= 5418.76589
τ= (S*10^3)/(b*j*d)
= 31.51577

【Study on Shear Force Reinforcement】

Diameter	12	mm
Interval of Reinforcing Bar	250	mm

Cross Sectional Area of Shear Reinforcing Bar	Aw =	113.10	mm^2 ○
Required Cross Sectional Area of Shear Reinforcing Bar	Aw =	-8.47	mm^2

$$Aw = \frac{1.15*Sh*s}{\sigma sa*d}$$

Sh = Q - Sca

Sca =b*d*τa

where,

Sca : Shear force beared by concrete

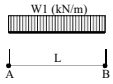
Sh : Shear force beared by stirrup reinforcement bars

Sca =	99.38	kN
Sh =	-12.38	kN

Type o

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.300 m

B×D = 100 × 40 cm

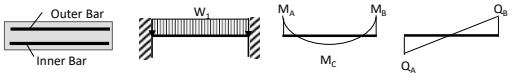
②Load Conditions

W1 = 102.300 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 102.30 kN/m

Load	M(kN·m) for outer bars	M(kN·m) for inner bars	Q(kN)
W1+w	45.10	22.55	98.00
Total	45.10	22.55	98.00

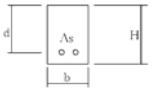


Type o

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	45.10	kN・m
Shear Force	S =	98.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.548	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	129.993	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.355	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

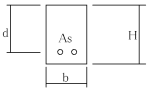
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.2394775
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 454.80921
σs = (M*10^5)/(b*d^2*p*j)
= 12999.2735
τ= (S*10^3)/(b*j*d)
= 35.50053

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	22.55	kN・m
Shear Force	S =	98.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.274	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	64.996	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.355	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

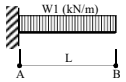
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.23948
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 227.40461
σs = (M*10^5)/(b*d^2*p*j)
= 6499.63674
τ= (S*10^3)/(b*j*d)
= 35.50053

Type o

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.650 m

B×D = 100 × 50 cm

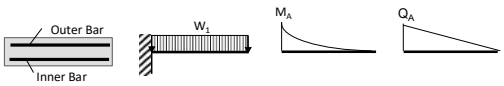
②Load Conditions

W1 = 90.300 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 90.30 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	19.08		37.00
Total	19.08		37.00

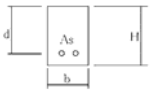


Type o

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	19.08	kN・m
Shear Force	S =	37.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	50.0	cm
Equivalent Height (Tensile Side)	d =	40.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.215	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	40.828	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.100	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

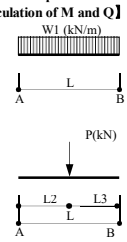
p = As/(b*d) x = k*d
= 0.00314 = 8.448
k = √(2*n*p+(n*p)^2)-n*p
= 0.2112124
j = 1-(k/3)
= 0.92960
σc = (2*M*10^5)/(b*d^2*k*j)
= 121.47162
σs = (M*10^5)/(b*d^2*p*j)
= 4082.7992
τ= (S*10^3)/(b*j*d)
= 9.95056

2.1.2.16 MANHOLE TYPE P

Type p

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

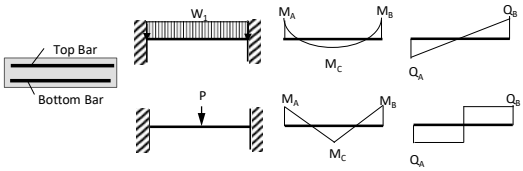
P = 52.000 kN : Point Load

L2 = 1.050 m L3 = 1.050 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	4.41	2.21	12.00
P	13.65	13.65	26.00
Total	18.06	15.86	38.00

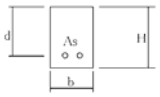


Type p

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	18.06	kN・m
Shear Force	S =	38.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.720	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	132.073	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.224	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 471.96580

σ s = (M*10^5)/(b*d^2*p*j)

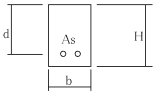
= 13207.29195

τ= (S*10^3)/(b*j*d)

= 22.35382

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	15.86	kN・m
Shear Force	S =	38.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.145	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	115.984	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.224	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 414.47273

σ s = (M*10^5)/(b*d^2*p*j)

= 11598.43025

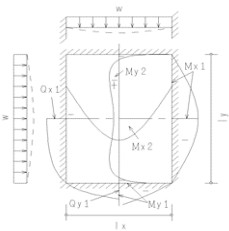
τ= (S*10^3)/(b*j*d)

= 22.35382

Type p

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 2.100 m

ly = 3.000 m

B×D = 100 × 50 cm

②Load Conditions

w = 110.460 kN/m : Uniform Load

ΣW = 110.46 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.5

α for Mx2 = 0.034

α for Mx1 = 0.076

α for Qx1 = 0.510

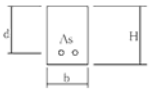
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	16.57	37.03	118.31

Type p

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter 25 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 16.57 kN・m

Shear Force S = 118.31 kN

Width of Member b = 100.0 cm

Height of Member H = 50.0 cm

Equivalent Height (Tensile Side) d = 40.000 cm

Total Cross-Sectional (Tensile Side) A_s = 19.636 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 0.883 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 23.068 N/mm^2 ○

Shearing Stress of Concrete τ = 0.323 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00491 = 10.254

k = √(2*n*p+(n*p)^2)-n*p

= 0.25634

j = 1-(k/3)

= 0.91455

σ c = (2*M*10^5)/(b*d^2*k*j)

= 88.34955

σ s = (M*10^5)/(b*d^2*p*j)

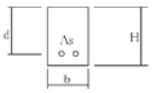
= 2306.75114

τ= (S*10^3)/(b*j*d)

= 32.34095

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter 25 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 37.03 kN・m

Shear Force S = 118.31 kN

Width of Member b = 100.0 cm

Height of Member H = 50.0 cm

Equivalent Height (Tensile Side) d = 40.000 cm

Total Cross-Sectional (Tensile Side) A_s = 19.636 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 1.974 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 51.550 N/mm^2 ○

Shearing Stress of Concrete τ = 0.323 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00491 = 10.254

k = √(2*n*p+(n*p)^2)-n*p

= 0.25634

j = 1-(k/3)

= 0.91455

σ c = (2*M*10^5)/(b*d^2*k*j)

= 197.44017

σ s = (M*10^5)/(b*d^2*p*j)

= 5155.03890

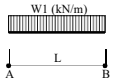
τ= (S*10^3)/(b*j*d)

= 32.34095

Type p

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 50 cm

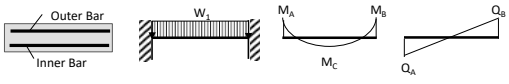
②Load Conditions

W1 = 105.050 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 105.05 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	38.61	19.31	85.00
Total	38.61	19.31	85.00

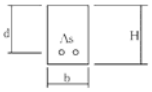


Type p

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	38.61	kN・m
Shear Force	S =	85.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	50.0	cm
Equivalent Height (Tensile Side)	d =	40.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.059	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	53.750	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.232	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00491 = 10.254

k = √(2*n*p+(n*p)^2)-n*p

= 0.2563418

j = 1-(k/3)

= 0.91455

σ c = (2*M*10^5)/(b*d^2*k*j)

= 205.86457

σ s = (M*10^5)/(b*d^2*p*j)

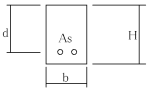
= 5374.99466

τ= (S*10^3)/(b*j*d)

= 23.23540

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	19.31	kN・m
Shear Force	S =	85.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	50.0	cm
Equivalent Height (Tensile Side)	d =	40.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.030	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	26.882	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.232	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00491 = 10.254

k = √(2*n*p+(n*p)^2)-n*p

= 0.25634

j = 1-(k/3)

= 0.91455

σ c = (2*M*10^5)/(b*d^2*k*j)

= 102.95895

σ s = (M*10^5)/(b*d^2*p*j)

= 2688.19339

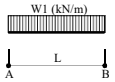
τ= (S*10^3)/(b*j*d)

= 23.23540

Type p

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 3.000 m

B×D = 100 × 50 cm

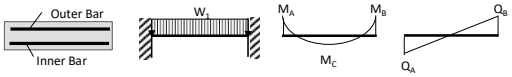
②Load Conditions

W1 = 105.050 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 105.05 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	78.79	39.40	131.00
Total	78.79	39.40	131.00

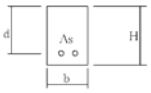


Type p

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	78.79	kN・m
Shear Force	S =	131.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	50.0	cm
Equivalent Height (Tensile Side)	d =	40.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.201	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	109.686	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.358	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00491 = 10.254

k = √(2*n*p+(n*p)^2)-n*p

= 0.2563418

j = 1-(k/3)

= 0.91455

σ c = (2*M*10^5)/(b*d^2*k*j)

= 420.10022

σ s = (M*10^5)/(b*d^2*p*j)

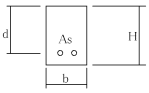
= 10968.5529

τ= (S*10^3)/(b*j*d)

= 35.80985

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	25	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	39.40	kN・m
Shear Force	S =	131.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	50.0	cm
Equivalent Height (Tensile Side)	d =	40.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.101	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	54.850	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.358	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) = 0.00491

k = √(2*n*p+(n*p)^2)-n*p = 0.25634

j = 1-(k/3) = 0.91455

σ c = (2*M*10^5)/(b*d^2*k*j) = 210.07677

σ s = (M*10^5)/(b*d^2*p*j) = 5484.97253

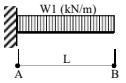
τ = (S*10^3)/(b*j*d) = 35.80985

x = k*d = 10.254

Type p

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.050 m

B×D = 100 × 60 cm

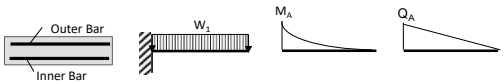
②Load Conditions

W1 = 90.800 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 90.80 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	50.06		69.00
Total	50.06		69.00

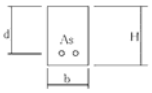


Type p

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	25	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	50.06	kN・m
Shear Force	S =	69.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	60.0	cm
Equivalent Height (Tensile Side)	d =	50.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.864	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	55.279	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.150	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) = 0.00393

k = √(2*n*p+(n*p)^2)-n*p = 0.2328694

j = 1-(k/3) = 0.92238

σ c = (2*M*10^5)/(b*d^2*k*j) = 186.44898

σ s = (M*10^5)/(b*d^2*p*j) = 5527.89028

τ = (S*10^3)/(b*j*d) = 14.96135

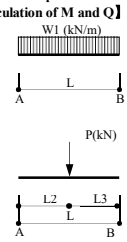
x = k*d = 11.643

2.1.2.17 MANHOLE TYPE Q

Type q

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.400 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

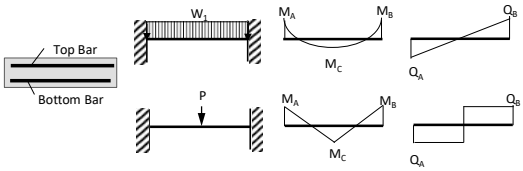
P = 52.000 kN : Point Load

L2 = 0.700 m L3 = 0.700 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	1.96	0.98	7.00
P	9.10	9.10	26.00
Total	11.06	10.08	33.00

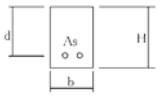


Type q

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	11.06	kN・m
Shear Force	S =	33.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.890	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	80.882	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.194	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 289.03332

σ s = (M*10^5)/(b*d^2*p*j)

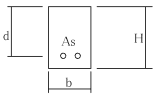
= 8088.18654

τ= (S*10^3)/(b*j*d)

= 19.41253

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	10.08	kN・m
Shear Force	S =	33.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.634	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	73.715	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.194	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 263.42277

σ s = (M*10^5)/(b*d^2*p*j)

= 7371.51178

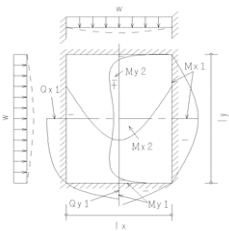
τ= (S*10^3)/(b*j*d)

= 19.41253

Type q

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.400 m

ly = 2.100 m

B×D = 100 × 40 cm

②Load Conditions

w = 135.250 kN/m : Uniform Load

ΣW = 135.25 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.5

α for Mx2 = 0.034

α for Mx1 = 0.076

α for Qx1 = 0.510

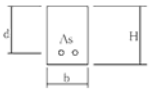
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	9.02	20.15	96.57

Type q

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter 20 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 9.02 kN・m

Shear Force S = 96.57 kN

Width of Member b = 100.0 cm

Height of Member H = 40.0 cm

Equivalent Height (Tensile Side) d = 30.000 cm

Total Cross-Sectional (Tensile Side) A_s = 12.568 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 0.910 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 25.999 N/mm^2 ○

Shearing Stress of Concrete τ = 0.350 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p

= 0.23948

j = 1-(k/3)

= 0.92017

σ c = (2*M*10^5)/(b*d^2*k*j)

= 90.96184

σ s = (M*10^5)/(b*d^2*p*j)

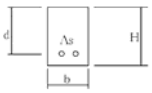
= 2599.85470

τ= (S*10^3)/(b*j*d)

= 34.98251

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter 20 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 20.15 kN・m

Shear Force S = 96.57 kN

Width of Member b = 100.0 cm

Height of Member H = 40.0 cm

Equivalent Height (Tensile Side) d = 30.000 cm

Total Cross-Sectional (Tensile Side) A_s = 12.568 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 2.032 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 58.079 N/mm^2 ○

Shearing Stress of Concrete τ = 0.350 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00419 = 7.184

k = √(2*n*p+(n*p)^2)-n*p

= 0.23948

j = 1-(k/3)

= 0.92017

σ c = (2*M*10^5)/(b*d^2*k*j)

= 203.20190

σ s = (M*10^5)/(b*d^2*p*j)

= 5807.87940

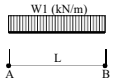
τ= (S*10^3)/(b*j*d)

= 34.98251

Type q

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 40 cm

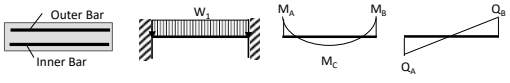
②Load Conditions

W1 = 114.000 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 114.00 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	41.90	20.95	97.00
Total	41.90	20.95	97.00

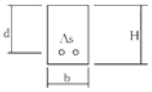


Type q

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	41.90	kN・m
Shear Force	S =	97.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.225	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	120.769	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.351	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

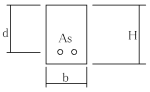
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.2394775
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 422.53894
σs = (M*10^5)/(b*d^2*p*j)
= 12076.9304
τ= (S*10^3)/(b*j*d)
= 35.13828

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	20.95	kN・m
Shear Force	S =	97.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.113	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	60.385	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.351	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

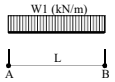
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.23948
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 211.26947
σs = (M*10^5)/(b*d^2*p*j)
= 6038.46518
τ= (S*10^3)/(b*j*d)
= 35.13828

Type q

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.400 m

B×D = 100 × 40 cm

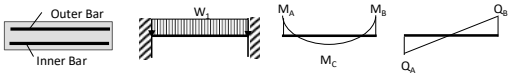
②Load Conditions

W1 = 114.000 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 114.00 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	18.62	9.31	57.00
Total	18.62	9.31	57.00

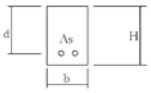


Type q

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	18.62	kN・m
Shear Force	S =	57.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.878	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	53.669	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.206	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

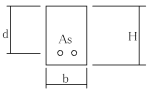
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00419 = 7.184
k = √(2*n*p+(n*p)^2)-n*p
= 0.2394775
j = 1-(k/3)
= 0.92017
σc = (2*M*10^5)/(b*d^2*k*j)
= 187.77267
σs = (M*10^5)/(b*d^2*p*j)
= 5366.88409
τ= (S*10^3)/(b*j*d)
= 20.64827

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	9.31	kN・m
Shear Force	S =	57.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	40.0	cm
Equivalent Height (Tensile Side)	d =	30.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.939	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	26.834	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.206	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) = 0.00419

x = k*d = 7.184

k = √(2*n*p+(n*p)^2)-n*p = 0.23948

j = 1-(k/3) = 0.92017

σc = (2*M*10^5)/(b*d^2*k*j) = 93.88634

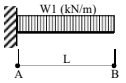
σs = (M*10^5)/(b*d^2*p*j) = 2683.44204

τ = (S*10^3)/(b*j*d) = 20.64827

Type q

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.250 m

B×D = 100 × 45 cm

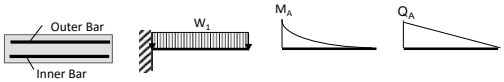
②Load Conditions

W1 = 104.250 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 104.25 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	3.26		3.00
Total	3.26		3.00

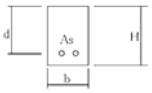


Type q

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	3.26	kN・m
Shear Force	S =	3.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	45.0	cm
Equivalent Height (Tensile Side)	d =	35.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.257	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	8.009	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.009	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) = 0.00359

x = k*d = 7.839

k = √(2*n*p+(n*p)^2)-n*p = 0.2239631

j = 1-(k/3) = 0.92535

σc = (2*M*10^5)/(b*d^2*k*j) = 25.68213

σs = (M*10^5)/(b*d^2*p*j) = 800.902051

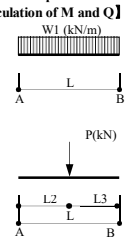
τ = (S*10^3)/(b*j*d) = 0.92629

2.1.2.18 MANHOLE TYPE R

Type r

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

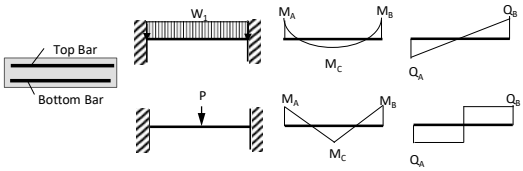
P = 52.000 kN : Point Load

L2 = 1.050 m L3 = 1.050 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN・m) for top bars	M(kN・m) for bottom bars	Q(kN)
W1+w	4.41	2.21	12.00
P	13.65	13.65	26.00
Total	18.06	15.86	38.00

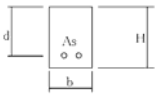


Type r

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	18.06	kN・m
Shear Force	S =	38.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.720	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	132.073	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.224	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 471.96580

σ s = (M*10^5)/(b*d^2*p*j)

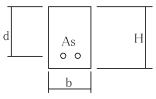
= 13207.29195

τ= (S*10^3)/(b*j*d)

= 22.35382

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	15.86	kN・m
Shear Force	S =	38.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.145	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	115.984	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.224	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 414.47273

σ s = (M*10^5)/(b*d^2*p*j)

= 11598.43025

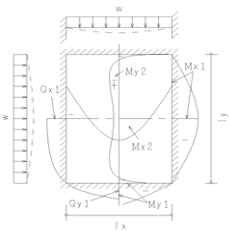
τ= (S*10^3)/(b*j*d)

= 22.35382

Type r

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 2.100 m

ly = 3.200 m

B×D = 100 × 60 cm

②Load Conditions

w = 131.720 kN/m : Uniform Load

ΣW = 131.72 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.6

α for Mx2 = 0.036

α for Mx1 = 0.078

α for Qx1 = 0.520

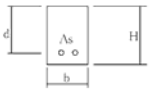
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	20.92	45.31	143.84

Type r

Analysis of Bottom Slab

【Stress Intensity Calcularion】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	20.92	kN・m
Shear Force	S =	143.84	kN
Width of Member	b =	100.0	cm
Height of Member	H =	60.0	cm
Equivalent Height (Tensile Side)	d =	50.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.779	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	23.101	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.312	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00393 = 11.643

k = √(2*n*p+(n*p)^2)-n*p

= 0.23287

j = 1-(k/3)

= 0.92238

σ c = (2*M*10^5)/(b*d^2*k*j)

= 77.91675

σ s = (M*10^5)/(b*d^2*p*j)

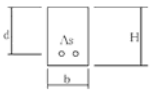
= 2310.09718

τ= (S*10^3)/(b*j*d)

= 31.18899

【Stress Intensity Calcularion】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	45.31	kN・m
Shear Force	S =	143.84	kN
Width of Member	b =	100.0	cm
Height of Member	H =	60.0	cm
Equivalent Height (Tensile Side)	d =	50.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.688	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	50.034	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.312	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00393 = 11.643

k = √(2*n*p+(n*p)^2)-n*p

= 0.23287

j = 1-(k/3)

= 0.92238

σ c = (2*M*10^5)/(b*d^2*k*j)

= 168.75756

σ s = (M*10^5)/(b*d^2*p*j)

= 5003.37013

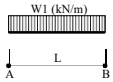
τ= (S*10^3)/(b*j*d)

= 31.18899

Type r

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.100 m

B×D = 100 × 60 cm

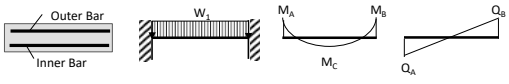
②Load Conditions

W1 = 120.050 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 120.05 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	44.12	22.06	91.00
Total	44.12	22.06	91.00

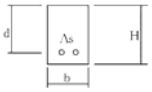


Type r

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	44.12	kN・m
Shear Force	S =	91.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	60.0	cm
Equivalent Height (Tensile Side)	d =	50.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.643	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	48.720	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.197	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

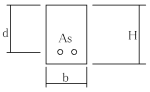
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00393 = 11.643
k = √(2*n*p+(n*p)^2)-n*p
= 0.2328694
j = 1-(k/3)
= 0.92238
σc = (2*M*10^5)/(b*d^2*k*j)
= 164.32539
σs = (M*10^5)/(b*d^2*p*j)
= 4871.96403
τ= (S*10^3)/(b*j*d)
= 19.73163

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	22.06	kN・m
Shear Force	S =	91.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	60.0	cm
Equivalent Height (Tensile Side)	d =	50.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.822	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	24.360	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.197	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

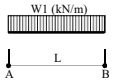
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00393 = 11.643
k = √(2*n*p+(n*p)^2)-n*p
= 0.23287
j = 1-(k/3)
= 0.92238
σc = (2*M*10^5)/(b*d^2*k*j)
= 82.16269
σs = (M*10^5)/(b*d^2*p*j)
= 2435.98201
τ= (S*10^3)/(b*j*d)
= 19.73163

Type r

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

L = 3.200 m

B×D = 100 × 60 cm

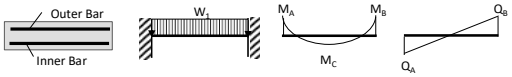
②Load Conditions

W1 = 120.050 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 120.05 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	102.45	51.23	157.00
Total	102.45	51.23	157.00

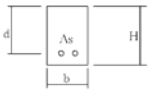


Type r

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	102.45	kN・m
Shear Force	S =	157.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	60.0	cm
Equivalent Height (Tensile Side)	d =	50.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.816	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	113.131	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.340	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

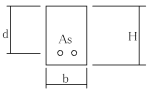
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00393 = 11.643
k = √(2*n*p+(n*p)^2)-n*p
= 0.2328694
j = 1-(k/3)
= 0.92238
σc = (2*M*10^5)/(b*d^2*k*j)
= 381.57607
σs = (M*10^5)/(b*d^2*p*j)
= 11313.0715
τ= (S*10^3)/(b*j*d)
= 34.04248

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	25	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	51.23	kN・m	
Shear Force	S =	157.00	kN	
Width of Member	b =	100.0	cm	
Height of Member	H =	60.0	cm	
Equivalent Height (Tensile Side)	d =	50.000	cm	
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2	
Modulous of Elasticity	n =	9.000		
Compressive Stress of Concrete	σc=	1.908	N/mm^2	○
Tensile Stress of Rainforcing Bar	σs=	56.571	N/mm^2	○
Shearing Stress of Concrete	τ =	0.340	N/mm^2	○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00393 = 11.643

k = √(2*n*p+(n*p)^2)-n*p
= 0.23287

j = 1-(k/3)
= 0.92238

σ c = (2*M*10^5)/(b*d^2*k*j)
= 190.80666

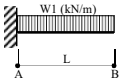
σ s = (M*10^5)/(b*d^2*p*j)
= 5657.08788

τ= (S*10^3)/(b*j*d)
= 34.04248

Type r

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

L = 0.700 m

B×D = 100 × 60 cm

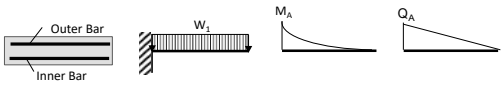
②Load Conditions

W1 = 103.550 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 103.55 kN/m

Load	M(kN・m) for outer bars		Q(kN)
W1+w	25.37		42.00
Total	25.37		42.00

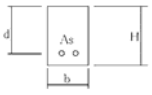


Type r

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	25	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	

Bending Moment	M =	25.37	kN・m	
Shear Force	S =	42.00	kN	
Width of Member	b =	100.0	cm	
Height of Member	H =	60.0	cm	
Equivalent Height (Tensile Side)	d =	50.000	cm	
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2	
Modulous of Elasticity	n =	9.000		
Compressive Stress of Concrete	σc=	0.945	N/mm^2	○
Tensile Stress of Rainforcing Bar	σs=	28.015	N/mm^2	○
Shearing Stress of Concrete	τ =	0.091	N/mm^2	○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00393 = 11.643

k = √(2*n*p+(n*p)^2)-n*p
= 0.2328694

j = 1-(k/3)
= 0.92238

σ c = (2*M*10^5)/(b*d^2*k*j)
= 94.49082

σ s = (M*10^5)/(b*d^2*p*j)
= 2801.48974

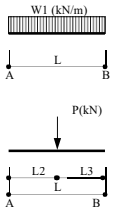
τ= (S*10^3)/(b*j*d)
= 9.10691

2.1.2.19 MANHOLE TYPE S

Type s

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

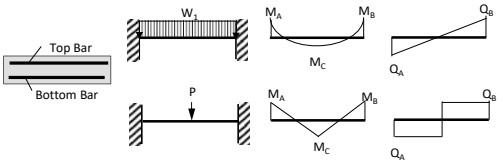
P = 52.000 kN : Point Load

L2 = 0.600 m L3 = 0.600 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN･m) for top bars	M(kN･m) for bottom bars	Q(kN)
W1+w	1.44	0.72	6.00
P	7.80	7.80	26.00
Total	9.24	8.52	32.00



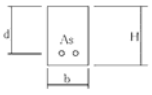
1

Type s

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	9.24	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.050	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	117.823	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 304.98173

σ s = (M*10^5)/(b*d^2*p*j)

= 11782.28829

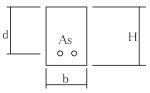
τ= (S*10^3)/(b*j*d)

= 18.45994

2

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	12	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	8.52	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.812	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	108.642	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.185	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00245 = 3.495

k = √(2*n*p+(n*p)^2)-n*p

= 0.18895

j = 1-(k/3)

= 0.93702

σ c = (2*M*10^5)/(b*d^2*k*j)

= 281.21692

σ s = (M*10^5)/(b*d^2*p*j)

= 10864.18790

τ= (S*10^3)/(b*j*d)

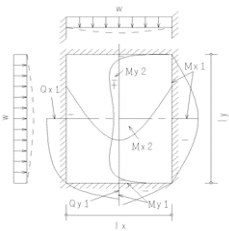
= 18.45994

3

Type s

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 1.200 m

ly = 2.600 m

B×D = 100 × 30 cm

②Load Conditions

w = 56.490 kN/m : Uniform Load

ΣW = 56.49 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 2.2

α for Mx2 = 0.040

α for Mx1 = 0.083

α for Qx1 = 0.520

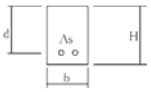
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	3.26	6.76	35.25

Type s

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter 16 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 3.26 kN・m

Shear Force S = 35.25 kN

Width of Member b = 100.0 cm

Height of Member H = 30.0 cm

Equivalent Height (Tensile Side) d = 20.000 cm

Total Cross-Sectional (Tensile Side) A_s = 8.044 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 0.752 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 21.988 N/mm^2 ○

Shearing Stress of Concrete τ = 0.191 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 75.17165

σ s = (M*10^5)/(b*d^2*p*j)

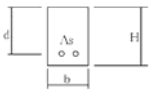
= 2198.80834

τ= (S*10^3)/(b*j*d)

= 19.12498

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter 16 mm

Interval of Reinforcing Bar 250 mm

Number of Reinforcing Bar 4.0 per meter

Cover Concrete 10.0 cm

Bending Moment M = 6.76 kN・m

Shear Force S = 35.25 kN

Width of Member b = 100.0 cm

Height of Member H = 30.0 cm

Equivalent Height (Tensile Side) d = 20.000 cm

Total Cross-Sectional (Tensile Side) A_s = 8.044 cm^2

Modulous of Elasticity n = 9.000

Compressive Stress of Concrete σc= 1.559 N/mm^2 ○

Tensile Stress of Rainforcing Bar σs= 45.595 N/mm^2 ○

Shearing Stress of Concrete τ = 0.191 N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca= 8.2 N/mm^2

Allowable Tensile Stress of Rainforcing Bar σsa= 140.0 N/mm^2

Allowable Shear Stress of Concrete τa = 0.36 N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)

= 155.87740

σ s = (M*10^5)/(b*d^2*p*j)

= 4559.49215

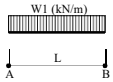
τ= (S*10^3)/(b*j*d)

= 19.12498

Type s

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 30 cm

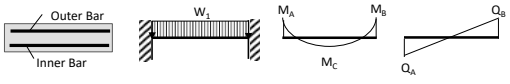
②Load Conditions

W1 = 40.650 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 40.65 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	4.88	2.44	19.00
Total	4.88	2.44	19.00

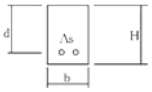


Type s

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Reinforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	4.88	kN・m
Shear Force	S =	19.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.125	N/mm^2 ○
Tensile Stress of Reinforcing Bar	σs=	32.915	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.103	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Reinforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.2352910

j = 1-(k/3)

= 0.92157

σc = (2*M*10^5)/(b*d^2*k*j)

= 112.52688

σs = (M*10^5)/(b*d^2*p*j)

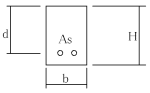
= 3291.4677

τ= (S*10^3)/(b*j*d)

= 10.30850

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	2.44	kN・m
Shear Force	S =	19.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height (Tensile Side)	d =	20.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.563	N/mm^2 ○
Tensile Stress of Reinforcing Bar	σs=	16.457	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.103	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Reinforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00402 = 4.706

k = √(2*n*p+(n*p)^2)-n*p

= 0.23529

j = 1-(k/3)

= 0.92157

σc = (2*M*10^5)/(b*d^2*k*j)

= 56.26344

σs = (M*10^5)/(b*d^2*p*j)

= 1645.73385

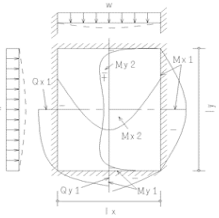
τ= (S*10^3)/(b*j*d)

= 10.30850

Type s

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q by Uniform Load】



①Dimensional Conditions

lx = 2.600 m

ly = 2.750 m

B×D = 100 × 30 cm

②Load Conditions

w = 30.900 kN/m : Uniform Load

ΣW = 30.90 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.1

α for Mx1 = 0.058

α for My1 = 0.054

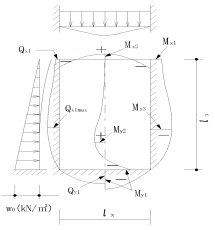
α for Qy1 = 0.450

Load	Mx1 (kN・m)	My1 (kN・m)	Q(kN)
Uniform	12.12	11.28	36.16

Type s

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 2.600 m

ly = 2.750 m

B×D = 100 × 30 cm

②Load Conditions

p = 9.750 kN/m : Triangle Load

(= 40.65 - 30.90)

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Ly/Lx	Mx1	Mx1max	My1	Qx1	Qy1
1.0		0.027	0.034		0.33
1.1		0.03	0.036		0.34
1.2		0.034	0.038		0.36
1.3		0.037	0.04		0.37
1.4		0.04	0.042		0.37
1.5		0.042	0.043		0.38
1.6		0.044	0.044		0.38
1.7		0.046	0.044		0.39
1.8		0.047	0.045		0.39
1.9		0.048	0.045		0.4
2.0		0.05	0.046		0.4
Ly/Lx	Mx1	Mx1max	My1	Qx1	Qy1

Iy/Ix = 1.1

α for Mx1max = 0.030

α for My1 = 0.036

α for Qy1 = 0.340

Load	Mx1max (kN・m)	My1 (kN・m)	Q(kN)
Triangle	1.98	2.38	8.62

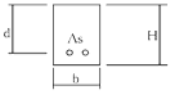
Load	M@side center (kN・m)	M@bottom end (kN・m)	Q(kN)
Uniform	12.12	11.28	36.16
Triangle	1.98	2.38	8.62
Total	14.10	13.66	44.78

Type s

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calcularion】

Position of Rainforcing Bar



Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	14.10	kN・m
Shear Force	S =	44.78	kN
Width of Member	b =	100.0	cm
Height of Member	H =	30.0	cm
Equivalent Height（Tensile Side）	d =	20.000	cm
Total Cross-Sectional （Tensile Side）	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.251	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	95.102	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.243	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d)
= 0.00402

x = k*d
= 4.706

k = √(2*n*p+(n*p)^2)-n*p
= 0.23529

j = 1-(k/3)
= 0.92157

σ c = (2*M*10^5)/(b*d^2*k*j)
= 325.12890

σ s = (M*10^5)/(b*d^2*p*j)
= 9510.18332

τ= (S*10^3)/(b*j*d)
= 24.29550

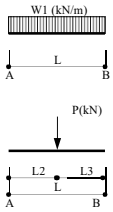
12

2.1.2.20 MANHOLE TYPE T

Type t

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 2.000 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

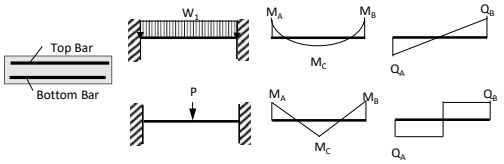
P = 52.000 kN : Point Load

L2 = 1.000 m L3 = 1.000 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN･m) for top bars	M(kN･m) for bottom bars	Q(kN)
W1+w	4.00	2.00	11.00
P	13.00	13.00	26.00
Total	17.00	15.00	37.00

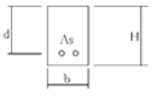


Type t

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	17.00	kN・m
Shear Force	S =	37.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	4.443	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	124.321	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.218	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 444.26459

σ s = (M*10^5)/(b*d^2*p*j)

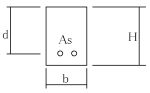
= 12432.11313

τ= (S*10^3)/(b*j*d)

= 21.76556

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	16	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	6.5	cm	
Bending Moment	M =	15.00	kN・m
Shear Force	S =	37.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.920	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	109.695	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.218	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 391.99817

σ s = (M*10^5)/(b*d^2*p*j)

= 10969.51158

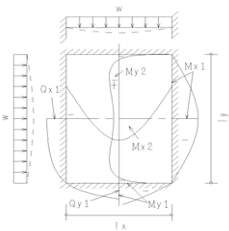
τ= (S*10^3)/(b*j*d)

= 21.76556

Type t

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 2.000 m

ly = 4.150 m

B×D = 100 × 55 cm

②Load Conditions

w = 93.480 kN/m : Uniform Load

ΣW = 93.48 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 2.1

α for Mx2 = 0.040

α for Mx1 = 0.083

α for Qx1 = 0.520

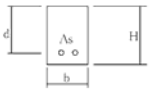
Load	Mx2 (kN・m) for top bars	Mx1 (kN・m) for bottom bars	Q(kN)
w	14.96	31.04	97.22

Type t

Analysis of Bottom Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar



Diameter	25	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	
Bending Moment	M =	14.96	kN・m
Shear Force	S =	97.22	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height (Tensile Side)	d =	45.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.660	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	18.427	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.235	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00436 = 10.968

k = √(2*n*p+(n*p)^2)-n*p

= 0.24372

j = 1-(k/3)

= 0.91876

σ c = (2*M*10^5)/(b*d^2*k*j)

= 65.98392

σ s = (M*10^5)/(b*d^2*p*j)

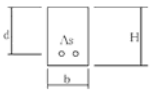
= 1842.74178

τ= (S*10^3)/(b*j*d)

= 23.51481

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar



Diameter	25	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	
Bending Moment	M =	31.04	kN・m
Shear Force	S =	97.22	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height (Tensile Side)	d =	45.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	19.636	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.369	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	38.234	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.235	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00436 = 10.968

k = √(2*n*p+(n*p)^2)-n*p

= 0.24372

j = 1-(k/3)

= 0.91876

σ c = (2*M*10^5)/(b*d^2*k*j)

= 136.90781

σ s = (M*10^5)/(b*d^2*p*j)

= 3823.44284

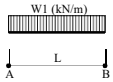
τ= (S*10^3)/(b*j*d)

= 23.51481

Type t

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 2.000 m

B×D = 100 × 55 cm

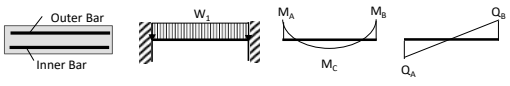
②Load Conditions

W1 = 87.850 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 87.85 kN/m

Load	M(kN・m) for outer bars	M(kN・m) for inner bars	Q(kN)
W1+w	29.29	14.65	64.00
Total	29.29	14.65	64.00

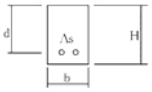


Type t

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Reinforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	29.29	kN・m
Shear Force	S =	64.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height (Tensile Side)	d =	45.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	1.546	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	55.498	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.152	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

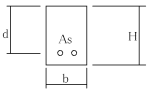
Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00279 = 9.022
k = √(2*n*p+(n*p)^2)-n*p
= 0.2004827
j = 1-(k/3)
= 0.93317
σc = (2*M*10^5)/(b*d^2*k*j)
= 154.62704
σs = (M*10^5)/(b*d^2*p*j)
= 5549.81865
τ= (S*10^3)/(b*j*d)
= 15.24072

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	14.65	kN・m
Shear Force	S =	64.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height (Tensile Side)	d =	45.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.773	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	27.759	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.152	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

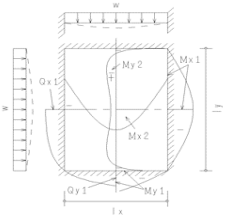
Single Rainforcing Bar

p = As/(b*d) x = k*d
= 0.00279 = 9.022
k = √(2*n*p+(n*p)^2)-n*p
= 0.20048
j = 1-(k/3)
= 0.93317
σc = (2*M*10^5)/(b*d^2*k*j)
= 77.33992
σs = (M*10^5)/(b*d^2*p*j)
= 2775.85672
τ= (S*10^3)/(b*j*d)
= 15.24072

Type t

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q by Uniform Load】



①Dimensional Conditions

lx = 4.150 m
ly = 5.750 m
B×D = 100 × 55 cm

②Load Conditions

w = 6.250 kN/m : Uniform Load

ΣW = 6.25 kN/m

③Calculation of M and Q for 4-sided (2-way) slab
M and Q are obtained by following equations,
while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)
Q=α * w * lx (kN)

ly/lx	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

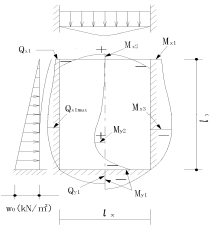
ly/lx = 1.4
α for Mx1 = 0.072
α for My1 = 0.056
α for Qy1 = 0.460

Load	Mx1 (kN・m)	My1 (kN・m)	Q(kN)
Uniform	7.76	6.03	11.94

Type t

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 4.150 m
ly = 5.750 m
B×D = 100 × 55 cm

②Load Conditions

p = 81.600 kN/m : Triangle Load
(= 87.85 - 6.25)

③Calculation of M and Q for 4-sided (2-way) slab
M and Q are obtained by following equations,
while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)
Q=α * w * lx (kN)

Ly/Lx	Mx1	Mx1max	My1	Qx1	Qy1
1.0		0.027	0.034		0.33
1.1		0.03	0.036		0.34
1.2		0.034	0.038		0.36
1.3		0.037	0.04		0.37
1.4		0.04	0.042		0.37
1.5		0.042	0.043		0.38
1.6		0.044	0.044		0.38
1.7		0.046	0.044		0.39
1.8		0.047	0.045		0.39
1.9		0.048	0.045		0.4
2.0		0.05	0.046		0.4
Ly/Lx	Mx1	Mx1max	My1	Qx1	Qy1

ly/lx = 1.4
α for Mx1max = 0.040
α for My1 = 0.042
α for Qy1 = 0.370

Load	Mx1max (kN・m)	My1 (kN・m)	Q(kN)
Triangle	56.22	59.03	125.30

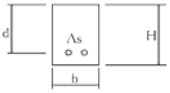
Load	M@side center (kN・m)	M@bottom end (kN・m)	Q(kN)
Uniform	7.76	6.03	11.94
Triangle	56.22	59.03	125.30
Total	63.98	65.06	137.24

Type t

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calcularion】

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	65.06	kN・m
Shear Force	S =	137.24	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height（Tensile Side）	d =	45.000	cm
Total Cross-Sectional （Tensile Side）	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.435	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	123.275	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.327	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d)
= 0.00279

x = k*d
= 9.022

k = √(2*n*p+(n*p)^2)-n*p
= 0.20048

j = 1-(k/3)
= 0.93317

σ c = (2*M*10^5)/(b*d^2*k*j)
= 343.46314

σ s = (M*10^5)/(b*d^2*p*j)
= 12327.45652

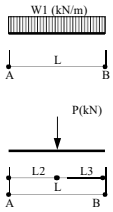
τ= (S*10^3)/(b*j*d)
= 32.68183

2.1.2.21 MANHOLE TYPE U

Type u

Analysis of Top Slab

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 25 cm

②Load Conditions

W1 = 6.000 kN/m : Uniform Load

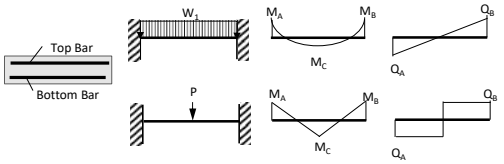
P = 52.000 kN : Point Load

L2 = 0.600 m L3 = 0.600 m

w = 6.00 kN/m : Self Weight

ΣW = 12.00 kN/m

Load	M(kN･m) for top bars	M(kN･m) for bottom bars	Q(kN)
W1+w	1.44	0.72	6.00
P	7.80	7.80	26.00
Total	9.24	8.52	32.00



1

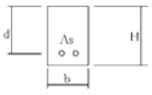
Type u

Analysis of Top Slab

【Stress Intensity Calculation】 FOR TOP BARS

Position of Rainforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm



Bending Moment	M =	9.24	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.415	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	67.572	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.188	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 241.47087

σ s = (M*10^5)/(b*d^2*p*j)

= 6757.21914

τ= (S*10^3)/(b*j*d)

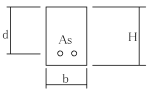
= 18.82427

2

【Stress Intensity Calculation】 FOR BOTTOM BARS

Position of Rainforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm



Bending Moment	M =	8.52	kN・m
Shear Force	S =	32.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	25.0	cm
Equivalent Height (Tensile Side)	d =	18.500	cm
Total Cross-Sectional (Tensile Side)	A_s =	8.044	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	2.227	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	62.307	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.188	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00435 = 4.502

k = √(2*n*p+(n*p)^2)-n*p

= 0.24335

j = 1-(k/3)

= 0.91888

σ c = (2*M*10^5)/(b*d^2*k*j)

= 222.65496

σ s = (M*10^5)/(b*d^2*p*j)

= 6230.68258

τ= (S*10^3)/(b*j*d)

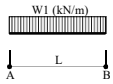
= 18.82427

3

Type u

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 55 cm

②Load Conditions

W1 = 95.210 kN/m : Uniform Load

ΣW = 95.21 kN/m

Load	M(kN･m) for outer bars	M(kN･m) for inner bars	Q(kN)
W1+w	11.43	5.72	31.00
Total	11.43	5.72	31.00

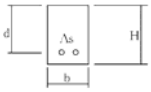


Type u

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Top Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	11.43	kN・m
Shear Force	S =	31.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height （Tensile Side）	d =	45.000	cm
Total Cross-Sectional （Tensile Side）	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.603	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	21.657	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.074	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00279 = 9.022

k = √(2*n*p+(n*p)^2)-n*p

= 0.2004827

j = 1-(k/3)

= 0.93317

σ c = (2*M*10^5)/(b*d^2*k*j)

= 60.34097

σ s = (M*10^5)/(b*d^2*p*j)

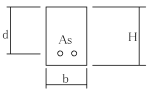
= 2165.73667

τ= (S*10^3)/(b*j*d)

= 7.38223

【Stress Intensity Calculation】 For Bottom Bars

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	5.72	kN・m
Shear Force	S =	31.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height （Tensile Side）	d =	45.000	cm
Total Cross-Sectional （Tensile Side）	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.302	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	10.838	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.074	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00279 = 9.022

k = √(2*n*p+(n*p)^2)-n*p

= 0.20048

j = 1-(k/3)

= 0.93317

σ c = (2*M*10^5)/(b*d^2*k*j)

= 30.19688

σ s = (M*10^5)/(b*d^2*p*j)

= 1083.81573

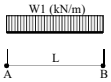
τ= (S*10^3)/(b*j*d)

= 7.38223

Type u

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



①Dimensional Conditions

L = 1.200 m

B×D = 100 × 55 cm

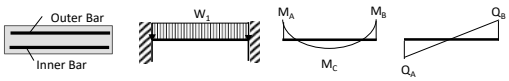
②Load Conditions

W1 = 71.750 kN/m : Uniform Load

w = kN/m : Self Weight

ΣW = 71.75 kN/m

Load	M(kN･m) for outer bars	M(kN･m) for inner bars	Q(kN)
W1+w	8.61	4.31	24.00
Total	8.61	4.31	24.00

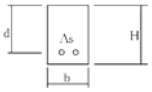


Type u

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】 For Outer Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	
Bending Moment	M =	8.61	kN・m
Shear Force	S =	24.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height (Tensile Side)	d =	45.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.455	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	16.314	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.057	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00279 = 9.022

k = √(2*n*p+(n*p)^2)-n*p

= 0.2004827

j = 1-(k/3)

= 0.93317

σc = (2*M*10^5)/(b*d^2*k*j)

= 45.45370

σs = (M*10^5)/(b*d^2*p*j)

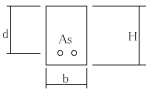
= 1631.40794

τ= (S*10^3)/(b*j*d)

= 5.71527

【Stress Intensity Calculation】 For Inner Bars

Position of Rainforcing Bar



Diameter	20	mm	
Interval of Reinforcing Bar	250	mm	
Number of Reinforcing Bar	4.0	per meter	
Cover Concrete	10.0	cm	
Bending Moment	M =	4.31	kN・m
Shear Force	S =	24.00	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height (Tensile Side)	d =	45.000	cm
Total Cross-Sectional (Tensile Side)	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	0.228	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	8.167	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.057	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d) x = k*d

= 0.00279 = 9.022

k = √(2*n*p+(n*p)^2)-n*p

= 0.20048

j = 1-(k/3)

= 0.93317

σc = (2*M*10^5)/(b*d^2*k*j)

= 22.75324

σs = (M*10^5)/(b*d^2*p*j)

= 816.65136

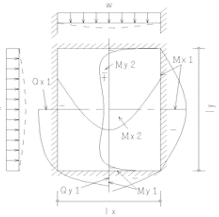
τ= (S*10^3)/(b*j*d)

= 5.71527

Type u

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q by Uniform Load】



①Dimensional Conditions

lx = 4.750 m

ly = 5.850 m

B×D = 100 × 55 cm

②Load Conditions

w = 6.250 kN/m : Uniform Load

ΣW = 6.25 kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Iy/Ix	Mx1	Mx2	My1	My2max	Qx1	Qy1
1	0.052	0.017	0.052	0.017	0.44	0.44
1.1	0.058	0.022	0.054	0.016	0.47	0.45
1.2	0.064	0.025	0.055	0.015	0.49	0.45
1.3	0.068	0.029	0.056	0.014	0.5	0.46
1.4	0.072	0.031	0.056	0.013	0.51	0.46
1.5	0.076	0.034	0.057	0.011	0.51	0.46
1.6	0.078	0.036	0.057	0.01	0.52	0.46
1.7	0.079	0.037	0.057	0.01	0.52	0.46
1.8	0.081	0.038	0.057	0.01	0.52	0.46
1.9	0.082	0.039	0.057	0.01	0.52	0.46
2	0.083	0.04	0.057	0.01	0.52	0.46
2.3	0.083	0.042	0.057	0.01	0.51	0.46
2.4	0.083	0.042	0.057	0.01	0.51	0.46
2.5	0.083	0.042	0.057	0.01	0.51	0.46

Iy/Ix = 1.3

α for Mx1 = 0.068

α for My1 = 0.056

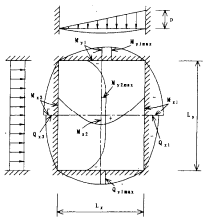
α for Qy1 = 0.460

Load	Mx1 (kN・m)	My1 (kN・m)	Q(kN)
Uniform	9.59	7.90	13.66

Type u

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

lx = 4.750 m

ly = 5.850 m

B×D = 100 × 55 cm

②Load Conditions

p = 65.500 kN/m : Triangle Load

(= 71.75 - 6.25)

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

while α can be obtained in reference to the table below.

M=α * w * lx^2 (kN・m)

Q=α * w * lx (kN)

Ly/Lx	Mx1	Mx1max	My1	Qx1	Qy1
1.0	0.034			0.33	
1.1	0.037			0.34	
1.2	0.04			0.35	
1.3	0.043			0.35	
1.4	0.045			0.35	
1.5	0.046			0.35	
1.6	0.046			0.35	
1.7	0.047			0.35	
1.8	0.048			0.35	
1.9	0.049			0.35	
2.0	0.049			0.35	

Iy/Ix = 1.3

α for Mx1max = 0.043

α for My1 = 0.000

α for Qy1 = 0.350

Load	Mx1max (kN・m)	My1 (kN・m)	Q(kN)
Triangle	63.55	0.00	108.90

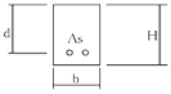
Load	M@side center (kN・m)	M@bottom end (kN・m)	Q(kN)
Uniform	9.59	7.90	13.66
Triangle	63.55	0.00	108.90
Total	73.14	7.90	122.56

Type u

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calcularion】

Position of Rainforcing Bar



Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

Bending Moment	M =	73.14	kN・m
Shear Force	S =	122.56	kN
Width of Member	b =	100.0	cm
Height of Member	H =	55.0	cm
Equivalent Height （Tensile Side）	d =	45.000	cm
Total Cross-Sectional （Tensile Side）	A_s =	12.568	cm^2
Modulous of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc=	3.861	N/mm^2 ○
Tensile Stress of Rainforcing Bar	σs=	138.584	N/mm^2 ○
Shearing Stress of Concrete	τ =	0.292	N/mm^2 ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar	σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete	τa =	0.36	N/mm^2

Single Rainforcing Bar

p = As/(b*d)
= 0.00279

x = k*d
= 9.022

k = √(2*n*p+(n*p)^2)-n*p
= 0.20048

j = 1-(k/3)
= 0.93317

σ c = (2*M*10^5)/(b*d^2*k*j)
= 386.11887

σ s = (M*10^5)/(b*d^2*p*j)
= 13858.44097

τ= (S*10^3)/(b*j*d)
= 29.18598

2.2 Sluiceway

2.2.1 Conditions and Outline of Structural Analysis of Sluiceway

2.2.1.1 Categorizing of Calculation Type

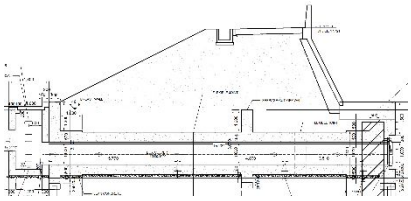
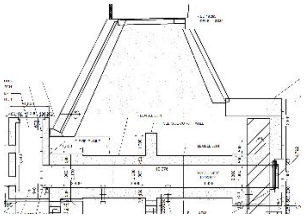
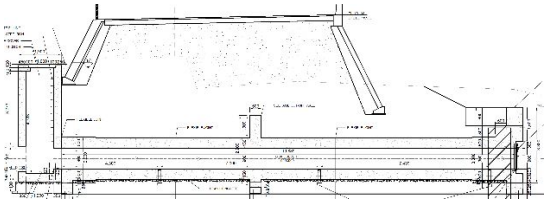
Sluiceways designed in this project can be categorized into several types of calculation models based on similarity in proportion and soil condition. Following tables explain categorization of all sluiceways.

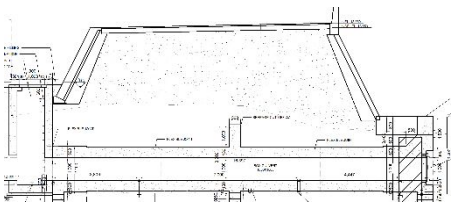
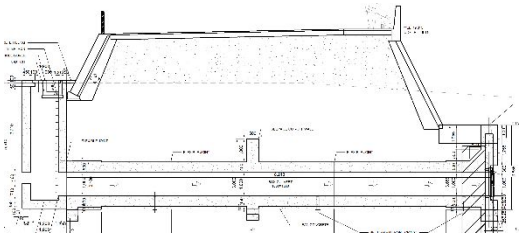
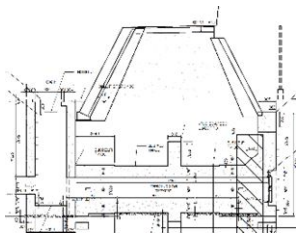
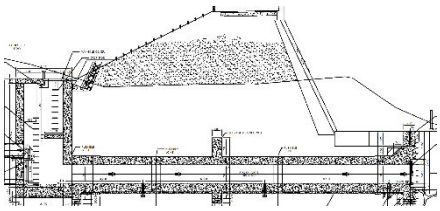
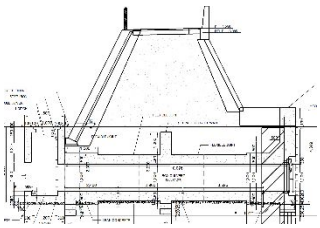
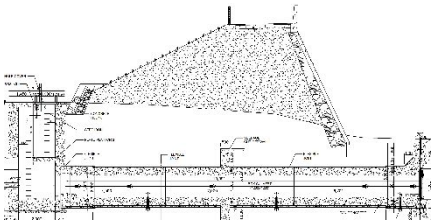
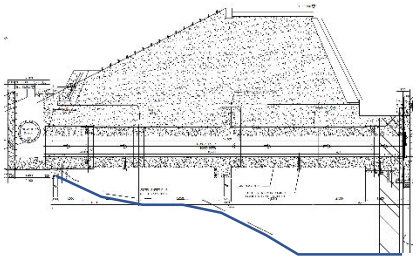
Table 2.2.1 Grouping of Sluiceway and Selection of Calculation Model Type

LOCATION			NAME OF SLUICEWAY	Opening (mm)	Length (m)	DFL (m)	EL (m)	GL at Center (m)	DFL-GL at Center (m)	DFL-EL	DFL-Box Top	Thickness of Soil Layers			Structural Type
												As	Ac	Dc	
LEFT BANK	CP2	7+223	ML097A	1000.00	16.280	17.721	10.300	14.351	3.370	7.421	5.971			6.88	TYPE-A
		7+801	ML087A	1000.00	11.007	18.073	10.400	13.993	4.080	7.673	6.223			16.28	TYPE-B
		7+780	ML087B	1000.00	10.777	18.085	10.400	14.525	3.560	7.685	6.235	0.10		14.62	TYPE-B
		7+801	ML091.1	1200.00	10.933	18.000	10.200	13.760	4.240	7.800	6.150	0.25		11.95	TYPE-H
		7+828	ML087.2	1000.00	11.126	18.061	10.400	13.661	4.400	7.661	6.211	0.46		11.41	TYPE-B
		7+856	ML087.1	1000.00	10.146	18.109	11.600	14.819	3.290	6.509	5.059	1.60		10.90	TYPE-B
		7+880	ML087C	1000.00	9.877	18.121	11.400	14.921	3.200	6.721	5.271	1.29		10.53	TYPE-B
		7+980	ML087D	1000.00	9.560	18.182	12.000	14.462	3.720	6.182	4.732	1.11		9.25	TYPE-B
		9+220	ML068A	1000.00	20.189	18.933	10.300	15.996	2.937	8.633	7.183		4.90	1.58	TYPE-C
	CP3	9+320	ML068B	1000.00	17.697	18.659	10.300	15.254	3.405	8.359	6.909		4.99	2.41	TYPE-D
		9+420	ML068C	1000.00	17.477	19.054	10.300	16.954	2.100	8.754	7.304		6.84	0.30	TYPE-D
		9+520	ML068D	1000.00	19.513	19.115	10.400	17.000	2.115	8.715	7.265		1.59	4.77	TYPE-E
		9+527	ML068	1000.00	19.513	19.115	10.400	17.000	2.115	8.715	7.265		1.56	4.79	TYPE-E
RIGHT BANK	CP1	6+060	MR125A	1000.00	17.700	17.400	11.700	12.700	4.700	5.700	4.250			0.26	TYPE-J
	CP2	7+203	MR074	1000.00	9.741	17.709	11.800	14.598	3.111	5.909	4.459	2.04		9.34	TYPE-B
		7+357	MR073	1000.00	7.726	17.806	10.967	15.086	2.720	6.839	5.389	1.35		10.43	TYPE-F
		7+399	MR072.1	1000.00	7.472	17.830	11.363	15.590	2.240	6.467	5.017	1.62		10.88	TYPE-F
		7+509	MR072	1000.00	6.973	17.891	11.402	16.621	1.270	6.489	5.039	0.96		11.25	TYPE-F
		7+840	MR067A	1200.00	10.162	18.097	10.200	14.497	3.600	7.897	6.247			7.81	TYPE-H
	CP3	10+936	MR009A	1000.00	18.375	19.956	10.900	15.576	4.380	9.056	7.606			16.82	TYPE-G
		10+972	MR008	1200.00	19.651	19.966	10.700	14.966	5.000	9.266	7.616			16.51	TYPE-I

Source: JICA Study Team

Table 2.2.2 Typical Model and Description of Each Type

Structural Type	Description	
Type A		[Inner Size] 1.0m x 1.0m [Characteristic of Longitudinal Shape] Levee slope at land side slope is not protected by concrete thus gentle, making the sluiceway longer as 16.3m.
Type B		[Inner Size] 1.0m x 1.0m [Characteristic of Longitudinal Shape] ✓ Both side of Levee slopes concrete-protected and steep, thus sluiceway is relatively short as 9.9m -12.4m. ✓ Elevation of existing ground is relatively low which makes the height of embankment greater. Therefore, greater subsidence due to soil consolidation is expected in this type.
Type C		[Inner Size] 1.0m x 1.0m [Characteristic of Longitudinal Shape] The length of sluiceway is 20.2m which makes the longest among all type, since levee crown is as wide as 10m and also levee is setting back from SSP retaining wall.

Type D		[Inner Size] 1.0m x 1.0m [Characteristic of Longitudinal Shape] Length of sluiceway is around 17.5m since levee crown is as wide as 10m.
Type E		[Inner Size] 1.0m x 1.0m [Characteristic of Longitudinal Shape] Length of sluiceway is around 19.5m since levee crown is as wide as 12m.
Type F		[Inner Size] 1.0m x 1.0m [Characteristic of Longitudinal Shape] Sluiceway is the shortest among all types as 7.0m – 7.7m, since coping concrete of SSP retaining wall is narrower than other types in addition to that the both side of Levee slopes are concrete-protected and steep.
Type G		[Inner Size] 1.0m x 1.0m [Characteristic of Longitudinal Shape] Shape of levee and length of sluiceway are similar to type A. However, since levee is setting back from SSP retaining wall, sluiceway is longer than Type A.
Type H		[Inner Size] 1.2m x 1.2m [Characteristic of Longitudinal Shape] Shape of levee and length of sluiceway are similar to type B, however, inner size of culvert is different.
Type I		[Inner Size] 1.2m x 1.2m (Double Barrel) [Characteristic of Longitudinal Shape] Shape of levee and length of sluiceway are similar to type G, however, inner size of culvert is different and double barrel.
Type J		[Inner Size] 1.0m x 1.0m [Characteristic of Longitudinal Shape] Shape of levee and length of sluiceway are similar to type A. However, since hard strata is shallow and inclined towards the river, longitudinal distribution of consolidation settlement must be unique.

Source: JICA Study Team

2.2.1.2 Study on the Ground Settlement at the Sluiceway Site

The sluiceway shall be designed to allow ground settlement due to embankment, to minimize the gap of the settlement between sluiceway and adjoining levee. Therefore, first of all residual settlement due to the embankment at sluiceway sites shall be studied for design conditions of sluiceway. Residual settlement is obtained as the arithmetic summation of immediate settlement and consolidation settlement at the bottom level of sluiceway.

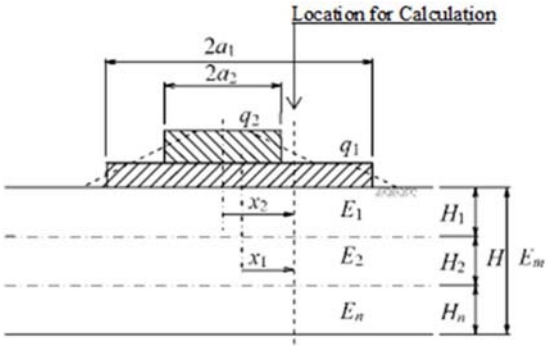
(1) Immediate Settlement

Immediate settlement is calculated with the aid of the following formula as shown below, on the assumption that the ground is elastic.

$$S_x = \sum_{i=1}^{n} \frac{-3a_i \cdot q_i}{E_m \cdot \pi} \log \cdot \sin\left(\tan^{-1}\frac{a_i}{H}\right) \cdot \left\{1.0 - \frac{0.75}{\pi}\left[\left(1+\frac{x}{a_i}\right)\log\left|1+\frac{x}{a_i}\right| + \left(1-\frac{x}{a_i}\right)\log\left|1-\frac{x}{a_i}\right|\right]\right\}$$

Where,

S = Immediate Settlement on xi , m
qi = Load of Embankment, tf/m^2 or kN/m^2
Em = Modulus of Deformation of the ground, tf/m^2 or kN/m^2
ai = Load width, m
H = Depth for considering the effect of immediate settlement, m
n = Number of uniform load
x = Distance from the center of the ach uniform load, m



Source: JICA Study Team

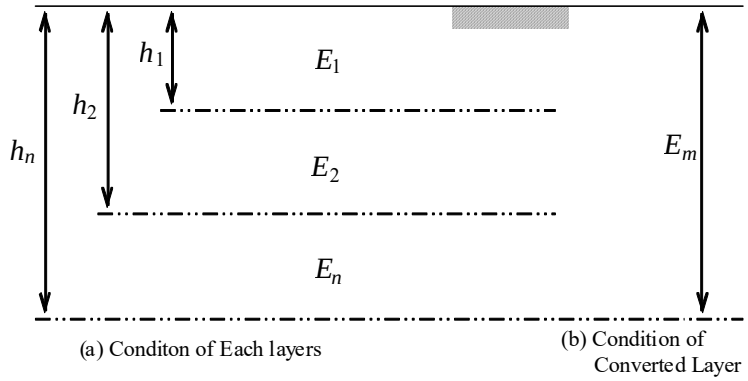
Figure 2.2.1 Calculation Model for Immediate Settlement

$$E_m = \frac{\log\frac{(B+2h_n\tan\theta)L}{(L+2h_n\tan\theta)B}}{\sum_{i=1}^{n}\frac{1}{E_{mi}}\log\frac{(B+2h_i\tan\theta)(L+2h_{i-1}\tan\theta)}{(L+2h_i\tan\theta)(B+2h_{i-1}\tan\theta)}}$$

Where,

Em = Converted modulus of deformation (Figure R 6.2.3) of the ground, in B ≠ L considering several layers, kgf/cm^2 or kN/m^2

B = Load width, m
L = Load Length, m
Hn = Depth for considering the effect, more than 3 times of load width, m
Hi = Depth to the bottom of each layer, m
Emi = Modulus of deformation of the ground of the layer i, kgf/cm^2 or kN/m^2
θ = Angle of load distribution, θ = 30°



Source: JICA Study Team

Figure 2.2.2 Converted Modulus of Deformation in case of each layer having different depth

(2) Consolidation Settlement

Consolidation settlement is calculated wherein the vertical stress in the ground is increased by the weight of the embankment and is the summation of the settlement of each silt layer as described below:

$$Sc = \frac{e1 - e2}{1 + e1} H$$

$$= mv \; _{H} \Delta p$$

$$= \frac{av}{1 + e1} H \Delta p$$

Where,

Sc : Total consolidation settlement (m)
e_1, e_2 : Initial void ratio after embankment
H : Thickness of compressive stratum (m)
mv : Coefficient of volume compressibility (m^2/kN)
Δp : Increased compressive stress (kN/m^2)
av : Coefficient of compressibility (m^2/kN)

(3) Conditions for Calculation of Ground Settlement

Soil properties used in calculation of sluiceway are shown in Table 7.2.13. Ground reaction factor Em used in calculation of immediate settlement can be calculated as Em=700N, where N is average

N value of each layer.

Table 2.2.3 Mechanical Properties of Soil

Geological age		Holocene		Pleistocene			
Layer		As	Ac	Ds	Dc	GFw	GFf
N value		9.9	7.8	21.1	22.5	38.2	44.4
		0.0 - 30.0	0.0 - 44.0	3.0 - 48.0	0.0 - 50.0	7.0 - >50	12.0 - >50
Mechanical Properties	φ (degree)	27.2	-	32.8	-		
	c (kN/m^2)	-	46.9	-	135.0		
	qu	-	-	-	26.7	-	6,643
	(kN/m^2)	-	-	-	18.8 - 34.7	-	474.7 - 19,460.7
	Es	6,936	5,469	14,756	15,747	26,759	31,057
	(kN/m^2)	⇒6,900	⇒5,400	⇒14,700	⇒15,700	⇒26,700	
	Pc	-	-	-	100.9	-	-
	(kg/cm^2)	-	-	-	49.1 - 196.2	-	-

Source: JICA Study Team

In this project, soil consolidation test for upper Marikina was conducted with 5 borehole samples. Table 7.2.14 shows test samples and corresponding soil layer and station No. for each sample. Consolidation settlement of sluiceway is calculated using e-logP curb.

Table 2.2.4 Applied Consolidation Test Samples by Sluiceway Location

Location / Station No.		Sluiceway No.	Applied Test Sample	
			Ac	Dc
Left Bank	Downstream of STA8+400	ML097A～ML087D	-	DD-BH-L01
	Upstream of STA8+400	ML068A～ML068	DD-BH-L10	DD-BH-L13
Right Bank	Downstream of STA8+100	MR125A～MR067A	-	DD-BH-R03
	Upstream of STA8+100	MR009A, MR008	DD-BH-L10*	DD-BH-R13

Note: Consolidation test was conducted only in left bank for Ac layer (DD-BH-L10). However, similarities are found in the result of two consolidation test samples of both bank at near station No., such as DD-BH-R03 to DD-BH-L01 and DD-BH-R13 to DD-BH-L13. Therefore, e-logP curb of DD-BH-L10 can be applied for Ac layer in right bank as well.

Source: JICA Study Team

(4) Summerly of Residual Settlement

The residual settlement at sluiceway site are obtained as summation of immediate and consolidation settlement. When the residual settlement exceeds 5cm, the sluiceway must be designed as flexible sluiceway to follow the deformation of the ground. Residual settlement is allowed up to 30cm based on capacity of flexible joint. If the settlement exceeds 30cm, camber bedding shall be considered.

Table 2.2.5 Calculation Results of Residual Settlement

Structural Type of Sluiceway	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)		Allowable Settlement (mm)		Foundation Type
TYPE-A	13.0	227.9		240.9	<	300	OK	Flexible
TYPE-B	15.9	304.3	50	270.2	<	300	OK	Flexible
TYPE-C	26.8	125.6		152.4	<	300	OK	Flexible
TYPE-D	42.1	208.8		250.9	<	300	OK	Flexible
TYPE-E	14.3	111.1		125.4	<	300	OK	Flexible
TYPE-F	13.9	122.8		137.0	<	300	OK	Flexible
TYPE-G	14.3	83.3		97.6	<	300	OK	Flexible
TYPE-H	15.0	287.4	50	252.4	<	300	OK	Flexible
TYPE-I	18.2	118.8		137.0	<	300	OK	Flexible
TYPE-J	35.4	135.0		170.4	<	300	OK	Flexible

Source: JICA Study Team

(5) Box Culvert

1) Span Arrangement

Considering the basic concept of flexible sluiceway, which is to follow the settlement of adjoining dike, 3-span is reasonable arrangement as the center span beneath the levee crown and both river side and land side spans beneath levee slope. Specific length of those span may be adjusted when some spans are found over-stressed by bending moment in the longitudinal analysis.

2) Design Condition

The design conditions are shown below.

Table 2.2.6 Design Condition of Box Culvert

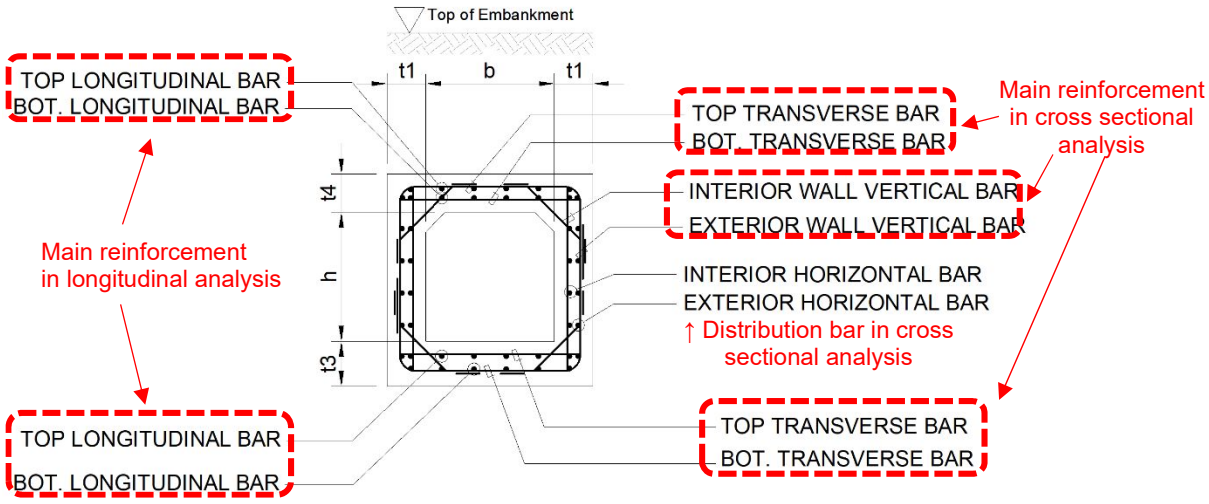
Item			Design Condition
Material Unit Weight	Concrete Reinforced		24.0 kN/m^3
	Concrete Plain		23.5kN/m^3
	Structural Steel		77.0 kN/m^3
	Water		9.8 kN/m^3
Soil Condition	Quality of Soil		
	Unit Weight	Damped and Wet Condition	19.0 kN/m^3
		Saturated Condition	20.0 kN/m^3
		Submerged Condition	10.0 kN/m^3
Surcharge on the Ground			Normal: 10 kN/m^2 Seismic 5 kN/m^2 1/
Live load on Top Slab			T-25

1/Seismic Condition is Considered only in calculation of longitudinal direction.

Source: JICA Study Team

3) Thickness of Culvert and Bar Arrangement

Thickness of culvert members and bar arrangement are designed by cross sectional analysis and longitudinal analysis as described in "9.3.6.4 Design Method" of "CHAPTER 9 DESIGN CRITERIA". Longitudinal bars of top slab and bottom slab are functioning as main reinforcement in longitudinal calculation while transverse/wall vertical bars are functioning in cross sectional calculation while horizontal bar of side wall are functioning as distribution bar in cross sectional calculation.



Source: JICA Study Team

Figure 2.2.3 Typical Bar Arrangement of Box Culvert Cross Section

4) Calculation Result

Outline of calculation result is as follows. Details of calculation process are shown in appendix.

Table 2.2.7 Calculation Results of Box Culvert (Longitudinal Analysis)

Structural Type of Sluiceway	b	h	Span	Block	Bottom Slab					Top Slab				
					t3	Longitudinal				t4	Longitudinal			
						Outer Side		Inner Side			Outer Side		Inner Side	
						Dia.	Interval	Dia.	Interval		Dia.	Interval	Dia.	Interval
TYPE A	1,000	1,000	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			2	1	450	D22(A)	@250	D22(A)	@250	450	D22(A)	@250	D22(A)	@250
			3	1	450	D22(A)	@250	D22(A)	@250	450	D22(A)	@250	D22(A)	@250
				2	500	D22(A)	@250	D22(A)	@250	500	D22(A)	@250	D22(A)	@250
TYPE B	1,000	1,000	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			2	1	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			3	1	450	D19(A)	@250	D19(A)	@250	450	D19(A)	@250	D19(A)	@250
				2	700	D19(A)	@250	D19(A)	@250	500	D19(A)	@250	D19(A)	@250
TYPE C	1,000	1,000	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			2	1	450	D19(A)	@250	D19(A)	@250	450	D19(A)	@250	D19(A)	@250
			3	1	450	D22(A)	@250	D22(A)	@250	450	D22(A)	@250	D22(A)	@250
				2	500	D22(A)	@250	D22(A)	@250	500	D22(A)	@250	D22(A)	@250
TYPE D	1,000	1,000	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			2	1	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			3	1	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
				2	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
TYPE E	1,000	1,000	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			2	1	450	D19(A)	@250	D19(A)	@250	450	D19(A)	@250	D19(A)	@250
			3	1	450	D22(A)	@250	D22(A)	@250	450	D22(A)	@250	D22(A)	@250
				2	500	D22(A)	@250	D22(A)	@250	500	D22(A)	@250	D22(A)	@250
TYPE F	1,000	1,000	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			2	1	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			3	1	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
				2	500	D25(A)	@250	D25(A)	@250	500	D25(A)	@250	D25(A)	@250
TYPE G	1,000	1,000	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			2	1	450	D22(A)	@250	D22(A)	@250	450	D22(A)	@250	D22(A)	@250
			3	1	450	D22(A)	@250	D22(A)	@250	450	D22(A)	@250	D22(A)	@250
				2	500	D22(A)	@250	D22(A)	@250	500	D22(A)	@250	D22(A)	@250
TYPE H	1,200	1,200	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			2	1	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			3	1	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
				2	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
TYPE I	1,200	1,200	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			2	1	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
			3	1	450	D16(A)	@250	D16(A)	@250	450	D16(A)	@250	D16(A)	@250
				2	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
TYPE J	1,000	1,000	1	1	500	D16(A)	@250	D16(A)	@250	500	D16(A)	@250	D16(A)	@250
				2	450	D22(A)	@250	D22(A)	@250	450	D22(A)	@250	D22(A)	@250
			2	1	450	D22(A)	@250	D22(A)	@250	450	D22(A)	@250	D22(A)	@250
			3	1	450	D19(A)	@250	D19(A)	@250	450	D19(A)	@250	D19(A)	@250
				2	500	D19(A)	@250	D19(A)	@250	500	D19(A)	@250	D19(A)	@250

Source: JICA Study Team

Table 2.2.8 Calculation Results of Box Culvert (Cross-Sectional Analysis)

Structural Type of Sluiceway	Span	Block	Side Wall				Bottom Slab				Top Slab			
			Vertical				Transverse				Transverse			
			Outer Side		Inner Side		Outer Side		Inner Side		Outer Side		Inner Side	
			Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval
TYPE A	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
TYPE B	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
TYPE C	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
TYPE D	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
TYPE E	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
TYPE F	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
TYPE G	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
TYPE H	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
TYPE I	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
TYPE J	1	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	2	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
	3	1	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250

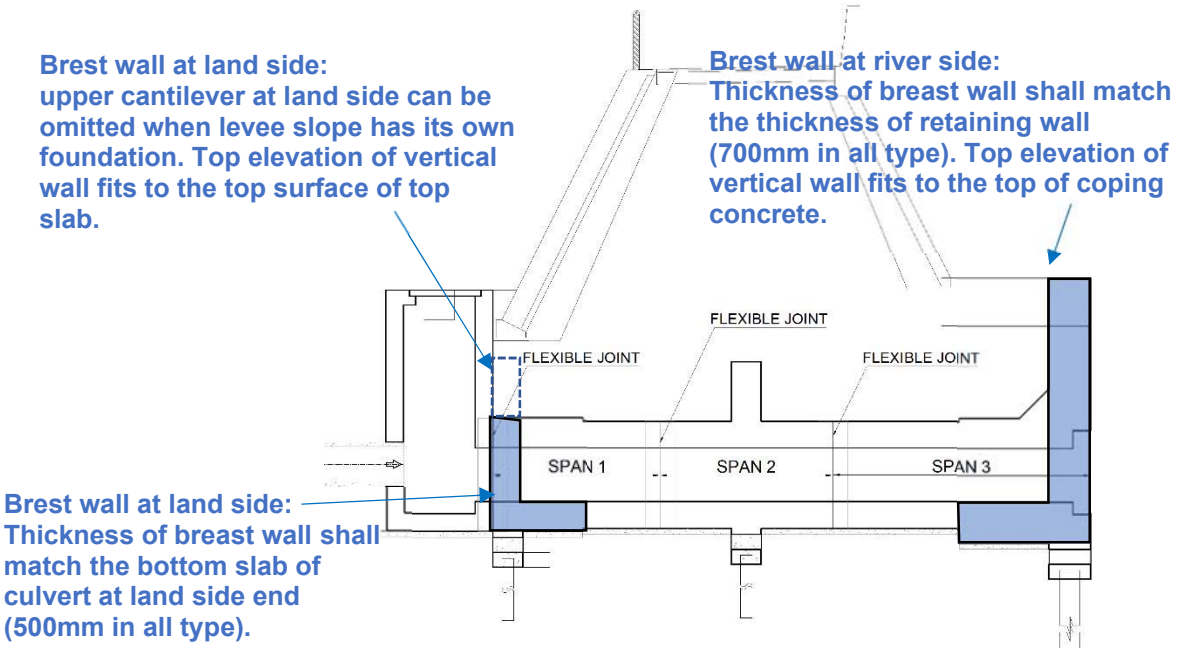
Source: JICA Study Team

(6) Breast Wall

1) Dimension of Breast Wall

Brest walls at river side are part of continuous retaining wall of river structure. Therefore, thickness of breast wall shall match the thickness of adjoining concrete coping of river structure (700mm in all type). Top elevation of vertical wall fits to the top of coping concrete.

As for the breast walls at land side, thickness shall match that of bottom slab of culvert at land side end (500mm in all type). e top of coping concrete. Breast wall often has upper cantilever to serve as foundation of levee slope. However, since in this project levee slope has its own foundation, upper cantilever at land side can be omitted except Type A.



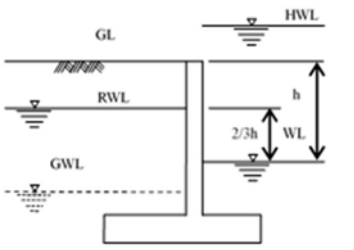
Source: JICA Study Team

Figure 2.2.4 Dimension of Breast Wall

2) Design Condition

The Breast wall is considered as cantilever with the end fixed on the box culvert. Residual water level (RWL) is applied for back water level for the breast wall at river side as shown in Figure 7.2.16, while front water level is ordinary.

$$RWL=(GL-WL)\times 2/3$$



Where,

RWL	:	Residual water level
GWL	:	Natural ground water level
WL	:	Water level at front
GL	:	Ground level

Source: JICA Study Team

Figure 2.2.5 Water Level Conditions for Breast Wall at River Side

As for the breast wall at land side, water level difference of front side and back side is ignorable since the top of wall is under ground water level.

3) Results of Calculation

The dimensions based on the results of structural calculation are shown below. Details of calculation process are shown in appendix.

Table 2.2.9 Calculation Results of Breast Wall (River Side)

SCHEDULE OF BREAST WALL AT RIVER SIDE																
Structural Type of Sluiceway	Vertical Wall								Bottom Slab							
	Horizontal				Vertical				Longitudinal				Transverse			
	Outer Side		Inner Side		Outer Side		Inner Side		Bottom		Top		Bottom		Top	
	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval
TYPE-A	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250
TYPE-B	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D19(A)	@250	D19(A)	@250
TYPE-C	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250
TYPE-D	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D19(A)	@250	D19(A)	@250
TYPE-E	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250
TYPE-F	D16(A)	@250	D22(A)	@250	D16(A)	@250	D22(A)	@250	D12(A)	@250	D12(A)	@250	D22(A)	@250	D22(A)	@250
TYPE-G	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D19(A)	@250	D19(A)	@250
TYPE-H	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D19(A)	@250	D19(A)	@250
TYPE-I	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250
TYPE-J	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250

Source: JICA Study Team

Table 2.2.10 Calculation Results of Breast Wall (Land Side)

Structural Type of Sluiceway	Vertical Wall								Bottom Slab							
	Horizontal				Vertical				Longitudinal				Transverse			
	Outer Side		Inner Side		Outer Side		Inner Side		Bottom		Top		Bottom		Top	
	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval	Dia.	Interval
TYPE-A	D16(A)	@250	D16(A)	@250	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250
TYPE-B	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D19(A)	@250	D19(A)	@250
TYPE-C	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250
TYPE-D	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D19(A)	@250	D19(A)	@250
TYPE-E	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250
TYPE-F	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D22(A)	@250	D22(A)	@250
TYPE-G	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250
TYPE-H	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D19(A)	@250	D19(A)	@250
TYPE-I	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250
TYPE-J	D16(A)	@250	D16(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D12(A)	@250	D16(A)	@250	D16(A)	@250

Source: JICA Study Team

2.2.2 Calculation Details by Sluiceway Type

The calculation sheets of each sluiceway type are shown from next page by following order. Type D and E are omitted since similar to Type C and Type G is omitted since similar to Type A

2.2.2.1 SLUICEWAY TYPE A
(1) BOX – LONGITUDINAL
(2) BOX - TRANSVERCE
(3) BREAST WALL – LAND SIDE
(4) BREAST WALL – RIVER SIDE

2.2.2.2 SLUICEWAY TYPE B
(1) BOX – LONGITUDINAL
(2) BOX - TRANSVERCE
(3) BREAST WALL – LAND SIDE
(4) BREAST WALL – RIVER SIDE

2.2.2.3 SLUICEWAY TYPE C
(1) BOX – LONGITUDINAL
(2) BOX - TRANSVERCE
(3) BREAST WALL – LAND SIDE
(4) BREAST WALL – RIVER SIDE

2.2.2.4 SLUICEWAY TYPE F
(1) BOX – LONGITUDINAL
(2) BOX - TRANSVERCE
(3) BREAST WALL – LAND SIDE
(4) BREAST WALL – RIVER SIDE

2.2.2.5 SLUICEWAY TYPE H
(1) BOX – LONGITUDINAL
(2) BOX - TRANSVERCE
(3) BREAST WALL – LAND SIDE
(4) BREAST WALL – RIVER SIDE

2.2.2.6 SLUICEWAY TYPE I
(1) BOX – LONGITUDINAL
(2) BOX - TRANSVERCE
(3) BREAST WALL – LAND SIDE
(4) BREAST WALL – RIVER SIDE

2.2.2.7 SLUICEWAY TYPE J
(1) BOX – LONGITUDINAL
(2) BOX - TRANSVERCE
(3) BREAST WALL – LAND SIDE
(4) BREAST WALL – RIVER SIDE

2.2.2.1 SLUICEWAY TYPE A

(1) BOX - LONGITUDINAL

Structural Calculation of Sluiceway Type-A

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1 Design Condition

1.1 Design Condition

1.1.1 Basic Condition

1) Culvert Shape:Rectanglar

2) Culvert Type: Double Holes

3) Allowable Displacement

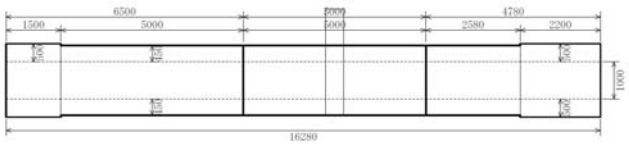
Residual Settlement		: 300.0 (mm)
Residual Settlement for Rigid Support		: 50.0 (mm)
Relative Displacement	Base Width	: 1.0 (%)
		± : 50.0 (mm)

4) Type of Joint : Flexible Joint

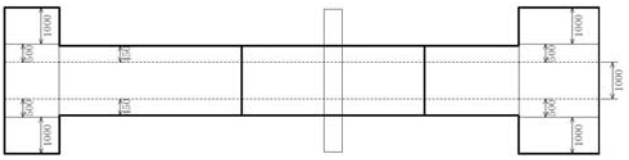
5) Allowable Opening : 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

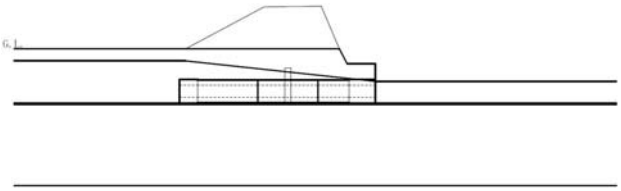
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Leeve Cross-section



1.2 Shape of Culvert Body

1.2.1 Span and Block

1) Spans

Number of Spans: 3
Total Length of Spans: 16.280 (m)

Span No	Name of Span	Length of Span (m)	Number of Blocks
1	Land Side	6.500	2
2	Center	5.000	1
3	River Side	4.780	2

2) Blocks

Span/ Block	Length of Block (m)	Depth for Subgrade Reaction(m)
1- 1	1.500	11.700
1- 2	5.000	5.700
2- 1	5.000	5.700
3- 1	2.580	5.700
3- 2	2.200	11.700

1.2.2 Sectional Dimension

1) Dimension (Block)

Span/ Block	Left Inside Width X2 (m)	Inside Height Y2 (m)
1- 1	1.000	1.000
1- 2	1.000	1.000
2- 1	1.000	1.000
3- 1	1.000	1.000
3- 2	1.000	1.000

Span/ Block	Thickness of Left Side Wall X1(m)	Thickness of Top Slab Y1(m)	Thickness of Bottom Slab Y3(m)	Height of Overhang Y4(m)	Length of Left Overhang B1(m)
1- 1	0.500	0.500	0.500	0.500	1.000
1- 2	0.450	0.450	0.450	0.000	0.000
2- 1	0.450	0.450	0.450	0.000	0.000
3- 1	0.450	0.450	0.450	0.000	0.000
3- 2	0.500	0.500	0.500	0.700	1.000

1.3 Reinforcement

Main Re-bar

Span No	Block No	Flange			Reinforcing Bar			
		Portion	b (mm)	t (mm)	Outside Diameter@Pitch (Number)	Outside Cover (mm)	Inside Diameter@Pitch (Number)	Inside Cover (mm)
1	1	Top Slab	2000.0	500.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	2000.0	500.0	D16@250(6)	115.0	D16@250(8)	90.0
	2	Top Slab	1900.0	450.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	1900.0	450.0	D16@250(6)	115.0	D16@250(8)	90.0
2	1	Top Slab	1900.0	450.0	D22@250(6)	90.0	D22@250(8)	90.0
		Bottom Slab	1900.0	450.0	D22@250(6)	115.0	D22@250(8)	90.0
3	1	Top Slab	1900.0	450.0	D22@250(6)	90.0	D22@250(8)	90.0
		Bottom Slab	1900.0	450.0	D22@250(6)	115.0	D22@250(8)	90.0
	2	Top Slab	2000.0	500.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	2000.0	500.0	D16@250(6)	115.0	D16@250(8)	90.0

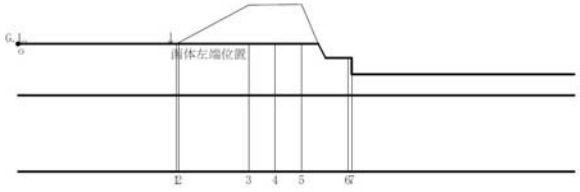
2 Settlement and Lateral Displacement

2.1 Immediate Settlement

2.1.1 Settlemet Calculation Points

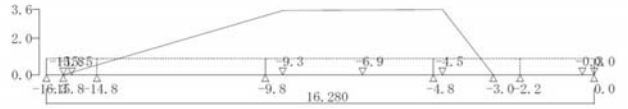
Settlemet Calculation Points

No	Calculation Point (m)	Name
1	-15.780	Box end (land side)
2	-15.530	Breast wall (land side)
3	-9.261	Levee end (land side)
4	-6.886	Levee center
5	-4.510	Levee end (river side)
6	-0.350	Breast wall (river side)
7	0.000	Box end (river side)



2.1.2 Summery of Immediate Settlement

No	Calculation Point (m)	Name	Immediate Settlement (mm)
1	-15.780	Box end (land side)	3.7
2	-15.530	Breast wall (land side)	4.0
3	-9.261	Levee end (land side)	12.8
4	-6.886	Levee center	12.7
5	-4.510	Levee end (river side)	10.5
6	-0.350	Breast wall (river side)	3.6
7	0.000	Box end (river side)	3.3



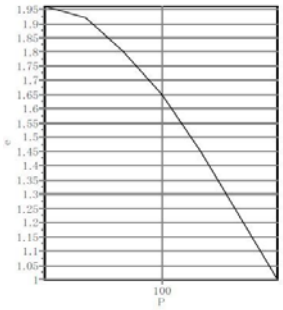


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

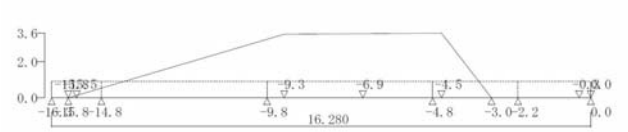
No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/m³)	Unit Weight (Saturated) (kN/m³)	Pre-Consolidation Stress q0 (kN/m²)	Elastic Modulus Es (kN/m²)
1	Adobe BL	Sand	4.550	17.500	18.500	0.0	6900.0
2	Dc1	Clay	11.430	17.500	18.500	0.0	15700.0

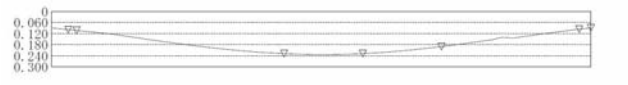
No	Concolidation Pressure P(kN/m²)	Void Ratio e
1	12.0000	1.9600
2	25.0000	1.9200
3	50.0000	1.8000
4	100.0000	1.6500
5	200.0000	1.4500
6	800.0000	1.0000



2.2.2 Summery of Consolidation Settlement

No	Calculation Point (m)	Name	Consolidation Settlement (mm)
1	-15.780	Box end (land side)	98.4
2	-15.530	Breast wall (land side)	102.9
3	-9.261	Levee end (land side)	228.2
4	-6.886	Levee center	228.0
5	-4.510	Levee end (river side)	190.2
6	-0.350	Breast wall (river side)	96.3
7	0.000	Box end (river side)	89.1



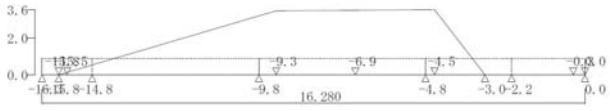


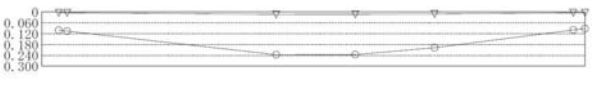
2.3 Residual Settlement

2.3.1 Sumarry of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vaue	Judge
1	-15.780	Box end (land side)	3.7	96.8	0.0	100.5	300.000	OK
2	-15.530	Breast wall (land side)	4.0	101.1	0.0	105.1	300.000	OK
3	-9.261	Levee end (land side)	12.8	223.4	0.0	236.2	300.000	OK
4	-6.886	Levee center	12.7	223.1	0.0	235.8	300.000	OK
5	-4.510	Levee end (river side)	10.5	186.5	0.0	197.0	300.000	OK
6	-0.350	Breast wall (river side)	3.6	95.1	0.0	98.7	300.000	OK
7	0.000	Box end (river side)	3.3	88.0	0.0	91.3	300.000	OK

The maximum of residual settlement is above 50.0(mm), herence the foundation is taken as flexible





▽ : Immediate Settlement
○ : Residual Settlement

3 Calculation of Box Culvert regarding Longitudal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B}\cdot\frac{d^4w}{dx^4}+k_v(w-w_g)=q \text{ (Swag)}$$

$$\frac{EA}{U}\cdot\frac{d^2u}{dx^2}+k_s(u-u_g)=p \text{ (Displacement in axial direction of Box Culvert)}$$

Thus,

w : Displacement of Box Culvert (Swag : cm {m})
w_g : Displacement of the Ground (Residual Settlement: cm {m})
k_v : Modulus of Sub grade Reaction in Vertical Direction (kgf/cm^3) {kN/m^3}
B : Width of Box Culvert (cm) {m}
EI : Rigidity of Box Culvert (kgf･cm^2) {kN･m^2}
q : Vertical External Force (kgf/cm^2) {kN/m^2}
u : Displacement on axial direction of Box Culvert (cm) {m}
u_g : Displacement of Ground (Lateral Displacement ; cm {m})
k_s : Modulus of Lateral Shear Sub grade Reaction (kgf/cm^3) {kN/m^3}
U : Circumference of Box Culvert (cm) {m}
EA : Rigidity of Box Culvert in axial direction (kgf) {kN}
p : Axial External Force (kgf/cm^2) {kN/m^2}

3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{om}=\frac{\log\frac{(B+2h_n\cdot\tan\theta)\cdot L}{(L+2h_n\cdot\tan\theta)\cdot B}}{\Sigma\frac{1}{E_i}\log\frac{(B+2h_i\cdot\tan\theta)(L+2h_{i-1}\cdot\tan\theta)}{(L+2h_i\cdot\tan\theta)(B+2h_{i-1}\cdot\tan\theta)}}$$

In case of B=L

$$E_{om}=\frac{-\frac{1}{B+2h_n\cdot\tan\theta}+\frac{1}{B}}{\Sigma\frac{1}{E_i}\left(-\frac{1}{B+2h_i\cdot\tan\theta}+\frac{1}{B+2h_{i-1}\cdot\tan\theta}\right)}$$

Thus,

Eom ; Converted Modulus of Deformation
B ; Loading Width = Width of Culvert
L ; Loading Length = Length of a span
hn ; Depth for Calculation
hn ; Depth from the ground to the bottom Elevation of Each Layer（m）
Ei ; Converted Modulus of Deformation of Each Layer(kN/m^2)
θ ; Angle of Load Dispersion（θ=30°）

Span1-Block1 Land Side

B	4.000 (m)		
L	6.500 (m)		
hn	11.700 (m)		
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	11.700	1.070	62800.0
Total	11.700		
Eom	62800.0 (kN/m^2)		

※Layer Thickness and Depths are the values based on subgrade Surface.

Span1-Block2 Land Side

B	1.900 (m)		
L	6.500 (m)		
hn	5.700 (m)		
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	5.700	5.700	62800.0
Total	5.700		
Eom	62800.0 (kN/m^2)		

※Layer Thickness and Depths are values Calculated from the subgrade

Span2-Block1 Center

B	1.900 (m)		
L	5.000 (m)		
hn	5.700 (m)		
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	5.700	5.700	62800.0
Total	5.700		
Eom	62800.0 (kN/m^2)		

※Layer and Depth is the values from the subgrade

Span3-Block1 River Side

B	1.900 (m)		
L	4.780 (m)		
hn	5.700 (m)		
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	5.700	5.700	62800.0
Total	5.700		
Eom	62800.0(kN/m^2)		

※Layer and Depth is the values from the subgrade

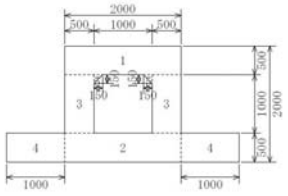
Span3-Block2 River Side

B	4.000 (m)		
L	4.780 (m)		
hn	11.700 (m)		
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	11.700	11.700	62800.0
Total	11.700		
Eom	62800.0 (kN/m^2)		

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

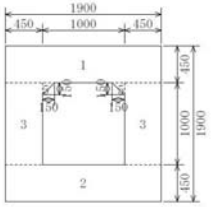
Span1-Block1 Land Side



Position	Ai (m^2)	Yi (m)	Ai･Yi (m^3)	Ai･Yi^2 (m^3)	Ioi (m^4)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.022	1.450	0.0326	0.0473	0.00003
Total	4.022		3.2826	4.2348	0.14586

Yg = Σ(Ai･Yi)/ΣAi = 3.2826 / 4.022 = 0.8161 (m)
I = Σ(Ai･Yi2)+ΣIoi - Yg2･ΣAi = 4.2348 + 0.14586 - 0.6660･4.022= 1.70183 (m^4)

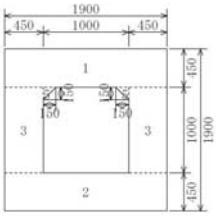
Span1-Block2 Land Side



Position	Ai (m^2)	Yi (m)	Ai･Yi (m^3)	Ai･Yi^2 (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.632 = 0.9538 (m)
I = Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.632= 1.00722 (m^4)

Span2-Block1　Center

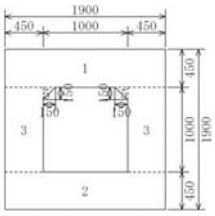


Position	Ai (m^2)	Yi (m)	Ai･Yi (m^3)	Ai･Yi^2 (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.632 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.632= 1.00722 (m^4)

Span3-Block1　River Side

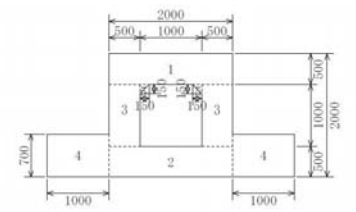


Position	Ai (m^2)	Yi (m)	Ai･Yi (m^3)	Ai･Yi^2 (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.632 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.632 = 1.00722 (m^4)

Span3-Block2　River Side



Position	Ai (m^2)	Yi (m)	Ai･Yi (m^3)	Ai･Yi^2 (m^3)	Ioi (m^4)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.400	0.350	0.4900	0.1715	0.05717
5	0.022	1.450	0.0326	0.0473	0.00003
Total	4.423		3.5226	4.3438	0.18219

Yg = Σ(Ai・Yi)/ΣAi = 3.5226 / 4.423 = 0.7965 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 4.3438 + 0.18219 - 0.6344・4.423 = 1.72015 (m^4)

3.2.3 Table of Modulus of Subgarade Reaction

Coefficient of Lateral Shear Reaction of Soil

$k_s=\lambda \cdot k_v$

Thus、

ks　: Coefficient of Lateral Shear Reaction of Soil (kN/m2)

λ　; Ratio between the coefficient of Lateral Shear Reaction of Soil and Vertical Sub grade Reaction (=0.333)

kv　: Coefficient of Vertical Sub grade Reaction

3.2.4 List of Modulus of Subgrade Reaction

Calculated Value

Normal Condition

Span Block	Position (m)	B (m)	kv (kN/m3)	ks (kN/m3)	kv･B (kN/m2)	ks･B (kN/m2)
1-1	-16.280～-14.780	4.000	25007.2	8327.4	100028.6	33309.5
1-2	-14.780～ -9.780	1.900	33060.1	11009.0	62814.2	20917.1
2-1	-9.780～ -4.780	1.900	36478.2	12147.2	69308.5	23079.7
3-1	-4.780～ -2.200	1.900	37098.9	12353.9	70487.9	23472.5
3-2	-2.200～ 0.000	4.000	28062.2	9344.7	112248.7	37378.8

Seismic Condition

Span Block	Position (m)	B (m)	kv (kN/m3)	ks (kN/m3)	kv･B (kN/m2)	ks･B (kN/m2)
1-1	-16.280～-14.780	4.000	50014.3	16654.8	200057.3	66619.1
1-2	-14.780～ -9.780	1.900	66120.2	22018.0	125628.4	41834.3
2-1	-9.780～ -4.780	1.900	72956.3	24294.5	138617.0	46159.5
3-1	-4.780～ -2.200	1.900	74197.8	24707.9	140975.9	46945.0
3-2	-2.200～ 0.000	4.000	56124.4	18689.4	224497.4	74757.6

Used Value

Normal Condition

Span Block	Position (m)	kv･B (kN/m2)	ks･B (kN/m2)
1-1	-16.280～-14.780	100202.3	33367.4
1-2	-14.780～ -9.780	62923.3	20953.4
2-1	-9.780～ -4.780	70377.7	23435.8
3-1	-4.780～ -2.200	69412.8	23114.4
3-2	-2.200～ 0.000	110536.5	36808.7

Seismic Condition

Span Block	Position (m)	Reduction Ratio DE	kv･B (kN/m2)	ks･B (kN/m2)
1-1	-16.280～-14.780	1.000	200404.6	66734.7
1-2	-14.780～ -9.780	1.000	125846.5	41906.9
2-1	-9.780～ -4.780	1.000	140755.3	46871.5
3-1	-4.780～ -2.200	1.000	138825.5	46228.9
3-2	-2.200～ 0.000	1.000	221073.1	73617.3

3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

W = (A1 + A2 + A3) ・γc (kN/m)

A1: Cross Sectional Area (Excluding Hunch) (m^2)

A2: Area of Upper Side Hunch (m^2)

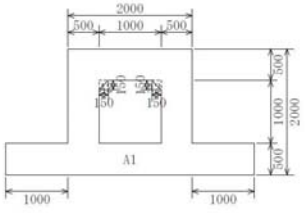
A3: Area of Lower Side Hunch (m^2)

γc: Unit Weight (Concrete) (kN/m^3)

Span No.　1-1　Land Side

W = (　4.000 +　　0.022 +　　0.000)・ 24.000

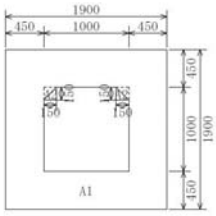
=　　96.540 (kN/m)



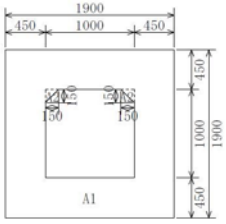
Span No.　1-2　Land Side

W = (　2.610 +　　0.022 +　　0.000)・ 24.000

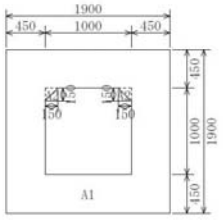
=　　63.180 (kN/m)



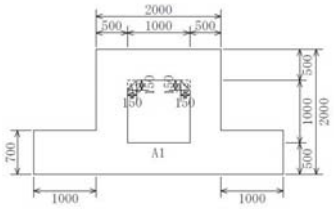
Span No. 2-1 Center
W = (2.610 + 0.022 + 0.000) · 24.000
= 63.180 (kN/m)



Span No. 3-1 River Side
W = (2.610 + 0.022 + 0.000) · 24.000
= 63.180 (kN/m)



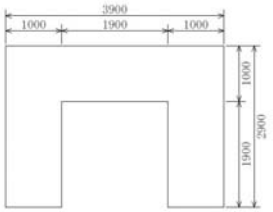
Span No. 3-2 River Side
W = (4.400 + 0.022 + 0.000 + 0.000) · 24.000
= 106.140 (kN/m)



2) Seepage Cutoff Wall Body Weight

A1 = X1・L2
A2 = L1・Y1・2
W = (A1 + A2) ・B・γc (kN)
X1: Top Slab Width (m)
Y1: Side Wall Height (m)
L1: Side Wall Width (m)
L2: Top Slab Height (m)
A1: Top Slab Area (m^2)
A2: Side Wall Area (m^2)
B : Thickness (m)
γc: Unit Weight (Concrete) (kN/m^3)

SpanNo.2-SpanDistance from Base Point (2.400)
A1 = 3.900・ 1.000
= 3.900 (m^2)
A2 = 1.000・ 1.900・2
= 3.800 (m^2)
W = (3.900 + 3.800)・ 0.500・ 24.00
= 92.400 (kN)



3.3.2 Ground Displacement Load (Settlement、Lateral Displacement)

1) Equivalent Load for Ground Settlement

【Normal Condition】
Span1 Name of Span: [Land Side]

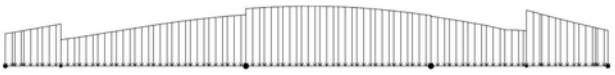
Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-16.280～-16.030	4.000	100202.3	91.2	95.8	-9140.118	-9599.814
1-(2)	-16.030～-15.780	4.000	100202.3	95.8	100.5	-9599.814	-10071.440
1-(3)	-15.780～-15.280	4.000	100202.3	100.5	109.7	-10071.440	-10993.081
1-(4)	-15.280～-14.780	4.000	100202.3	109.7	119.2	-10993.081	-11941.186
2-(5)	-14.780～-14.280	1.900	62923.3	119.2	129.9	-7498.614	-8174.450
2-(6)	-14.280～-13.780	1.900	62923.3	129.9	143.6	-8174.450	-9038.547
2-(7)	-13.780～-13.280	1.900	62923.3	143.6	157.3	-9038.547	-9895.970
2-(8)	-13.280～-12.780	1.900	62923.3	157.3	170.7	-9895.970	-10741.654
2-(9)	-12.780～-12.280	1.900	62923.3	170.7	184.1	-10741.654	-11584.901
2-(10)	-12.280～-11.780	1.900	62923.3	184.1	196.1	-11584.901	-12341.032
2-(11)	-11.780～-11.280	1.900	62923.3	196.1	206.9	-12341.032	-13018.772
2-(12)	-11.280～-10.780	1.900	62923.3	206.9	216.4	-13018.772	-13615.200
2-(13)	-10.780～-10.280	1.900	62923.3	216.4	224.5	-13615.200	-14123.827
2-(14)	-10.280～ -9.780	1.900	62923.3	224.5	231.0	-14123.827	-14537.958

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(15)	-9.780～ -9.280	1.900	70377.7	231.0	236.0	-16260.244	-16610.964
1-(16)	-9.280～ -8.780	1.900	70377.7	236.0	239.3	-16610.964	-16843.506
1-(17)	-8.780～ -8.280	1.900	70377.7	239.3	240.9	-16843.506	-16953.452
1-(18)	-8.280～ -7.780	1.900	70377.7	240.9	240.7	-16953.452	-16937.923
1-(19)	-7.780～ -7.280	1.900	70377.7	240.7	238.7	-16937.923	-16795.773
1-(20)	-7.280～ -6.780	1.900	70377.7	238.7	234.8	-16795.773	-16527.802
1-(21)	-6.780～ -6.280	1.900	70377.7	234.8	229.3	-16527.802	-16136.953
1-(22)	-6.280～ -5.780	1.900	70377.7	229.3	222.1	-16136.953	-15628.554
1-(23)	-5.780～ -5.280	1.900	70377.7	222.1	213.3	-15628.554	-15010.327
1-(24)	-5.280～ -4.780	1.900	70377.7	213.3	203.1	-15010.327	-14292.004

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(25)	-4.780～ -4.280	1.900	69412.8	203.1	191.6	-14096.055	-13298.989
1-(26)	-4.280～ -3.780	1.900	69412.8	191.6	178.8	-13298.989	-12413.740
1-(27)	-3.780～ -3.280	1.900	69412.8	178.8	165.3	-12413.740	-11473.810
1-(28)	-3.280～ -2.780	1.900	69412.8	165.3	148.3	-11473.810	-10292.081
1-(29)	-2.780～ -2.280	1.900	69412.8	148.3	145.2	-10292.081	-10081.708
1-(30)	-2.280～ -2.200	1.900	69412.8	145.2	143.2	-10081.708	-9937.712
2-(31)	-2.200～ -1.780	4.000	110536.5	143.2	132.4	-15825.334	-14637.431
2-(32)	-1.780～ -1.280	4.000	110536.5	132.4	120.0	-14637.431	-13269.575
2-(33)	-1.280～ -0.780	4.000	110536.5	120.0	108.3	-13269.575	-11967.497
2-(34)	-0.780～ -0.350	4.000	110536.5	108.3	98.7	-11967.497	-10910.038
2-(35)	-0.350～ -0.280	4.000	110536.5	98.7	97.2	-10910.038	-10743.804
2-(36)	-0.280～ 0.000	4.000	110536.5	97.2	91.3	-10743.804	-10096.144



2) Equivalent Load for Ground Settlement

【Seismic Condition】

Span1 Name of Span: [Land Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-16.280～-16.030	4.000	200404.6	91.2	95.8	-18280.237	-19199.627
1-(2)	-16.030～-15.780	4.000	200404.6	95.8	100.5	-19199.627	-20142.880
1-(3)	-15.780～-15.280	4.000	200404.6	100.5	109.7	-20142.880	-21986.162
1-(4)	-15.280～-14.780	4.000	200404.6	109.7	119.2	-21986.162	-23882.373
2-(5)	-14.780～-14.280	1.900	125846.5	119.2	129.9	-14997.227	-16348.899
2-(6)	-14.280～-13.780	1.900	125846.5	129.9	143.6	-16348.899	-18077.094
2-(7)	-13.780～-13.280	1.900	125846.5	143.6	157.3	-18077.094	-19791.940
2-(8)	-13.280～-12.780	1.900	125846.5	157.3	170.7	-19791.940	-21483.308
2-(9)	-12.780～-12.280	1.900	125846.5	170.7	184.1	-21483.308	-23169.802
2-(10)	-12.280～-11.780	1.900	125846.5	184.1	196.1	-23169.802	-24682.064
2-(11)	-11.780～-11.280	1.900	125846.5	196.1	206.9	-24682.064	-26037.544
2-(12)	-11.280～-10.780	1.900	125846.5	206.9	216.4	-26037.544	-27230.401
2-(13)	-10.780～-10.280	1.900	125846.5	216.4	224.5	-27230.401	-28247.654
2-(14)	-10.280～ -9.780	1.900	125846.5	224.5	231.0	-28247.654	-29075.917

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(15)	-9.780～ -9.280	1.900	140755.3	231.0	236.0	-32520.488	-33221.929
1-(16)	-9.280～ -8.780	1.900	140755.3	236.0	239.3	-33221.929	-33687.012
1-(17)	-8.780～ -8.280	1.900	140755.3	239.3	240.9	-33687.012	-33906.905
1-(18)	-8.280～ -7.780	1.900	140755.3	240.9	240.7	-33906.905	-33875.847
1-(19)	-7.780～ -7.280	1.900	140755.3	240.7	238.7	-33875.847	-33591.546
1-(20)	-7.280～ -6.780	1.900	140755.3	238.7	234.8	-33591.546	-33055.604
1-(21)	-6.780～ -6.280	1.900	140755.3	234.8	229.3	-33055.604	-32273.907
1-(22)	-6.280～ -5.780	1.900	140755.3	229.3	222.1	-32273.907	-31257.109
1-(23)	-5.780～ -5.280	1.900	140755.3	222.1	213.3	-31257.109	-30020.654
1-(24)	-5.280～ -4.780	1.900	140755.3	213.3	203.1	-30020.654	-28584.007

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(25)	-4.780～ -4.280	1.900	138825.5	203.1	191.6	-28192.109	-26597.978
1-(26)	-4.280～ -3.780	1.900	138825.5	191.6	178.8	-26597.978	-24827.480
1-(27)	-3.780～ -3.280	1.900	138825.5	178.8	165.3	-24827.480	-22947.619
1-(28)	-3.280～ -2.780	1.900	138825.5	165.3	148.3	-22947.619	-20584.162
1-(29)	-2.780～ -2.280	1.900	138825.5	148.3	145.2	-20584.162	-20163.416
1-(30)	-2.280～ -2.200	1.900	138825.5	145.2	143.2	-20163.416	-19875.423
2-(31)	-2.200～ -1.780	4.000	221073.1	143.2	132.4	-31650.668	-29274.863
2-(32)	-1.780～ -1.280	4.000	221073.1	132.4	120.0	-29274.863	-26539.150
2-(33)	-1.280～ -0.780	4.000	221073.1	120.0	108.3	-26539.150	-23934.993
2-(34)	-0.780～ -0.350	4.000	221073.1	108.3	98.7	-23934.993	-21820.075
2-(35)	-0.350～ -0.280	4.000	221073.1	98.7	97.2	-21820.075	-21487.608
2-(36)	-0.280～ 0.000	4.000	221073.1	97.2	91.3	-21487.608	-20192.288



3.3.3 Point Load from Breast Walls

1) Normal Condition (Case Number: 1)

Case of Normal Condition 1

Name of Normal Load: [Gate Piers and Breast Walls (Normal) 1]

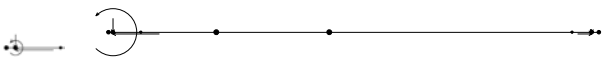
Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-98.63	82.55	-14.07
3	Right Breast Wall	15.930	406.44	257.25	-102.75



2) Seismic Condition (Total Number: 2)

Case of Seismic Conditon 1 [Land Side →River Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-174.82	58.75	67.46
3	Right Breast Wall	15.930	368.88	82.16	-117.15



Case of Seimic Condition 2 [River Side→Land Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-263.72	58.75	145.15
3	Right Breast Wall	15.930	244.37	82.16	-16.81



3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
2	Fixed Load Data 2	Water Weight (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Engaging Load (Normal)1	Gate Structure ･Breast Wall (Normal)1	1.0000
6	Engaging Load (Normal)1	Gate Structure ･Breast Wall (Normal)1	1.0000

2) Seismic Condition

1) Case 1 [Seismic Condition: Land Side→River Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Dead Load)1	Gate Structure ･Breast Wall (Dead Load)1	1.0000
6	Ingaging Load (Seismic)1	Seismic Load :Land Side →River Side	1.0000

2) Case 2 [Seismic Condition: River Side→Land Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Dead Load)2	Seismic Load	1.0000
6	Ingaging Load (Dead Load)2	Gate Structure ･Breast Wall (Dead Load)2	1.0000

3.4 Displacement between Sluiceway and Adjoining Levee

3.4.1 Normal Condition

1) Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-8.8	-8.3	89.7	91.2	-1.6	-50.0	○	-156.393
2	0.250	-8.8	-8.3	95.4	95.8	-0.4	-50.0	○	-39.099
3	0.500	-8.8	-8.3	101.2	100.5	0.7	40.0	○	66.263
4	1.000	-8.8	-8.4	112.7	109.7	3.0	40.0	○	298.600
5	1.500	-8.8	-8.5	124.2	119.2	5.0	19.0	○	504.474
6	2.000	-8.8	-8.5	135.7	129.9	5.8	19.0	○	365.611
7	2.500	-8.8	-8.6	147.2	143.6	3.6	19.0	○	226.171
8	3.000	-8.8	-8.6	158.8	157.3	1.5	19.0	○	93.407
9	3.500	-8.8	-8.7	170.3	170.7	-0.4	-50.0	○	-27.618
10	4.000	-8.8	-8.2	181.8	184.1	-2.3	-50.0	○	-146.207
11	4.500	-8.8	-7.3	193.3	196.1	-2.8	-50.0	○	-177.681
12	5.000	-8.8	-6.3	204.8	206.9	-2.1	-50.0	○	-130.765
13	5.500	-8.8	-5.3	216.3	216.4	0.0	-50.0	○	-2.539
14	6.000	-8.8	-4.3	227.9	224.5	3.4	19.0	○	213.488
15	6.500	-8.8	-3.3	239.4	231.0	8.3	19.0	○	524.010

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground Spring (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	1.7	-3.3	246.7	231.0	15.7	19.0	○	1104.078
2	0.500	1.7	-2.3	243.9	236.0	7.9	19.0	○	553.178
3	1.000	1.7	-1.3	241.0	239.3	1.7	19.0	○	120.456
4	1.500	1.7	-0.3	238.2	240.9	-2.7	-50.0	○	-189.673
5	2.000	1.7	0.7	235.4	240.7	-5.3	-50.0	○	-374.331
6	2.500	1.7	1.6	232.5	238.7	-6.1	-50.0	○	-432.374
7	3.000	1.7	2.6	229.7	234.8	-5.2	-50.0	○	-364.602
8	3.500	1.7	3.6	226.8	229.3	-2.5	-50.0	○	-173.958
9	4.000	1.7	4.6	224.0	222.1	1.9	19.0	○	134.231
10	4.500	1.7	5.7	221.1	213.3	7.8	19.0	○	552.247
11	5.000	1.7	6.7	218.3	203.1	15.2	19.0	○	1070.358

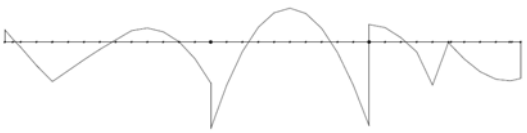
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	14.1	6.7	199.8	203.1	-3.2	-50.0	○	-224.402
2	0.500	14.1	7.7	188.9	191.6	-2.7	-50.0	○	-184.646
3	1.000	14.1	8.6	178.0	178.8	-0.8	-50.0	○	-56.707
4	1.500	14.1	8.7	167.1	165.3	1.8	19.0	○	125.914
5	2.000	14.1	8.6	156.2	148.3	7.9	19.0	○	550.336
6	2.500	14.1	8.5	145.3	145.2	0.0	19.0	○	3.404
7	2.580	14.1	8.5	143.5	143.2	0.4	19.0	○	41.774
8	3.000	14.1	8.5	134.4	132.4	2.0	40.0	○	216.664
9	3.500	14.1	8.4	123.5	120.0	3.4	40.0	○	378.555
10	4.000	14.1	8.4	112.6	108.3	4.3	40.0	○	474.672
11	4.430	14.1	8.3	103.2	98.7	4.5	40.0	○	495.005
12	4.500	14.1	8.3	101.7	97.2	4.5	40.0	○	492.405
13	4.780	14.1	8.3	95.5	91.3	4.2	40.0	○	464.727

Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-8.1	-8.3	89.7	91.2	-1.5	-50.0	○	-153.640
2	0.250	-8.1	-8.3	95.4	95.8	-0.4	-50.0	○	-37.292
3	0.500	-8.1	-8.3	101.2	100.5	0.7	40.0	○	67.125
4	1.000	-8.1	-8.4	112.7	109.7	3.0	40.0	○	297.571
5	1.500	-8.1	-8.5	124.2	119.2	5.0	19.0	○	501.554
6	2.000	-8.1	-8.5	135.7	129.9	5.8	19.0	○	362.590
7	2.500	-8.1	-8.6	147.2	143.6	3.5	19.0	○	221.964
8	3.000	-8.1	-8.6	158.7	157.3	1.4	19.0	○	88.013
9	3.500	-8.1	-8.7	170.2	170.7	-0.5	-50.0	○	-34.199
10	4.000	-8.1	-8.2	181.7	184.1	-2.4	-50.0	○	-153.973
11	4.500	-8.1	-7.3	193.2	196.1	-3.0	-50.0	○	-186.633
12	5.000	-8.1	-6.3	204.7	206.9	-2.2	-50.0	○	-140.902
13	5.500	-8.1	-5.3	216.2	216.4	-0.2	-50.0	○	-13.862
14	6.000	-8.1	-4.3	227.7	224.5	3.2	19.0	○	200.980
15	6.500	-8.1	-3.3	239.2	231.0	8.1	19.0	○	510.317

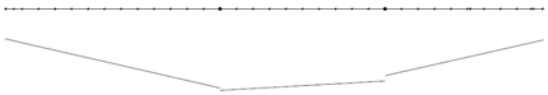
Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	1.7	-3.3	246.6	231.0	15.6	19.0	○	1094.498
2	0.500	1.7	-2.3	243.8	236.0	7.7	19.0	○	543.598
3	1.000	1.7	-1.3	240.9	239.3	1.6	19.0	○	110.877
4	1.500	1.7	-0.3	238.1	240.9	-2.8	-50.0	○	-199.252
5	2.000	1.7	0.7	235.2	240.7	-5.5	-50.0	○	-383.911
6	2.500	1.7	1.6	232.4	238.7	-6.3	-50.0	○	-441.953
7	3.000	1.7	2.6	229.5	234.8	-5.3	-50.0	○	-374.181
8	3.500	1.7	3.6	226.7	229.3	-2.6	-50.0	○	-183.538
9	4.000	1.7	4.6	223.8	222.1	1.8	19.0	○	124.652
10	4.500	1.7	5.7	221.0	213.3	7.7	19.0	○	542.667
11	5.000	1.7	6.7	218.1	203.1	15.1	19.0	○	1060.778

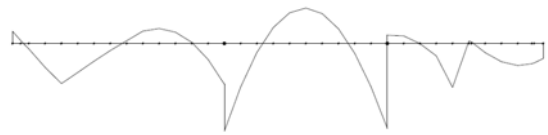
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	9.7	6.7	201.6	203.1	-1.5	-50.0	○	-103.676
2	0.500	9.7	7.7	190.2	191.6	-1.4	-50.0	○	-94.694
3	1.000	9.7	8.6	178.9	178.8	0.0	19.0	○	2.470
4	1.500	9.7	8.7	167.5	165.3	2.2	19.0	○	154.317
5	2.000	9.7	8.6	156.2	148.3	7.9	19.0	○	547.963
6	2.500	9.7	8.5	144.8	145.2	-0.4	-50.0	○	-29.745
7	2.580	9.7	8.5	143.0	143.2	-0.2	-50.0	○	-18.857
8	3.000	9.7	8.5	133.5	132.4	1.0	40.0	○	114.863
9	3.500	9.7	8.4	122.1	120.0	2.1	40.0	○	227.741
10	4.000	9.7	8.4	110.8	108.3	2.5	40.0	○	274.842
11	4.430	9.7	8.3	101.0	98.7	2.3	40.0	○	253.020
12	4.500	9.7	8.3	99.4	97.2	2.2	40.0	○	243.557
13	4.780	9.7	8.3	93.0	91.3	1.7	40.0	○	188.429

Displacement Diagram



Reaction Force of Ground



Reaction Force



2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-8.4	-8.3	90.2	91.2	-1.0	-50.0	○	-97.668
2	0.250	-8.4	-8.3	96.0	95.8	0.2	40.0	○	15.628
3	0.500	-8.4	-8.3	101.7	100.5	1.2	40.0	○	116.993
4	1.000	-8.4	-8.4	113.1	109.7	3.4	40.0	○	341.335
5	1.500	-8.4	-8.5	124.6	119.2	5.4	19.0	○	539.214
6	2.000	-8.4	-8.5	136.0	129.9	6.1	19.0	○	382.407
7	2.500	-8.4	-8.6	147.4	143.6	3.8	19.0	○	237.948
8	3.000	-8.4	-8.6	158.9	157.3	1.6	19.0	○	100.166
9	3.500	-8.4	-8.7	170.3	170.7	-0.4	-50.0	○	-25.877
10	4.000	-8.4	-8.2	181.7	184.1	-2.4	-50.0	○	-149.483
11	4.500	-8.4	-7.3	193.2	196.1	-3.0	-50.0	○	-185.973
12	5.000	-8.4	-6.3	204.6	206.9	-2.3	-50.0	○	-144.073
13	5.500	-8.4	-5.3	216.0	216.4	-0.3	-50.0	○	-20.863
14	6.000	-8.4	-4.3	227.5	224.5	3.0	19.0	○	190.148
15	6.500	-8.4	-3.3	238.9	231.0	7.9	19.0	○	495.654

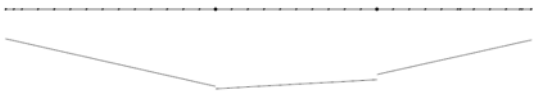
Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	1.7	-3.3	246.6	231.0	15.6	19.0	○	1094.498
2	0.500	1.7	-2.3	243.8	236.0	7.7	19.0	○	543.598
3	1.000	1.7	-1.3	240.9	239.3	1.6	19.0	○	110.877
4	1.500	1.7	-0.3	238.1	240.9	-2.8	-50.0	○	-199.252
5	2.000	1.7	0.7	235.2	240.7	-5.5	-50.0	○	-383.911
6	2.500	1.7	1.6	232.4	238.7	-6.3	-50.0	○	-441.953
7	3.000	1.7	2.6	229.5	234.8	-5.3	-50.0	○	-374.181
8	3.500	1.7	3.6	226.7	229.3	-2.6	-50.0	○	-183.538
9	4.000	1.7	4.6	223.8	222.1	1.8	19.0	○	124.652
10	4.500	1.7	5.7	221.0	213.3	7.7	19.0	○	542.667
11	5.000	1.7	6.7	218.1	203.1	15.1	19.0	○	1060.778

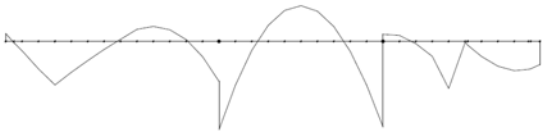
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	9.2	6.7	201.8	203.1	-1.3	-50.0	○	-86.889
2	0.500	9.2	7.7	190.5	191.6	-1.1	-50.0	○	-73.138
3	1.000	9.2	8.6	179.3	178.8	0.4	19.0	○	28.796
4	1.500	9.2	8.7	168.0	165.3	2.7	19.0	○	185.412
5	2.000	9.2	8.6	156.7	148.3	8.4	19.0	○	583.827
6	2.500	9.2	8.5	145.4	145.2	0.2	19.0	○	10.887
7	2.580	9.2	8.5	143.6	143.2	0.4	19.0	○	47.063
8	3.000	9.2	8.5	134.1	132.4	1.7	40.0	○	187.160
9	3.500	9.2	8.4	122.8	120.0	2.8	40.0	○	307.630
10	4.000	9.2	8.4	111.5	108.3	3.3	40.0	○	362.320
11	4.430	9.2	8.3	101.8	98.7	3.1	40.0	○	347.024
12	4.500	9.2	8.3	100.3	97.2	3.1	40.0	○	338.623
13	4.780	9.2	8.3	93.9	91.3	2.6	40.0	○	287.744

Displacement Diagram



Reaction Force of Ground



Reaction Force



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]
Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	-4.400	-50.966	-6.982
3	0.250	192.855	-216.066	21.158
4	0.500	188.696	-239.201	-36.300
5	1.000	181.086	-201.045	-151.210
6	1.500	174.434	-53.336	-219.102
7	2.000	170.860	80.885	-213.226
8	2.500	167.891	192.450	-141.980
9	3.000	165.529	235.965	-32.102
10	3.500	163.775	216.032	83.426
11	4.000	159.993	136.196	173.962
12	4.500	148.701	18.844	213.384
13	5.000	127.055	-94.647	193.463
14	5.500	95.056	-164.352	126.047
15	6.000	52.704	-147.995	43.464
16	6.500	0.001	0.000	0.000

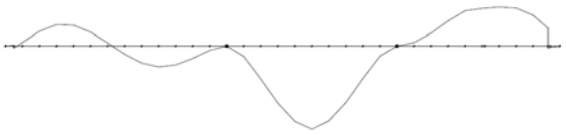
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	6.500	-0.001	0.000	0.000
2	7.000	52.286	377.934	105.957
3	7.500	92.994	509.963	336.944
4	8.000	122.125	456.279	584.965
5	8.500	139.679	278.899	772.606
6	9.000	145.655	40.843	853.753
7	9.000	145.656	-51.557	853.753
8	9.500	140.033	-287.180	767.659
9	10.000	122.706	-458.200	577.346
10	10.500	93.592	-504.511	330.253
11	11.000	52.690	-369.271	103.105
12	11.500	-0.001	0.000	0.000

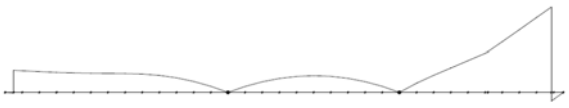
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	11.500	0.002	0.000	0.000
2	12.000	80.504	-138.642	-35.489
3	12.500	149.529	-235.360	-131.655
4	13.000	212.723	-254.438	-257.909
5	13.500	276.133	-121.755	-360.800
6	14.000	340.212	-19.700	-384.770
7	14.080	350.527	-24.338	-386.552
8	14.500	437.208	-18.668	-398.159
9	15.000	541.379	72.277	-388.137
10	15.500	646.609	227.724	-315.148
11	15.930	737.952	386.445	-183.419
12	15.930	-74.922	-128.053	22.081
13	16.000	-59.984	-101.595	14.044
14	16.280	-0.003	0.000	0.000

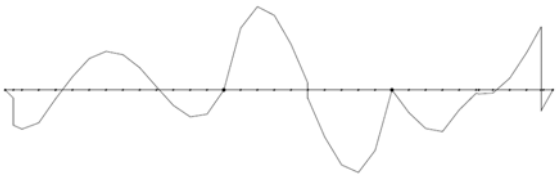
Bending Moment



Axial Force



Shear Force



3.5.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side →River Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	-3.191	-41.868	-5.832
3	0.250	171.624	-259.658	3.948
4	0.500	168.674	-274.334	-63.337
5	1.000	163.482	-221.179	-191.957
6	1.500	159.248	-61.029	-266.700
7	2.000	157.191	81.180	-262.607
8	2.500	155.742	199.129	-189.550
9	3.000	154.898	247.423	-75.071
10	3.500	154.663	230.664	47.047
11	4.000	152.399	152.399	145.357
12	4.500	142.626	35.013	192.940
13	5.000	122.498	-80.115	180.760
14	5.500	92.018	-153.061	119.867
15	6.000	51.185	-141.548	41.785
16	6.500	0.001	0.000	0.000

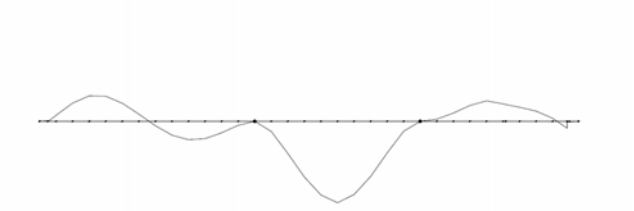
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	6.500	-0.001	0.000	0.000
2	7.000	52.286	377.934	105.957
3	7.500	92.994	509.963	336.944
4	8.000	122.125	456.279	584.965
5	8.500	139.679	278.899	772.606
6	9.000	145.655	40.843	853.753
7	9.000	145.656	-51.557	853.753
8	9.500	140.033	-287.180	767.659
9	10.000	122.706	-458.200	577.346
10	10.500	93.592	-504.511	330.253
11	11.000	52.690	-369.271	103.105
12	11.500	-0.001	0.000	0.000

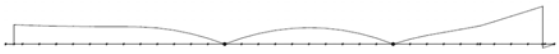
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	11.500	0.002	0.000	0.000
2	12.000	44.011	-91.775	-23.252
3	12.500	76.544	-154.124	-86.872
4	13.000	103.245	-151.330	-166.519
5	13.500	130.162	-9.273	-214.992
6	14.000	157.749	89.660	-182.980
7	14.080	162.225	83.363	-176.076
8	14.500	200.091	64.417	-147.126
9	15.000	246.148	107.747	-106.636
10	15.500	293.266	195.676	-31.961
11	15.930	334.631	280.413	70.607
12	15.930	-34.242	-56.965	9.357
13	16.000	-27.441	-43.945	5.827
14	16.280	-0.003	0.000	0.000

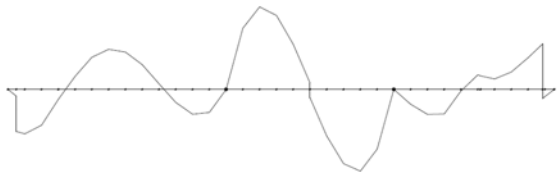
Bending Moment



Axial Force



Shear Force



Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	-7.981	-26.692	-3.916
3	0.250	255.733	-337.162	3.094
4	0.500	247.993	-337.564	-81.764
5	1.000	233.220	-258.566	-235.388
6	1.500	219.406	-76.179	-323.115
7	2.000	211.333	77.730	-323.577
8	2.500	203.868	205.115	-249.791
9	3.000	197.008	260.580	-130.433
10	3.500	190.757	248.730	-0.415
11	4.000	182.477	173.110	107.684
12	4.500	166.688	56.108	165.812
13	5.000	140.545	-60.901	163.804
14	5.500	104.049	-137.989	111.577
15	6.000	57.201	-132.880	39.524
16	6.500	0.001	0.000	0.000

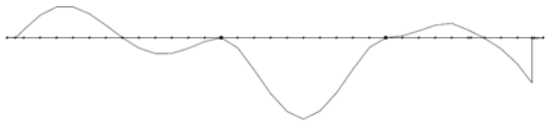
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	6.500	-0.001	0.000	0.000
2	7.000	52.286	377.934	105.957
3	7.500	92.994	509.963	336.944
4	8.000	122.125	456.279	584.965
5	8.500	139.679	278.899	772.606
6	9.000	145.655	40.843	853.753
7	9.000	145.656	-51.557	853.753
8	9.500	140.033	-287.180	767.659
9	10.000	122.706	-458.200	577.346
10	10.500	93.592	-504.511	330.253
11	11.000	52.690	-369.271	103.105
12	11.500	-0.001	0.000	0.000

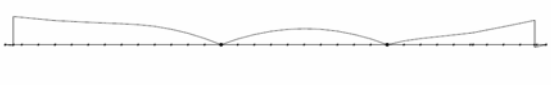
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	11.500	0.002	0.000	0.000
2	12.000	33.778	-76.841	-19.571
3	12.500	56.077	-122.977	-71.724
4	13.000	72.545	-102.692	-131.479
5	13.500	89.228	58.134	-150.993
6	14.000	106.582	177.113	-80.320
7	14.080	109.420	174.142	-66.287
8	14.500	133.598	183.857	6.759
9	15.000	163.359	263.176	115.881
10	15.500	194.179	389.127	277.691
11	15.930	221.529	508.187	470.769
12	15.930	-22.835	-86.011	14.469
13	16.000	-18.314	-67.261	9.106
14	16.280	-0.003	0.000	0.000

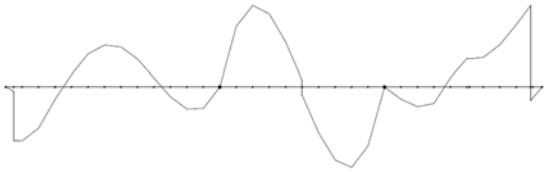
Bending Moment



Axial Force



Shear Force



3.6 Design of Flexible Joint

Opening

Opening = (Lateral Displacement of Span in Right Side) - (Lateral Displacement of Span in Left Side)

Bending Angle

θ = |θ1 - θ2| - Initial Bending Angle

Thus、

θ1: Angle of Displacement (Left Side) (rad)

θ2: Angle of Displacement (Right Side) (rad)

θ: Average Angle of Displacement (rad)

Unevenness

Unevenness = (Vertical Displacement of Span in Right Side) - (Vertical Displacement of Span in Left Side)

3.6.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Check of Opening Allowable Opening: 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-8.8	
Span (2- 1)	1.7- (-8.8)	10.5 OK
Span (3- 2)	14.1- (1.7)	12.5 OK
EP	14.1	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-1.31969 -0.02303	0.32594 0.00569	1.64563 0.02872
Span (3- 2)	0.00000 0.00000	0.32599 0.00569	1.25022 0.02182	0.92423 0.01613

Check for Unevenness Allowable Unevenness 100.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-89.7	
Span (2- 1)	-246.7- (-239.4)	7.4 OK
Span (3- 2)	-199.8- (-218.3)	18.4 OK
EP	-95.5	

3.6.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-8.1	
Span (2- 1)	1.7- (-8.1)	9.8 OK
Span (3- 2)	9.7- (1.7)	8.0 OK
EP	9.7	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-1.31753 -0.02300	0.32594 0.00569	1.64347 0.02868
Span (3- 2)	0.00000 0.00000	0.32599 0.00569	1.30103 0.02271	0.97503 0.01702

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-89.7	
Span (2- 1)	-246.6- (-239.2)	7.4 OK
Span (3- 2)	-201.6- (-218.1)	16.6 OK
EP	-93.0	

Calculation Case2 - Load: [Seismic Condition Land Side →River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-8.4	
Span (2- 1)	1.7- (-8.4)	10.1 OK
Span (3- 2)	9.2- (1.7)	7.6 OK
EP	9.2	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-1.31055 -0.02287	0.32594 0.00569	1.63649 0.02856
Span (3- 2)	0.00000 0.00000	0.32599 0.00569	1.29315 0.02257	0.96716 0.01688

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-90.2	
Span (2- 1)	-246.6- (-238.9)	7.7 OK
Span (3- 2)	-201.8- (-218.1)	16.3 OK
EP	-93.9	

3.7 Stress Intensity Analysis

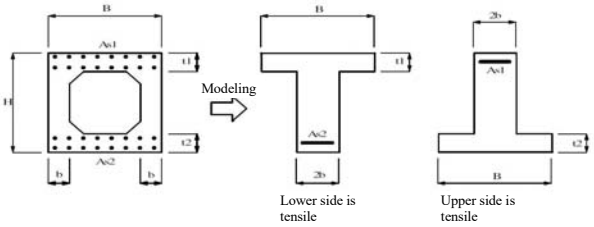
3.7.1 Calculation Condition

It is considered that double reinforced section which bending moment is acting on.
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.
Position of Neutral Axis

$$x=\frac{n\cdot(As\cdot d+As'\cdot d')+B\cdot t^2/2}{n\cdot(As+As')+B\cdot t}$$

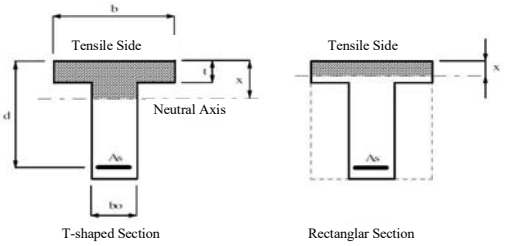
Thus,

- x : Position of Neutral Axis (mm)
- n : Ratio of Young modulus = 9.0
- As : Area of Re-bar in tensile side (mm^2)
- As' : Area of Re-bar in compressive side (mm^2)
- d : Effective Height of Beam (mm)
- d' : Distance from the compressive edge of concrete to the centric of Re-bar (mm)
- B : Width of Flange (mm)
- t : Thickness of Flange (mm)



The stress calculation is conducted as follows based on the position of neutral axis

1) In case the neutral axis is in web, the section is considered as T-shape.
2) In case the neutral axis is in top slab or Bottom slab, the section is considered as rectangle.



Calculation Condition (In Case Bottom Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation Section
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.265	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.299	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.299	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.285	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side As(mm^2)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side As' (mm^2)
1- 1	2.000	2.000	1.716	2780.4	0.273	2780.4
1- 2	1.900	1.900	1.645	2780.4	0.244	2780.4
2- 1	1.900	1.900	1.645	5419.4	0.244	5419.4
3- 1	1.900	1.900	1.645	5419.4	0.244	5419.4
3- 2	2.000	2.000	1.716	2780.4	0.273	2780.4

3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width Total Height Web Width Bending Moment		B H b M	m m mm kN.m	2.000 2.000 1000.0 21.158	2.000 2.000 1000.0 -219.102	2.000 2.000 1000.0 21.158	2.000 2.000 1000.0 -6.982
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	40.3	40.3	430.0	40.3	13.2
	Top Slab Inside	Aq2	53.8	53.8	573.4	53.8	17.6
	Bottom Slab Inside	Aq3	53.8	53.8	573.4	53.8	17.6
	Bottom Slab Outside	Aq4	40.3	40.3	430.0	40.3	13.2
Neutral Axis		X	m	0.199	0.201	0.199	0.201
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.07	0.68	0.07	0.02
		σs	N/mm^2	5.00	51.83	5.00	1.65
		σs'	N/mm^2	-0.32	-2.60	-0.32	-0.08
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	125.5	1337.9	125.5	41.2
		inp	mm^2	2780.4	2780.4	2780.4	2780.4

Calculation Condition (In Case Top Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b (m)	Thickness t (m)	Neutral Axis x (m)	Calculation
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.265	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.299	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.299	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.285	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side	Position of Re-bar in Compressive	Area of Re-bar in Tensile Side
1- 1	2.000	2.000	1.727	2780.4	0.284	2780.4
1- 2	1.900	1.900	1.656	2780.4	0.255	2780.4
2- 1	1.900	1.900	1.656	5419.4	0.255	5419.4
3- 1	1.900	1.900	1.656	5419.4	0.255	5419.4
3- 2	2.000	2.000	1.727	2780.4	0.284	2780.4

Calculation Case1: Normal Condition

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	213.384	-219.102	-219.102	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	434.9	447.0	447.0	
	Top Slab Inside	Aq2	mm^2	579.9	596.0	596.0	
	Bottom Slab Inside	Aq3	mm^2	579.9	596.0	596.0	
	Bottom Slab Outside	Aq4	mm^2	434.9	447.0	447.0	
Neutral Axis		X	m	0.198	0.199	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.73	0.74	0.74	----
		σs	N/mm^2	52.38	53.84	53.84	----
		σs'	N/mm^2	-3.58	-2.82	-2.82	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2				----
		req	mm^2	1353.0	1390.6	1390.6	----
		inp	mm^2	2780.4	2780.4	2780.4	----

Calculation Case1: Normal Condition

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	853.753	0.000	853.753	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	1807.6		1807.6	
	Top Slab Inside	Aq2	mm^2	2410.1		2410.1	
	Bottom Slab Inside	Aq3	mm^2	2410.1		2410.1	
	Bottom Slab Outside	Aq4	mm^2	1807.6		1807.6	
Neutral Axis		X	m	0.264	----	0.264	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	2.12	----	2.12	----
		σs	N/mm^2	109.93	----	109.93	----
		σs'	N/mm^2	-12.61	----	-12.61	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2	4441.5	----	4441.5	----
		req	mm^2	5623.5	----	5623.5	----
		inp	mm^2	5419.4	----	5419.4	----

Calculation Case1: Normal Condition

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-386.552	-386.552	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		799.3	799.3	
	Top Slab Inside	Aq2	mm^2		1065.8	1065.8	
	Bottom Slab Inside	Aq3	mm^2		1065.8	1065.8	
	Bottom Slab Outside	Aq4	mm^2		799.3	799.3	
Neutral Axis		X	m	----	0.266	0.266	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	0.95	0.95	----
		σs	N/mm^2	----	49.87	49.87	----
		σs'	N/mm^2	----	-4.88	-4.88	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	2486.8	2486.8	----
		inp	mm^2	----	5419.4	5419.4	----

Calculation Case1: Normal Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	22.081	-398.159	-183.419	22.081
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	42.1	792.5	358.7	42.1
	Top Slab Inside	Aq2	mm^2	56.2	1056.7	478.3	56.2
	Bottom Slab Inside	Aq3	mm^2	56.2	1056.7	478.3	56.2
	Bottom Slab Outside	Aq4	mm^2	42.1	792.5	358.7	42.1
Neutral Axis		X	m	0.199	0.201	0.201	0.199
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.07	1.23	0.57	0.07
		σs	N/mm^2	5.22	94.19	43.39	5.22
		σs'	N/mm^2	-0.34	-4.72	-2.18	-0.34
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	131.0	2465.7	1116.1	131.0
		inp	mm^2	2780.4	2780.4	2780.4	2780.4

3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	3.948	-266.700	3.948	-5.832
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	5.6	393.3	5.6	8.3
	Top Slab Inside	Aq2	mm^2	7.5	524.4	7.5	11.1
	Bottom Slab Inside	Aq3	mm^2	7.5	524.4	7.5	11.1
	Bottom Slab Outside	Aq4	mm^2	5.6	393.3	5.6	8.3
Neutral Axis		X	m	0.199	0.201	0.199	0.201
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.01	0.82	0.01	0.02
		σs	N/mm^2	0.93	63.09	0.93	1.38
		σs'	N/mm^2	-0.06	-3.16	-0.06	-0.07
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	17.5	1223.6	17.5	25.8
		inp	mm^2	2780.4	2780.4	2780.4	2780.4

Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	192.940	-266.700	-266.700	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	293.9	408.8	408.8	
	Top Slab Inside	Aq2	mm^2	391.8	545.0	545.0	
	Bottom Slab Inside	Aq3	mm^2	391.8	545.0	545.0	
	Bottom Slab Outside	Aq4	mm^2	293.9	408.8	408.8	
Neutral Axis		X	m	0.198	0.199	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.66	0.90	0.90	----
		σs	N/mm^2	47.36	65.54	65.54	----
		σs'	N/mm^2	-3.23	-3.44	-3.44	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				----
		req	mm^2	914.2	1271.8	1271.8	----
		inp	mm^2	2780.4	2780.4	2780.4	----

Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	853.753	0.000	853.753	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	1347.5		1347.5	
	Top Slab Inside	Aq2	mm^2	1796.7		1796.7	
	Bottom Slab Inside	Aq3	mm^2	1796.7		1796.7	
	Bottom Slab Outside	Aq4	mm^2	1347.5		1347.5	
Neutral Axis		X	m	0.264	----	0.264	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	2.12	----	2.12	----
		σs	N/mm^2	109.93	----	109.93	----
		σs'	N/mm^2	-12.61	----	-12.61	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	4192.4	----	4192.4	----
		inp	mm^2	5419.4	----	5419.4	----

Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-214.992	-176.076	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		328.2	267.8	
	Top Slab Inside	Aq2	mm^2		437.5	357.1	
	Bottom Slab Inside	Aq3	mm^2		437.5	357.1	
	Bottom Slab Outside	Aq4	mm^2		328.2	267.8	
Neutral Axis		X	m	----	0.266	0.266	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	0.53	0.43	----
		σs	N/mm^2	----	27.74	22.72	----
		σs'	N/mm^2	----	-2.71	-2.22	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	1020.9	833.2	----
		inp	mm^2	----	5419.4	5419.4	----

Calculation Case1: Seismic Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	70.607	-176.076	70.607	9.357
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	102.1	257.7	102.1	13.4
	Top Slab Inside	Aq2	mm^2	136.2	343.6	136.2	17.8
	Bottom Slab Inside	Aq3	mm^2	136.2	343.6	136.2	17.8
	Bottom Slab Outside	Aq4	mm^2	102.1	257.7	102.1	13.4
Neutral Axis		X	m	0.199	0.201	0.199	0.199
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.22	0.54	0.22	0.03
		σs	N/mm^2	16.69	41.65	16.69	2.21
		σs'	N/mm^2	-1.08	-2.09	-1.08	-0.14
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	317.7	801.8	317.7	41.5
		inp	mm^2	2780.4	2780.4	2780.4	2780.4

2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	3.094	-323.115	3.094	-3.916
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	4.4	478.4	4.4	5.6
	Top Slab Inside	Aq2	mm^2	5.9	637.8	5.9	7.4
	Bottom Slab Inside	Aq3	mm^2	5.9	637.8	5.9	7.4
	Bottom Slab Outside	Aq4	mm^2	4.4	478.4	4.4	5.6
Neutral Axis		X	m	0.199	0.201	0.199	0.201
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.01	1.00	0.01	0.01
		σs	N/mm^2	0.73	76.44	0.73	0.93
		σs'	N/mm^2	-0.05	-3.83	-0.05	-0.05
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	13.7	1488.3	13.7	17.3
		inp	mm^2	2780.4	2780.4	2780.4	2780.4

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	165.812	-323.577	-323.115	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	251.9	498.0	497.3	
	Top Slab Inside	Aq2	mm^2	335.9	664.0	663.1	
	Bottom Slab Inside	Aq3	mm^2	335.9	664.0	663.1	
	Bottom Slab Outside	Aq4	mm^2	251.9	498.0	497.3	
Neutral Axis		X	m	0.198	0.199	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.57	1.09	1.09	----
		σs	N/mm^2	40.70	79.52	79.40	----
		σs'	N/mm^2	-2.78	-4.17	-4.16	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				----
		req	mm^2	783.7	1549.4	1547.1	----
		inp	mm^2	2780.4	2780.4	2780.4	----

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	853.753	0.000	853.753	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	1347.5		1347.5	
	Top Slab Inside	Aq2	mm^2	1796.7		1796.7	
	Bottom Slab Inside	Aq3	mm^2	1796.7		1796.7	
	Bottom Slab Outside	Aq4	mm^2	1347.5		1347.5	
Neutral Axis		X	m	0.264	----	0.264	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	2.12	----	2.12	----
		σs	N/mm^2	109.93	----	109.93	----
		σs'	N/mm^2	-12.61	----	-12.61	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	4192.4	----	4192.4	----
		inp	mm^2	5419.4	----	5419.4	----

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-150.993	-66.287	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		229.1	99.5	
	Top Slab Inside	Aq2	mm^2		305.5	132.7	
	Bottom Slab Inside	Aq3	mm^2		305.5	132.7	
	Bottom Slab Outside	Aq4	mm^2		229.1	99.5	
Neutral Axis		X	m	----	0.266	0.266	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	0.37	0.16	----
		σs	N/mm^2	----	19.48	8.55	----
		σs'	N/mm^2	----	-1.91	-0.84	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	712.7	309.6	----
		inp	mm^2	----	5419.4	5419.4	----

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	470.769	-66.287	470.769	14.469
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	702.9	95.8	702.9	20.7
	Top Slab Inside	Aq2	mm^2	937.2	127.7	937.2	27.6
	Bottom Slab Inside	Aq3	mm^2	937.2	127.7	937.2	27.6
	Bottom Slab Outside	Aq4	mm^2	702.9	95.8	702.9	20.7
Neutral Axis		X	m	0.199	0.201	0.199	0.199
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	1.46	0.20	1.46	0.04
		σs	N/mm^2	111.29	15.68	111.29	3.42
		σs'	N/mm^2	-7.23	-0.79	-7.23	-0.22
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	2186.7	298.0	2186.7	64.4
		inp	mm^2	2780.4	2780.4	2780.4	2780.4

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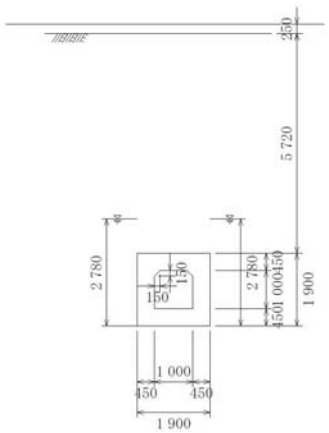
2.2.2.1 SLUICEWAY TYPE A

(2) BOX - TRANSVERSE

1 Calculation of Box Culvert in Transverse Direction

1.1 Design Condition

1.1.1 Dimension



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil(Wet)	γt	kN/m³	19.00
Soil(Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material	SD295			
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
Right Corner	D16	247	804.0	Right Corner	D16	250	794.4

Outside of Sidewall	Diameter	Pitch	Area (mm^2)	Inside of Sidewall	Diameter	Pitch	Area (mm^2)
Left Sidewall	D16	250	794.4	Left Sidewall	D13	250	506.8
Right Sidewall	D16	250	794.4	Right Sidewall	D13	250	506.8

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
Right Corner	D16	250	794.4	Right Corner	D16	250	794.4

■Cover

Location		Cover(mm)	Location		Cover(mm)
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Mid wall		—	—		—

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Top Slab	100	0.0
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Load

■Surcharge

	(kN/m^2)
Surcharge	0.000
Snow Load	0.000

■Dead Load (Water Level)

Case	External Water Level(m)	Internal Water Level(m)
1	2.780	0.000

External Water Level: Height from Bottom Surface of Bottom Slab
Internal Water Level: Height from Top Surface of Bottom Slab

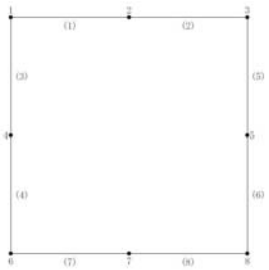
■Live Load

Intensity of Distribution Load Qw(kN/m^2)	10.000

1.2 Cross-section Calculation

1.2.1 Model

1) Frame Dimension



2) Coordinate

No	X(m)	Y(m)
1	0.000	1.450
2	0.725	1.450
3	1.450	1.450
4	0.000	0.725
5	1.450	0.725
6	0.000	0.000
7	0.725	0.000
8	1.450	0.000

3) Member Material and Sectional Characteristics

Member	Number	Point Number		Area (m^2)	Geometric Moment of Inertia (m^4)	Young Modules (kN/m^2)
		i Edge	j Edge			
Left Side of Top Slab	1	1	2	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Top Slab	2	2	3	4.500000E-001	7.593750E-003	2.310000E+007
Upper Side of Left Side Wall	3	1	4	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Left Side Wall	4	4	6	4.500000E-001	7.593750E-003	2.310000E+007
Upper side of Right Wall	5	3	5	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Right Wall	6	5	8	4.500000E-001	7.593750E-003	2.310000E+007
Left Side of Bottom Slap	7	6	7	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of	8	7	8	4.500000E-001	7.593750E-003	2.310000E+007

Bottom Slap						

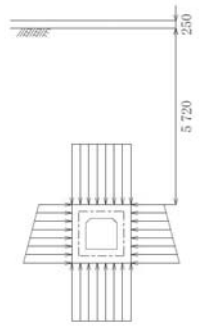
4) Supporting Point

Point	Horizontal (kN/m)	Vertical (kN/m)	Rotate (kN.m/rad)
6	-1	-1	0
8	0	-1	0

Note) -1: Fixed, 0: Free

1.2.2 Load

1) Dead Load (case-1) [RWL]



Weight of Box Culvert

(1) Top Slab
w = 0.450 × 24.00 = 10.80 (kN/m²)

(2) Left Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

(3) Right Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level) = 1.000 × 0.250 × 22.60 = 5.65 (kN/m²)
Embankment (Above Water Level) =1.000 × 4.840 × 18.00 = 87.12 (kN/m²)
Embankment (Below Water Level) =1.000 × 0.880 × 9.20 = 8.10 (kN/m²)
Water Pressure = 0.880 × 9.80 = 8.62 (kN/m²)

Σwd = 109.49 (kN/m²)

(2) Surcharge Load at Road
Surcharge = 0.000 (kN/m²)
Snow Load= 0.00 (kN/m²)

Σqd = 0.000 (kN/m²)

(3) Load Acting on Top Slab
Uniformly Distributed Load
w = 109.49 + 0.00 = 109.49 (kN/m²)

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

pi = Ko×(qd + Yo×γa + Zu×γ + (Zo - Zu)×γ') + (Zo - Zu)×γw

Ko: Coefficient of Earth Pressure at Rest = 0.500

Zo: Depth of Calculation Point from Embankment Top(m)

(1) Left Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	5.720	59.06
p_2	Center of Top Slab	5.945	62.30
p_3	Center of Bottom Slab	7.395	83.18
p_4	Bottom Surface of Bottom Slab	7.620	86.42

(2) Right Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	5.720	59.06
p_2	Center of Top Slab	5.945	62.30
p_3	Center of Bottom Slab	7.395	83.18
p_4	Bottom Surface of Bottom Slab	7.620	86.42

Uplift and Buoyancy

This Act on Bottom Slab Upward

$$U = 2.780 \times 1.900 \times 9.80 = 51.76 \ (kN/m)$$

$$w = \frac{-51.76}{1.900} = -27.24 \ (kN/m^2)$$

Summary of Acting Forces

Item			V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Weight of Body		Top Slab	21.06		0.950		20.01
		Left Side Wall	10.80		0.225		2.43
		Right Side Wall	10.80		1.675		18.09
Surcharge		Distribution Load	208.03		0.950		197.63
Earth Pressure and Water Pressure	Left Side Wall	Distribution		138.20		0.890	123.06
	Right Side Wall	Distribution		-138.20		0.890	-123.06
Uplift/Buoyancy			-51.76		0.950		-49.18
Total			198.93				188.98

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$Me = \Sigma V \times e = 0.00 \ (kN.m/m)$$

$$q1 = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 104.70 \ (kN/m^2)$$

$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 104.70 \ (kN/m^2)$$

$$q1' = q1 + \frac{qr - q1}{B} \times \frac{T}{2} = 104.70 \ (kN/m^2)$$

$$qr' = qr + \frac{q1 - qr}{B} \times \frac{T}{2} = 104.70 \ (kN/m^2)$$

Thus, T : Thickness of Side Wall

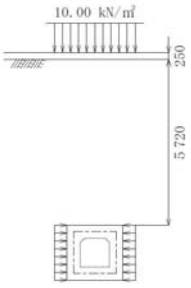
q1 : Subgrade Reaction Intensity on Left Edge

qr : Subgrade Reaction Intensity on Right Edge

q1': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface qL= 10.000 (kN/m²)

Load

(1)Vertical Load Effecting Top Slab
wl = qL= 10.00 (kN/m²)

(2)Horizontal Load Acting on Left Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

(3)Horizontal Load Effecting on Right Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

Summary of Acting Force

		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Top Slab	Distribution	19.00		0.950		18.05
Left Side Wall	Distribution		9.50		0.950	9.03
Right Side Wall	Distribution		-9.50		0.950	-9.03
Total		19.00				18.05

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$ql = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$ql' = ql + \frac{qr - ql}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

$$qr' = qr + \frac{ql - qr}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

Thus、T : Thickness of Side Wall

ql : Subgrade Reaction Intensity on Left Edge

qr : Subgrade Reaction Intensity on Right Edge

ql': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

Dead Load + Live Load

Load Number	Beginning Member Number	End Member Number	Load Intensity at i Edge	Load Intensity at j Edge	Distance from i Edge (m)	Distance from j Edge (m)	Load Width (m)
14	1	2	-10.80	-10.80	0.000	0.000	1.450
14	3	4	-10.80	-10.80	0.225	0.225	1.000
14	5	6	-10.80	-10.80	0.225	0.225	1.000
14	1	2	-109.49	-109.49	0.000	0.000	1.450
13	3	4	62.30	83.18	0.000	0.000	1.450
13	5	6	-62.30	-83.18	0.000	0.000	1.450
14	7	8	27.24	27.24	0.000	0.000	1.450
14	1	2	-10.00	-10.00	0.000	0.000	1.450
13	3	4	5.00	5.00	0.000	0.000	1.450
13	5	6	-5.00	-5.00	0.000	0.000	1.450
14	7	8	114.70	114.70	0.000	0.000	1.450

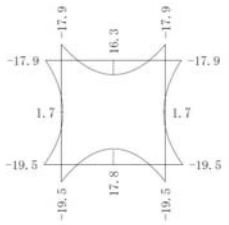
Load Number

13: Member Distribution Load (X Direction)

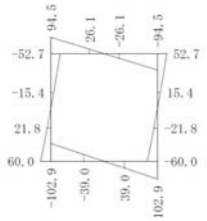
14: Member Distribution Load (Y Direction)

1.2.4 Calculation Results of Frame Analysis

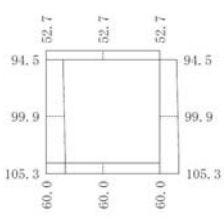
Bending Moment



Shear Force



Axial Force



1.2.5 Stress Intensity Calculation

■Bending Stress Intensity

Top Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-17.941	16.301	-17.941
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	371.7	0.0	371.7
	Internal	mm^2	0.0	337.1	0.0
Re-Bar	External	mm^2	D16 @ 250 D─ @── 794.4	D16 @ 250 D─ @── 794.4	D16 @ 247 D─ @── 804.0
	Internal	mm^2	D16 @ 250 D─ @── 794.4	D16 @ 250 D─ @── 794.4	D16 @ 250 D─ @── 794.4
Neutral Axis	X	m	0.065	0.065	0.065
Stress Intensity	σc	N/mm^2	1.63	1.48	1.62
	σs	N/mm^2	66.75	60.65	65.97
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	495.6	449.5	495.6
	inp	mm^2	794.4	794.4	804.0
Case	──	──	Dead-1+Live-1	Dead-1+Liva-1	Dead-1+Liev-1

※Axial force is not considered.

Left Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-17.941	1.696	-19.528
Axial Force	N	kN	94.460	99.860	105.260
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar Arrangement	External	mm^2	D16 @ 250 D—@— 794.4	D16 @ 250 D—@— 794.4	D16 @ 250 D—@— 794.4
	Internal	mm^2	D13 @ 250 D—@— 506.8	D13 @ 250 D—@— 506.8	D13 @ 250 D—@— 506.8
Neutral Axis	X	m	0.181	1.147	0.187
Stress Intensity	σc	N/mm^2	1.13	0.27	1.21
	σs	N/mm^2	10.05	0.00	10.13
	σs'	N/mm^2	0.00	-1.69	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2		-----	
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	794.4	506.8	794.4
Case	—	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Right Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-17.941	1.696	-19.528
Axial Force	N	kN	94.460	99.860	105.260
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar	External	mm^2	D16 @ 247 D—@— 804.0	D16 @ 250 D—@— 794.4	D16 @ 250 D—@— 794.4
	Internal	mm^2	D13 @ 250 D—@— 506.8	D13 @ 250 D—@— 506.8	D13 @ 250 D—@— 506.8
Neutral Axis	X	m	0.182	1.147	0.187
Stress Intensity	σc	N/mm^2	1.13	0.27	1.21
	σs	N/mm^2	9.99	0.00	10.13
	σs'	N/mm^2	0.00	-1.69	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2		-----	
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	804.0	506.8	794.4
Case	—	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Bottom Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-19.528	17.776	-19.528
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	115.0	115.0	115.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	437.0	0.0	437.0
	Internal	mm^2	0.0	368.3	0.0
Re-Bar	External	mm^2	D16 @ 250 D—@— 794.4	D16 @ 250 D—@— 794.4	D16 @ 250 D—@— 794.4
	Internal	mm^2	D16 @ 250 D—@— 794.4	D16 @ 250 D—@— 794.4	D16 @ 250 D—@— 794.4
Neutral Axis	X	m	0.062	0.065	0.062
Stress Intensity	σc	N/mm^2	1.99	1.62	1.99
	σs	N/mm^2	78.25	66.14	78.25
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	582.7	491.0	582.7
	inp	mm^2	794.4	794.4	794.4
Case	—	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

■Shear Stress Intensity

$$\tau m = \frac{S}{b \times d} \leqq \tau a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm^2)	τa (N/mm^2)	Cases	L (m)
Top Slap	Left τ Point	26.058	360.0	0.072	0.457	Dead-1+Live-1	0.525
	Right τ Point	-26.058	360.0	0.072	0.457	Dead-1+Live-1	0.525
Left Side Wall	Upper τ Point	-15.426	360.0	0.043	0.457	Dead-1+Live-1	0.525
	Lower τ Point	21.756	360.0	0.060	0.495	Dead-1+Live-1	0.450
Right Side Wall	Upper τ Point	15.426	360.0	0.043	0.457	Dead-1+Live-1	0.525
	Lower τ Point	-21.756	360.0	0.060	0.495	Dead-1+Live-1	0.450
Bottom Slab	Left τ Point	-39.034	360.0	0.108	0.478	Dead-1+Live-1	0.450
	Right τ Point	39.034	360.0	0.108	0.478	Dead-1+Live-1	0.450

Note) τ Point: Check point for shear stress intensity
L: Distance from grid point of corner

2.2.2.1 SLUICEWAY TYPE A

(3) BREAST WALL - LAND SIDE

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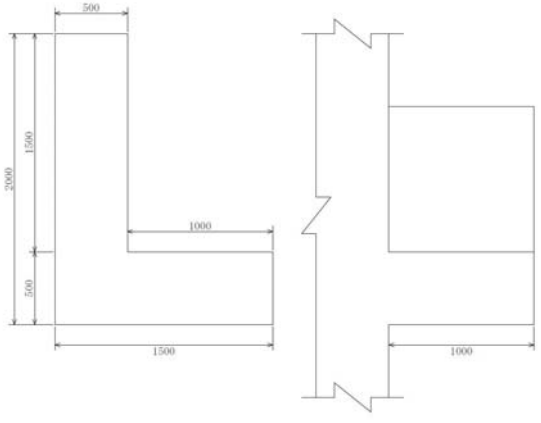
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1 Calculation of Land Side Breast Wall

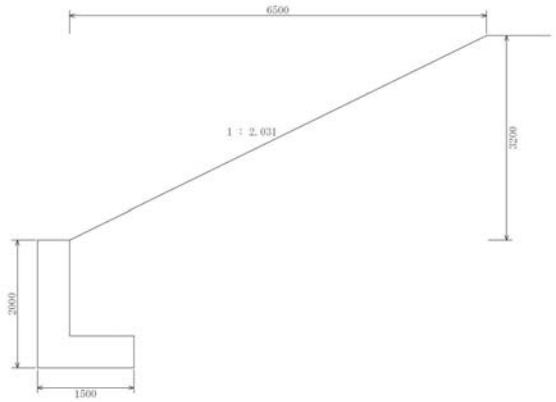
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/℃	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φres	○	30
Peak Angle of Internal Friction	φpeak	○	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm²/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D16	250	794.4
	Bottom Face	115.0	D16	250	794.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

1.1.4 Loads

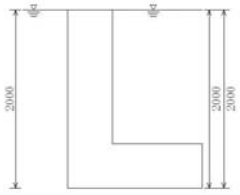
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

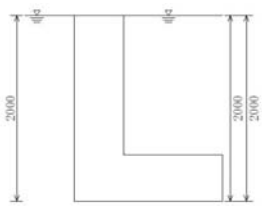
	(m)
Toe	2.000
Heel	2.000



1-2) Seismic Condition Number of Cases [1]

<Case 1>

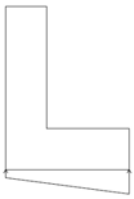
	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front



2) Subgrade Reaction

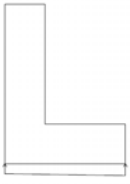
2-1) Normal <Case 1>

	(kN/m²), (m)
Toe	36.87
Heel	109.70
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m²), (m)
Toe	45.79
Heel	54.06
Load Width	0.000



3) Surcharge Load

Normal	kN/m²	10.00
Seismic	kN/m²	5.00

4) Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W =20.727 (kN/m)

※ξ_{EA}(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (20.727+ 10.00× 0.000)/ 1.500

= 13.818 (kN/m^2)

Earth Pressure at the Top

p1 = q0'・Ko = 13.818× 0.500 = 6.909 (kN/m^2)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.000+ 6.909

= 6.909 (kN/m^2)

Earth Pressure at Junction

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500× (20.00 - 9.80)× 1.500+ 6.909

= 14.559 (kN/m^2)

Design Earth Pressure

P = p3

= 14.559 (kN/m^2)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

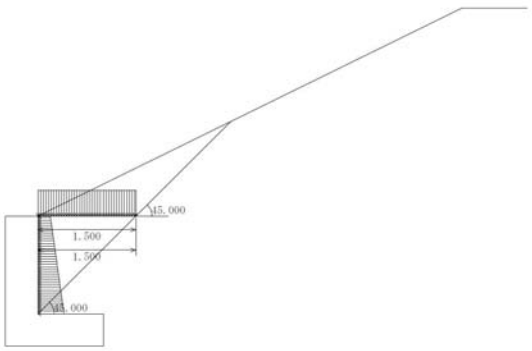
q_0 : Surcharge (kN/m^2)

w_{q0} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 1.500× 9.80 = 14.700 (kN/m^2)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

(2) Seismic Condition-1

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.500× 24.00× 0.20 = 2.400

Thus、

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	0.000	(m)
Embankment Height under the water level surface	H2	=	1.500	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γt	=	19.00	(kN/m^3)
Unit Weight of Soil (Saturated)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	0.000	(m)
Width of Converted Load	B	=	1.646	(m)
Internal Friction Angle of Soil	φ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh	=	0.303	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}$ (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}$ (kh')	=	16.855	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$\cot(\xi_{EA}-\alpha) = 0.85094$

Thus,

$$\cot(\xi_{EA} - 0.00^\circ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{ss}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 16.855^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 16.855^\circ)}}$$

$\cot(\xi_{ss}'-\alpha) = 1.09764$

Thus,

$$\cot(\xi_{ss}' - 0.00^\circ) = \frac{1}{\tan(\xi_{ss}')} = 1.09764$$

$$\xi_{ss}' = \tan^{-1}\left(\frac{1}{1.09764}\right) = 42.335^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$= 0.4733$

In case $\varphi-\alpha-\theta_o < 0$, $\sin(\varphi-\alpha-\theta_o) = 0$.

$$K_{ss}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 16.855^\circ - 0.00^\circ)}{\cos(16.855^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 16.855^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 16.855^\circ)}{\cos(0.00^\circ + 16.855^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$= 0.5726$

In case $\varphi-\alpha-\theta_o' < 0$, $\sin(\varphi-\alpha-\theta_o') = 0$.

Weight of Embankment W W = 21.819 (kN/m)

Converted Load q0' q0' = (W + q0・wq0) / B

= (21.819+ 5.00× 0.000) / 1.646

= 13.252 (kN/m^2)

Earth Pressure at the Top

P1 = q0'・K_{EA} = 13.252× 0.4733 = 6.272 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 0.000+ 6.272

= 6.272 (kN/m^2)

Earth Pressure at Junction

P3 = K_{EA}・ (γ_{sat} - γ_w)・h2 + p2

= 0.5726×(20.00- 9.80)× 1.500+ 6.272

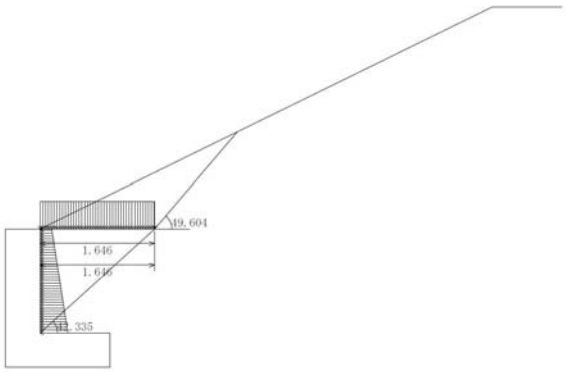
= 15.032 (kN/m^2)

Design Earth Pressure

$P_{HE} = P3 \cdot \cos\delta = 15.032 \times \cos(0.00°)$

$= 15.032$ (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$Ph = hh \cdot \gamma_w = 1.500 \times 9.80 = 14.700$ (kN/m^2)

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Water Pressure	14.70	1.000	7.35
Earth Pressure	14.56	1.000	7.28
Σ	29.26	----	14.63
Bending Moment M (kN.m/m) Σ(P・l^2/2) =14.63			
Shear Force S (kN/m) Σ(P・l) = 29.26			

2) Seismic Condition-1

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Inertia force	2.40	1.000	1.20
Water Pressure	14.70	1.000	7.35
Earth Pressure	15.03	1.000	7.52
Σ	32.13	----	16.07
Bending Moment M (kN.m/m) Σ(P・l^2/2) = 16.07			
Shear Force S (kN/m) Σ(P・l) = 32.13			

1.2.3 Stress Calculation

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Front	mm^2	D16 - 4.00 = 794.4
	Back	mm^2	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	14.63
Re-bar	d1 As1	mm mm^2	410.0 794.4
Required Area of Re-bar	Back	mm^2	263.8
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm^2	1.08
	σs	N/mm^2	47.62
Allowable Value	σca	N/mm^2	8.20
	σsa	N/mm^2	140.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	351.8
	inp	mm^2	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	16.07
Re-bar	d1 As1	mm mm^2	410.0 794.4
Required Area of Re-bar	Back	mm^2	217.4
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm^2	1.19
	σs	N/mm^2	52.29
Allowable Value	σca	N/mm^2	12.30
	σsa	N/mm^2	186.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	289.9
	inp	mm^2	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	29.26
Re-bar	d1 As1	mm mm^2	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.071
Allowable Value	τa	N/mm^2	0.360
	τa2	N/mm^2	1.600

■Seismic Condition-1

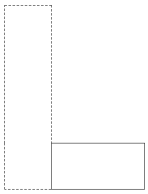
	Symbol	Unit	Junction
Shear Force	S	kN	32.13
Re-bar	d1 As1	mm mm^2	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.078
Allowable Value	τa	N/mm^2	0.540
	τa2	N/mm^2	2.400

1.3 Calculation of Heel Slab

1.3.1 Load

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

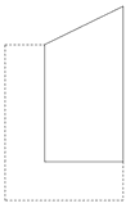
Thus,

Sw : Weight of Body (kN/m^2)

h : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

1-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.492× 19.00 + 1.500× 20.00 = 39.354

Thus,

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

1-3) Subgrade Reaction Force

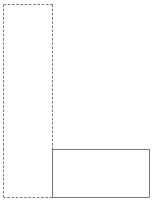
	Intensity of subgrade reaction (kN/m^2)
Base	61.15
Edge	109.70

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

(2) **) Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

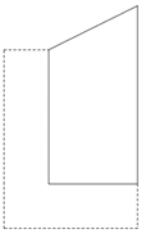
Thus、

Sw : Weight of Wall (kN/m^2)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.492× 19.00 + 1.500× 20.00 = 39.354

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	48.55
Edge	54.06

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

1.3.2 Summary of Cross-Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	61.15	1.000	30.57
Σ	38.75	----	19.37
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 19.37		
Shear Force S (kN/m)	Σ(P・l) = 38.75		

1-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-39.35	1.000	-19.68
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	109.70	1.000	54.85
Σ	77.95	----	38.97
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 38.97		
Shear Force S (kN/m)	Σ(P・l) = 77.95		

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	48.55	1.000	24.27
Σ	26.15	----	13.07
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 13.07		
Shear Force S (kN/m)	Σ(P・l) = 26.15		

2-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-39.35	1.000	-19.68
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	54.06	1.000	27.03
Σ	22.31	----	11.15
Bending Moment M (kN.m/m) Σ(P・l²/2) = 11.15			
Shear Force S (kN/m) Σ(P・l) = 22.31			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Upper	mm²	D16 - 4.00 = 794.4
	Lower	mm²	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	19.37	38.97
Re-bar	d1 As1	mm mm²	385.0 794.4	385.0 794.4
Required Area of Re-bar	Lower	mm²	374.9	767.1
Neutral Axis	X	m	0.067	0.067
Stress Intensity	σc	N/mm²	1.59	3.19
	σs	N/mm²	67.27	135.33
Allowable Value	σca	N/mm²	8.20	8.20
	σsa	N/mm²	140.00	140.00
Minimum of Re-bar Area	min	mm²		770.0
	req	mm²	499.9	1022.8
	inp	mm²	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	13.07	11.15
Re-bar	d1 As1	mm mm²	385.0 794.4	385.0 794.4
Required Area of Re-bar	Upper	mm²	188.2	160.2
	Lower	mm²	0.067	0.067
Neutral Axis	X	m	1.07	0.91
Stress Intensity	σc	N/mm²	45.39	38.73
	σs	N/mm²	12.30	12.30
Allowable Value	σca	N/mm²	186.00	186.00
	σsa	N/mm²	186.00	186.00
Minimum of Re-bar Area	min	mm²		
	req	mm²	250.9	213.6
	inp	mm²	794.4	794.4

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	38.75	77.95
Re-bar	d1 As1	mm mm²	385.0 794.4	385.0 794.4
Effective Height	d	mm	385.0	385.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.101	0.202
Allowable Value	τa	N/mm²	0.360	0.360
	τa2	N/mm²	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	26.15	22.31
Re-bar	d1 As1	mm mm²	385.0 794.4	385.0 794.4
Effective Height	d	mm	385.0	385.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.068	0.058
Allowable Value	τa	N/mm²	0.540	0.540
	τa2	N/mm²	2.400	2.400

2.2.2.1 SLUICEWAY TYPE A

(4) BREAST WALL - RIVER SIDE

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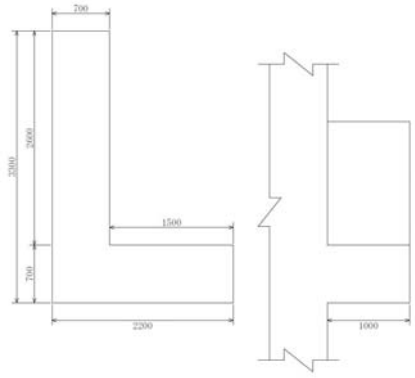
1.3.3 Stress Intensity Calculation....19

1 Calculation of River Side Breast Wall

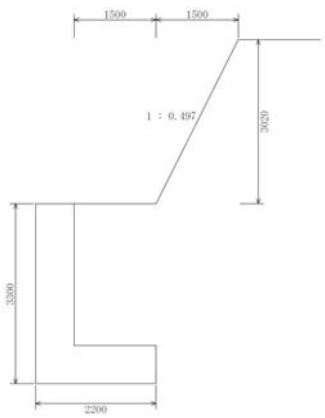
1.1 Design Condition

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil(Wet)	γt	kN/m³	19.00
Soil(Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φres	○	30
Peak Angle of Internal Friction	φpeak	○	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 **Reinforcement Arrangement**

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm^2/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D16	250	794.4
	Bottom Face	115.0	D16	250	794.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 **Loads**

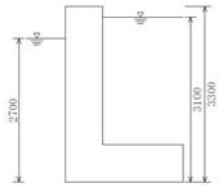
■Basic Load

1)Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

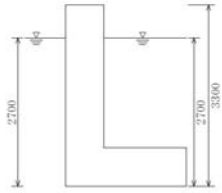
	(m)
Toe	2.700
Heel	3.100



1-2) Seismic Condition Number of Cases [1]

<Case 1>

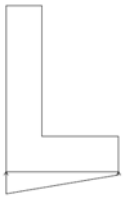
	(m)
Toe	2.700
Heel	2.700
Direction	Back → Front



2)Subgrade Reaction

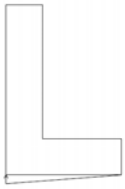
2-1) Normal <Case 1>

	(kN/m^2), (m)
Toe	108.99
Heel	15.12
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m^2), (m)
Toe	42.06
Heel	0.00
Load Width	2.200



3)Surcharge Load

Normal	kN/m^2	10.00
Seismic	kN/m^2	5.00

4)Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 **Load**

(1) **Normal Condition-1**

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W = 106.727 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (106.727+ 10.00× 2.620)/ 2.600

= 51.126 (kN/m^2)

Earth Pressure at the Top

p1 = q0'・Ko = 51.126× 0.500 = 25.563 (kN/m^2)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.200+ 25.563

= 27.463 (kN/m^2)

Earth Pressure at Bottom Surface of Base

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500× (20.00- 9.80)× 2.400+ 27.463

= 39.703 (kN/m^2)

Design Earth Pressure

P = p3

= 39.703 (kN/m^2)

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

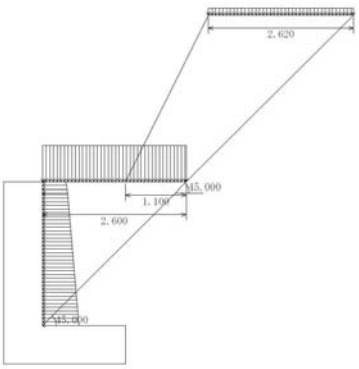
q_0 : Surcharge (kN/m^2)

w_{q0} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Loads Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 2.400× 9.80 = 23.520 (kN/m^2)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

(2) **Seismic Condition-1**

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.700× 24.00× 0.20 = 3.360

Thus、

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	0.600	(m)
Embankment Height under the water level surface	H2	=	2.000	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_t	=	19.00	(kN/m^3)
Unit Weight of Soil (Dry)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	2.298	(m)
Width of Converted Load	B	=	2.728	(m)
Internal Friction Angle of Soil	ϕ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh'	=	0.307	(degree)
Compound Angle in Seismic Condition	θ_0= tan^{-1} (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	θ_0= tan^{-1} (kh')	=	17.041	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$$\cot(\xi_{EA}-\alpha) = 0.85094$$

Thus,

$$\cot(\xi_{EA}-0.00^\circ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604(^\circ)$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 17.041^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 17.041^\circ)}}$$

$$\cot(\xi_{EA}'-\alpha) = 1.10859$$

Thus,

$$\cot(\xi_{EA}'-0.00^\circ) = \frac{1}{\tan(\xi_{EA}')} = 1.10859$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{1.10859}\right) = 42.052(^\circ)$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$$= 0.4733$$

In case φ-α-θ_o< 0, sin(φ-α-θ_o) = 0.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 17.041^\circ - 0.00^\circ)}{\cos(17.041^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 17.041^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 17.041^\circ)}{\cos(0.00^\circ + 17.041^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$$= 0.5765$$

In case φ-α-θ'$_o$< 0, sin(φ-α-θ'$_o$) = 0.

Weight of Embankment W W = 101.142 (kN/m)

Converted Load q0' q0' = (W + q0・wq0) / B

= (101.142+ 5.00× 2.298) / 2.728

= 41.290 (kN/m^2)

Earth Pressure at the Top

P1 = q0'・K_{EA} = 41.290× 0.4733 = 19.541 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 0.600+ 19.541

= 24.936 (kN/m^2)

Earth Pressure at Junction

P3 = K_{EA}・(γ_{sat} - γ_w) ・h2 + p2

= 0.5765×(20.00- 9.80)× 2.000+ 24.936

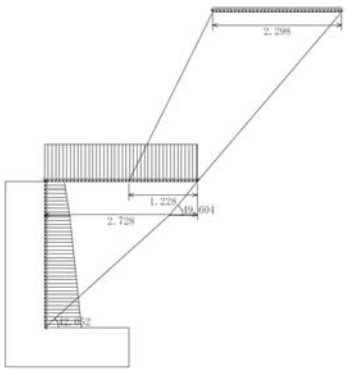
= 36.697 (kN/m^2)

Design Earth Pressure

P_{HE} = P3 ・cosδ= 36.697×cos(0.00°)

= 36.697 (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

Ph = hh・γ_w= 2.000× 9.80 = 19.600 (kN/m^2)

Thus、

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

1.2.2 **Summary of Cross-sectional Internal Forces**

1) Normal Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Water Pressure	23.52	1.000	11.76
Earth Pressure	39.70	1.000	19.85
Σ	63.22	----	31.61
Bending Moment	M (kN.m/m)	Σ(P･l²/2) = 31.61	
Shear Force	S (kN/m)	Σ(P･l) = 63.22	

2) Seismic Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Inertia force	-3.36	1.000	-1.68
Water Pressure	19.60	1.000	9.80
Earth Pressure	36.70	1.000	18.35
Σ	52.94	----	26.47
Bending Moment	M (kN.m/m)	Σ(P･l²/2) = 26.47	
Shear Force	S (kN/m)	Σ(P･l) = 52.94	

1.2.3 **Stress Calculation**

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Front	mm²	D16 - 4.00 = 794.4
	Back	mm²	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	31.61
Re-bar	d1 As1	mm mm²	610.0 794.4
Required Area of Re-bar	Back	mm²	383.0
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm²	1.26
	σs	N/mm²	68.47
Allowable Value	σca	N/mm²	8.20
	σsa	N/mm²	140.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	510.7
	inp	mm²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	26.47
Re-bar	d1 As1	mm mm²	610.0 794.4
Required Area of Re-bar	Back	mm²	239.7
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm²	1.05
	σs	N/mm²	57.33
Allowable Value	σca	N/mm²	12.30
	σsa	N/mm²	186.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	319.6
	inp	mm²	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	63.22
Re-bar	d1 As1	mm mm²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.104
Allowable Value	τa	N/mm²	0.360
	τa2	N/mm²	1.600

■Seismic Condition-1

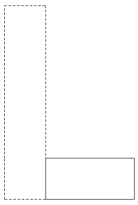
	Symbol	Unit	Junction
Shear Force	S	kN	52.94
Re-bar	d1 As1	mm mm²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.087
Allowable Value	τa	N/mm²	0.540
	τa2	N/mm²	2.400

1.3 **Calculation of Bottom Slab**

1.3.1 **Load**

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

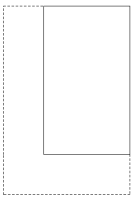
Thus,

Sw : Weight of Body (kN/m2)

h :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

1-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.200× 19.00 + 2.400× 20.00 = 51.800

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.200× 19.00 + 2.400× 20.00 = 51.800

Thus、

Pw1 : Wight of Embankment at basis (kN/m²)

Pw2 : Weight of Embankment at edge (kN/m²)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

1-3) Subgrade Reaction Force

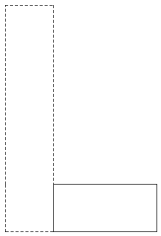
	Intensity of subgrade reaction (kN/m²)
Base	79.12
Edge	15.12

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m²)
Base	2.827× 9.80	27.707
Edge	3.100× 9.80	30.380

(2)) Seismic Condition-1

2-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

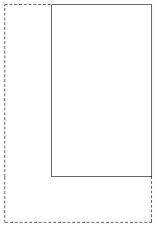
Thus、

Sw : Weight of Body (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.600× 19.00 + 2.000× 20.00 = 51.400

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.600× 19.00 + 2.000× 20.00 = 51.400

Thus、

Pw1 : Wight of Embankment at basis (kN/m²)

Pw2 : Weight of Embankment at edge (kN/m²)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	28.68
Edge	0.00

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m²)
Base	2.700× 9.80	26.460
Edge	2.700× 9.80	26.460

1.3.2 Summary of Cross Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.80	1.000	-25.90
Uplift Force	27.71	1.000	13.85
Intensity of Subgrade Reaction	79.12	1.000	39.56
Σ	38.23	----	19.11
Bending Moment M (kN.m/m) Σ(P・l²/2) = 19.11			
Shear Force S (kN/m) Σ(P・l) = 38.23			

1-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.80	1.000	-25.90
Uplift Force	30.38	1.000	15.19
Intensity of Subgrade Reaction	15.12	1.000	7.56
Σ	-23.10	----	-11.55
Bending Moment M (kN.m/m) Σ(P・l²/2) = 11.55			
Shear Force S (kN/m) Σ(P・l) = 23.10			

2) Seismic Condition-1

2-1) Base

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.40	1.000	-25.70
Uplift Force	26.46	1.000	13.23
Intensity of Subgrade Reaction	28.68	1.000	14.34
Σ	-13.06	----	-6.53
Bending Moment M (kN.m/m) Σ(P・l²/2) = 6.53			
Shear Force S (kN/m) Σ(P・l) = -13.06			

2-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.40	1.000	-25.70
Uplift Force	26.46	1.000	13.23
Intensity of Subgrade Reaction	0.00	1.000	0.00
Σ	-41.74	----	-20.87
Bending Moment M (kN.m/m) Σ(P・l²/2) = -20.87			
Shear Force S (kN/m) Σ(P・l) = -41.74			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Upper	mm^2	D16 - 4.00 = 794.4
	Lower	mm^2	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	19.11	-11.55
Re-bar	d1 As1	mm mm^2	585.0 794.4	585.0 794.4
Required Area of Re-bar		mm^2		138.1
Neutral Axis	X	m	240.0	
Stress Intensity	σc	N/mm^2	0.085	0.087
	σs	N/mm^2	0.81	0.46
Allowable Value	σca	N/mm^2	43.21	25.02
	σsa	N/mm^2	8.20	8.20
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	320.0	184.1
	inp	mm^2	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	-6.53	-20.87
Re-bar	d1 As1	mm mm^2	90.0 794.4	90.0 794.4
Required Area of Re-bar	Upper	mm^2	58.4	188.5
Neutral Axis	X	m	0.087	0.087
Stress Intensity	σc	N/mm^2	0.26	0.83
	σs	N/mm^2	14.15	45.21
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	77.8	251.3
	inp	mm^2	794.4	794.4

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	38.23	-23.10
Re-bar	d1 As1	mm mm^2	585.0 794.4	585.0 794.4
Effective Height	d	mm	585.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.065	0.038
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	-13.06	-41.74
Re-bar	d1 As1	mm mm^2	90.0 794.4	90.0 794.4
Effective Height	d	mm	610.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.021	0.068
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400

2.2.2.2 SLUICEWAY TYPE B

(1) BOX - LONGITUDINAL

Structural Calculation of Sluiceway Type-B

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1 Design Condition

1.1 Design Condition

1.1.1 Basic Condition

1) Culvert Shape:Rectanglar

2) Culvert Type: Double Holes

3) Allowable Displacement

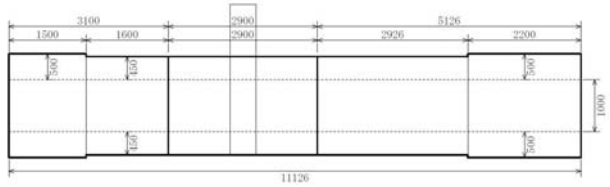
Residual Settlement		: 300.0 (mm)
Residual Settlement for Rigid Support		: 50.0 (mm)
Relative Displacement	Base Width	: 1.0 (%)
		± : 50.0 (mm)

4) Type of Joint : Flexible Joint

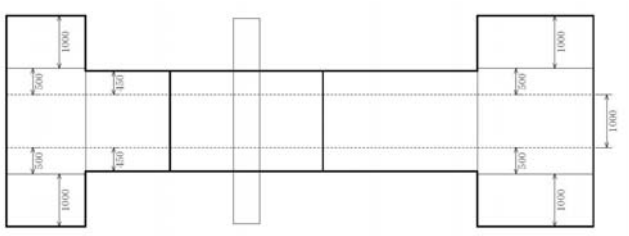
5) Allowable Opening : 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

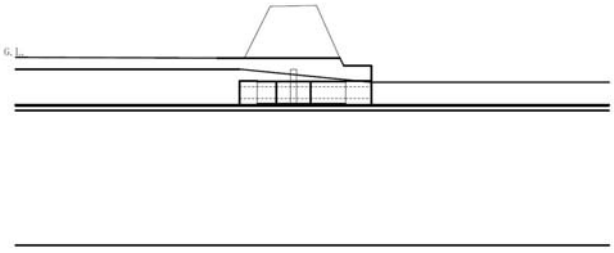
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Leeve Cross-section



1.2 Shape of Culvert Body

1.2.1 Span and Block

1) Spans

Number of Spans: 3
Total Length of Spans: 11.126 (m)

Span No	Name of Span	Length of Span (m)	Number of Blocks
1	Land Side	3.100	2
2	Center	2.900	1
3	River Side	5.126	2

2) Blocks

Span/ Block	Length of Block (m)	Depth for Subgrade Reaction(m)
1- 1	1.500	12.000
1- 2	1.600	5.700
2- 1	2.900	5.700
3- 1	2.926	5.700
3- 2	2.200	11.700

1.2.2 Sectional Dimension

1) Dimension (Block)

Span/ Block	Left Inside Width X2 (m)	Inside Height Y2 (m)
1- 1	1.000	1.000
1- 2	1.000	1.000
2- 1	1.000	1.000
3- 1	1.000	1.000
3- 2	1.000	1.000

Span/ Block	Thickness of Left Side Wall X1(m)	Thickness of Top Slab Y1(m)	Thickness of Bottom Slab Y3(m)	Height of Overhang Y4(m)	Length of Left Overhang B1(m)
1- 1	0.500	0.500	0.500	0.500	1.000
1- 2	0.450	0.450	0.450	0.000	0.000
2- 1	0.450	0.450	0.450	0.000	0.000
3- 1	0.450	0.450	0.450	0.000	0.000
3- 2	0.500	0.500	0.500	0.700	1.000

1.3 Reinforcement

Main Re-bar

Span No	Block No	Flange			Reinforcing Bar			
					Outside		Inside	
		Portion	b (mm)	t (mm)	Diameter@Pitch (Number)	Cover (mm)	Diameter@Pitch (Number)	Cover (mm)
1	1	Top Slab	2000.0	500.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	2000.0	500.0	D16@250(6)	115.0	D16@250(8)	90.0
	2	Top Slab	1900.0	450.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	1900.0	450.0	D16@250(6)	115.0	D16@250(8)	90.0
2	1	Top Slab	1900.0	450.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	1900.0	450.0	D16@250(6)	115.0	D16@250(8)	115.0
3	1	Top Slab	1900.0	450.0	D19@250(6)	90.0	D19@250(8)	90.0
		Bottom Slab	1900.0	450.0	D19@250(6)	115.0	D19@250(8)	90.0
	2	Top Slab	2000.0	500.0	D19@250(6)	90.0	D19@250(8)	90.0
		Bottom Slab	2000.0	500.0	D19@250(6)	115.0	D19@250(8)	90.0

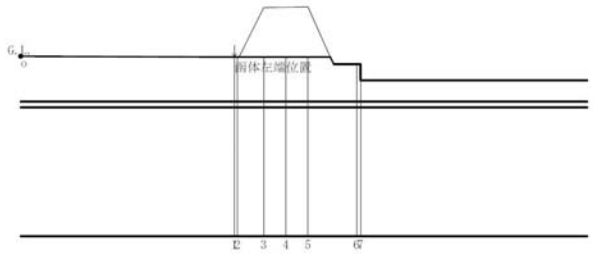
2 Settlement and Lateral Displacement

2.1 Immediate Settlement

2.1.1 Settlemet Calculation Points

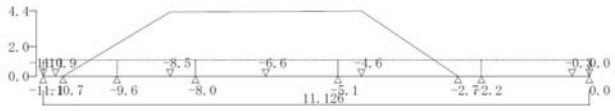
Settlemet Calculation Points

No	Calculation Point (m)	Name
1	-11.126	Box end (land side)
2	-10.876	Breast wall (land side)
3	-8.543	Levee end (land side)
4	-6.593	Levee center
5	-4.643	Levee end (river side)
6	-0.350	Breast wall (river side)
7	0.000	Box end (river side)



2.1.2 Summery of Immediate Settlement

No	Calculation Point (m)	Name	Immediate Settlement (mm)
1	-11.126	Box end (land side)	5.9
2	-10.876	Breast wall (land side)	6.5
3	-8.543	Levee end (land side)	14.3
4	-6.593	Levee center	16.0
5	-4.643	Levee end (river side)	14.1
6	-0.350	Breast wall (river side)	3.0
7	0.000	Box end (river side)	2.6





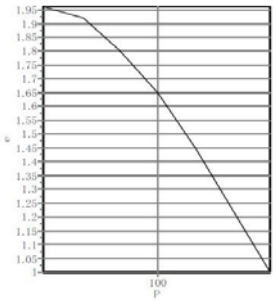
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2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/ m³)	Unit Weight (Saturated) (kN/ m³)	Pre-Consolidation Stress q0 (kN/m²)	Elastic Modulus Es (kN/m²)
1	Adobe BL	Sand	4.000	17.500	18.500	0.0	7000.0
2	As	Sand	4.510	17.500	18.500	0.0	7000.0
3	Dc1	Clay	15.920	17.500	18.500	0.0	17500.0

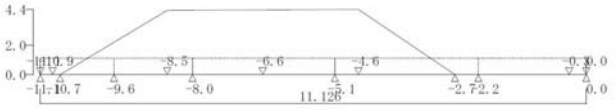
No	Concolidation Pressure P(kN/m²)	Void Ratio e
1	12.0000	1.9600
2	25.0000	1.9200
3	50.0000	1.8000
4	100.0000	1.6500
5	200.0000	1.4500
6	800.0000	1.0000



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2.2.2 Summery of Consolidation Settlement

No	Calculation Point (m)	Name	Consolidation Settlement (mm)
1	-11.126	Box end (land side)	229.7
2	-10.876	Breast wall (land side)	236.8
3	-8.543	Levee end (land side)	290.1
4	-6.593	Levee center	304.0
5	-4.643	Levee end (river side)	283.9
6	-0.350	Breast wall (river side)	175.6
7	0.000	Box end (river side)	166.2





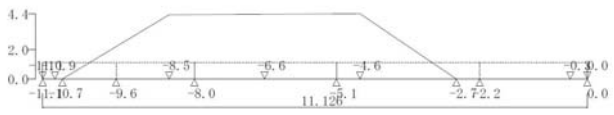
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2.3 Residual Settlement

2.3.1 Sumarry of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vaue	Judge
1	-11.126	Box end (land side)	5.9	229.7	0.0	235.7	300.000	OK
2	-10.876	Breast wall (land side)	6.5	236.8	4.0	239.3	300.000	OK
3	-8.543	Levee end (land side)	14.3	290.1	41.7	262.8	300.000	OK
4	-6.593	Levee center	16.0	304.0	50.0	270.0	300.000	OK
5	-4.643	Levee end (river side)	14.1	283.9	45.3	252.8	300.000	OK
6	-0.350	Breast wall (river side)	3.0	175.6	3.4	175.2	300.000	OK
7	0.000	Box end (river side)	2.6	166.2	0.0	168.7	300.000	OK

The maximum of residual settlement is above 50.0(mm), herence the foundation is taken as flexible





▽ : Immediate Settlement
○ : Residual Settlement

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3 Calculation of Box Culvert regarding Longitudal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B}\cdot\frac{d^4w}{dx^4}+k_v(w-w_g)=q \text{ (Swag)}$$

$$\frac{EA}{U}\cdot\frac{d^2u}{dx^2}+k_s(u-u_g)=p \text{ (Displacement in axial direction of Box Culvert)}$$

Thus,

w : Displacement of Box Culvert (Swag : cm {m})
w_g : Displacement of the Ground (Residual Settlement: cm {m})
k_v : Modulus of Sub grade Reaction in Vertical Direction (kgf/cm^3) {kN/m^3}
B : Width of Box Culvert (cm) {m}
EI : Rigidity of Box Culvert (kgf･cm^2) {kN･m^2}
q : Vertical External Force (kgf/cm^2) {kN/m^2}
u : Displacement on axial direction of Box Culvert (cm) {m}
u_g : Displacement of Ground (Lateral Displacement ; cm {m})
k_s : Modulus of Lateral Shear Sub grade Reaction (kgf/cm^3) {kN/m^3}
U : Circumference of Box Culvert (cm) {m}
EA : Rigidity of Box Culvert in axial direction (kgf) {kN}
p : Axial External Force (kgf/cm^2) {kN/m^2}

3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{om}=\frac{\log\frac{(B+2h_n\cdot\tan\theta)\cdot L}{(L+2h_n\cdot\tan\theta)\cdot B}}{\sum\frac{1}{E_i}\log\frac{(B+2h_i\cdot\tan\theta)(L+2h_{i-1}\cdot\tan\theta)}{(L+2h_i\cdot\tan\theta)(B+2h_{i-1}\cdot\tan\theta)}}$$

In case of B=L

$$E_{om}=\frac{-\frac{1}{B+2h_n\cdot\tan\theta}+\frac{1}{B}}{\sum\frac{1}{E_i}\left(-\frac{1}{B+2h_i\cdot\tan\theta}+\frac{1}{B+2h_{i-1}\cdot\tan\theta}\right)}$$

Thus,

Eom ; Converted Modulus of Deformation
B ; Loading Width = Width of Culvert
L ; Loading Length = Length of a span
h_n ; Depth for Calculation
h_n ; Depth from the ground to the bottom Elevation of Each Layer（m）
E_i ; Converted Modulus of Deformation of Each Layer(kN/m^2)
θ ; Angle of Load Dispersion（θ=30°）

Span1-Block1 Land Side

B			4.000 (m)
L			3.100 (m)
h_n			12.000 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	0.410	0.410	28000.0
2	11.590	12.000	70000.0
Total	12.000		
Eom	57216.6 (kN/m^2)		

※Layer Thickness and Depths are the values based on subgrade Surface.

Span1-Block2 Land Side

B			1.900 (m)
L			3.100 (m)
h_n			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	0.410	0.410	28000.0
2	5.290	5.700	70000.0
Total	5.700		
Eom	52339.3 (kN/m^2)		

※Layer Thickness and Depths are values Calculated from the subgrade

Span2-Block1 Center

B			1.900 (m)
L			2.900 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	0.410	0.410	28000.0
2	5.290	5.700	70000.0
Total	5.700		
Eom	52111.9 (kN/m^2)		

※Layer and Depth is the values from the subgrade

Span3-Block1 River Side

B			1.900 (m)
L			5.126 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	0.410	0.410	28000.0
2	5.290	5.700	70000.0
Total	5.700		
Eom	53835.5 (kN/m^2)		

※Layer and Depth is the values from the subgrade

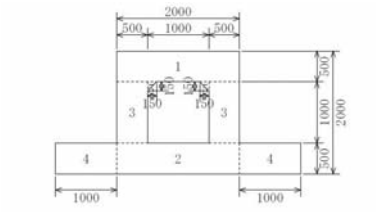
Span3-Block2 River Side

B			4.000 (m)
L			5.126 (m)
hn			11.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	0.410	0.410	28000.0
2	11.290	11.700	70000.0
Total	11.700		
Eom	58824.0 (kN/m^2)		

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

Span1-Block1　Land Side

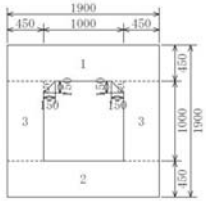


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi^2 (m^3)	Ioi (m^4)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.022	1.450	0.0326	0.0473	0.00003
Total	4.022		3.2826	4.2348	0.14586

Yg = Σ(Ai・Yi)/ΣAi = 3.2826 / 4.022 = 0.8161 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 4.2348 + 0.14586 - 0.6660・4.022= 1.70183 (m^4)

Span1-Block2　Land Side

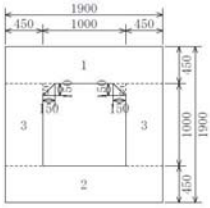


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi^2 (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.632 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.632= 1.00722 (m^4)

Span2-Block1　Center

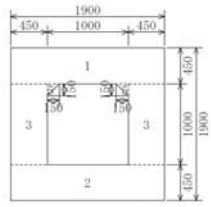


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi^2 (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.632 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.632= 1.00722 (m^4)

Span3-Block1　River Side

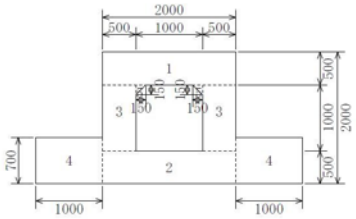


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi^2 (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.632 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.632 = 1.00722 (m^4)

Span3-Block2　River Side



Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi^2 (m^3)	Ioi (m^4)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.400	0.350	0.4900	0.1715	0.05717
5	0.022	1.450	0.0326	0.0473	0.00003
Total	4.423		3.5226	4.3438	0.18219

Yg = Σ(Ai・Yi)/ΣAi = 3.5226 / 4.423 = 0.7965 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 4.3438 + 0.18219 - 0.6344・4.423 = 1.72015 (m^4)

3.2.3 Table of Modulus of Subgarade Reaction

Coefficient of Lateral Shear Reaction of Soil

$k_s = \lambda \cdot k_v$

Thus、

ks　: Coefficient of Lateral Shear Reaction of Soil (kN/m2)

λ　; Ratio between the coefficient of Lateral Shear Reaction of Soil and Vertical Sub grade Reaction (=0.333)

kv　: Coefficient of Vertical Sub grade Reaction

3.2.4 List of Modulus of Subgrade Reaction

Calculated Value

Normal Condition

Span Block	Position (m)	B (m)	k_v (kN/m^3)	k_s (kN/m^3)	k_s・B (kN/m^2)	k_s・B (kN/m^2)
1-1	-11.126～ -9.626	4.000	30075.2	10015.0	120300.8	40060.2
1-2	-9.626～ -8.026	1.900	36370.9	12111.5	69104.7	23011.9
2-1	-8.026～ -5.126	1.900	37130.0	12364.3	70547.0	23492.1
3-1	-5.126～ -2.200	1.900	30980.5	10316.5	58863.0	19601.4
3-2	-2.200～ 0.000	4.000	25605.6	8526.7	102422.4	34106.7

Seismic Condition

Span Block	Position (m)	B (m)	k_v (kN/m^3)	k_s (kN/m^3)	k_s・B (kN/m^2)	k_s・B (kN/m^2)
1-1	-11.126～ -9.626	4.000	60150.4	20030.1	240601.5	80120.3
1-2	-9.626～ -8.026	1.900	72741.8	24223.0	138209.4	46023.7
2-1	-8.026～ -5.126	1.900	74260.0	24728.6	141093.9	46984.3
3-1	-5.126～ -2.200	1.900	61961.1	20633.0	117726.1	39202.8
3-2	-2.200～ 0.000	4.000	51211.2	17053.3	204844.8	68213.3

Used Value

Normal Condition

Span Block	Position (m)	k_v・B (kN/m^2)	k_s・B (kN/m^2)
1-1	-11.126～ -9.626	120300.8	40060.2
1-2	-9.626～ -8.026	69104.7	23011.9
2-1	-8.026～ -5.126	70547.0	23492.1
3-1	-5.126～ -2.200	58863.0	19601.4
3-2	-2.200～ 0.000	102422.4	34106.7

Seismic Condition

Span Block	Position (m)	Reduction Ratio DE	k_v・B (kN/m^2)	k_s・B (kN/m^2)
1-1	-11.126～ -9.626	1.000	240601.5	80120.3
1-2	-9.626～ -8.026	1.000	138209.4	46023.7
2-1	-8.026～ -5.126	1.000	141093.9	46984.3
3-1	-5.126～ -2.200	1.000	117726.1	39202.8
3-2	-2.200～ 0.000	1.000	204844.8	68213.3

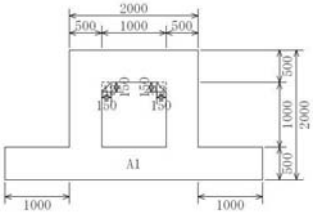
3.3 Load

3.3.1 Dead Load (Body Weight)

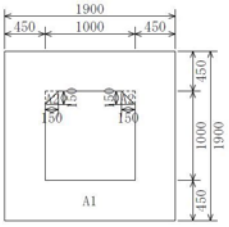
1) Weight of Main Body

W = (A1 + A2 + A3) ･γc (kN/m)
A1: Cross Sectional Area (Excluding Hunch) (m^2)
A2: Area of Upper Side Hunch (m^2)
A3: Area of Lower Side Hunch (m^2)
γc: Unit Weight (Concrete) (kN/m^3)

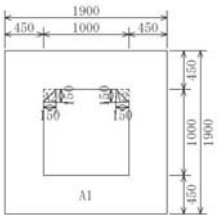
Span No. 1-1 Land Side
W = (4.000 + 0.023 + 0.000) ･ 24.000
= 96.540 (kN/m)



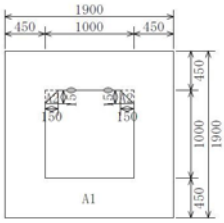
Span No. 1-2 Land Side
W = (2.610 + 0.023 + 0.000) ･ 24.000
= 63.180 (kN/m)



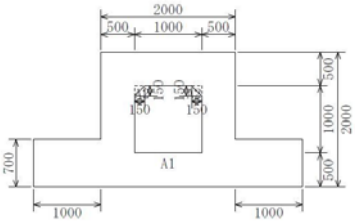
Span No. 2-1 Center
W = (2.610 + 0.023 + 0.000) ･ 24.000
= 63.180 (kN/m)



Span No. 3-1 River Side
W = (2.610 + 0.023 + 0.000) ･ 24.000
= 63.180 (kN/m)



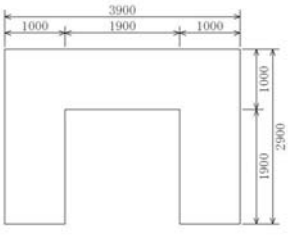
Span No. 3-2 River Side
W = (4.400 + 0.023 + 0.000 + 0.000) ･ 24.000
= 106.140 (kN/m)



2) Seepage Cutoff Wall Body Weight

A1 = X1･L2
A2 = L1･Y1･2
W = (A1 + A2) ･B･γc (kN)
X1: Top Slab Width (m)
Y1: Side Wall Height (m)
L1: Side Wall Width (m)
L2: Top Slab Height (m)
A1: Top Slab Area (m^2)
A2: Side Wall Area (m^2)
B: Thickness (m)
γc: Unit Weight (Concrete) (kN/m^3)

SpanNo.2-SpanDistance from Base Point (1.450)
A1 = 3.900･ 1.000
= 3.900 (m^2)
A2 = 1.000･ 1.900･2
= 3.800 (m^2)
W = (3.900 + 3.800)･ 0.500･ 24.00
= 92.400 (kN)



3.3.2 Ground Displacement Load (Settlement、Lateral Displacement)

1) Equivalent Load for Ground Settlement

【Normal Condition】

Span1 Name of Span: [Land Side]

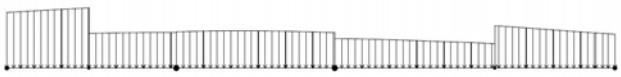
Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-11.126～-10.876	4.000	120300.8	235.7	239.3	-28349.788	-28782.413
1-(2)	-10.876～-10.626	4.000	120300.8	239.3	242.7	-28782.413	-29199.794
1-(3)	-10.626～-10.126	4.000	120300.8	242.7	249.2	-29199.794	-29983.195
1-(4)	-10.126～ -9.626	4.000	120300.8	249.2	255.5	-29983.195	-30739.937
2-(5)	-9.626～ -9.126	1.900	69104.7	255.5	260.3	-17658.026	-17988.225
2-(6)	-9.126～ -8.626	1.900	69104.7	260.3	262.6	-17988.225	-18147.881
2-(7)	-8.626～ -8.126	1.900	69104.7	262.6	262.8	-18147.881	-18157.967
2-(8)	-8.126～ -8.026	1.900	69104.7	262.8	262.5	-18157.967	-18141.787

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(9)	-8.026～ -7.526	1.900	70547.0	262.5	268.1	-18520.421	-18911.644
1-(10)	-7.526～ -7.026	1.900	70547.0	268.1	270.2	-18911.644	-19060.453
1-(11)	-7.026～ -6.526	1.900	70547.0	270.2	269.8	-19060.453	-19032.517
1-(12)	-6.526～ -6.026	1.900	70547.0	269.8	267.1	-19032.517	-18841.485
1-(13)	-6.026～ -5.526	1.900	70547.0	267.1	262.1	-18841.485	-18490.700
1-(14)	-5.526～ -5.126	1.900	70547.0	262.1	256.6	-18490.700	-15077.031

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(15)	-5.126～ -4.626	1.900	58863.0	256.6	252.6	-15101.429	-14868.978
1-(16)	-4.626～ -4.126	1.900	58863.0	252.6	246.6	-14868.978	-14517.307
1-(17)	-4.126～ -3.626	1.900	58863.0	246.6	238.2	-14517.307	-14023.280
1-(18)	-3.626～ -3.126	1.900	58863.0	238.2	228.8	-14023.280	-13469.568
1-(19)	-3.126～ -2.626	1.900	58863.0	228.8	222.4	-13469.568	-13091.354
2-(20)	-2.626～ -2.200	1.900	58863.0	222.4	211.7	-13091.354	-12462.888
2-(21)	-2.200～ -2.126	4.000	102422.4	211.7	210.3	-21685.577	-21535.728
2-(22)	-2.126～ -1.626	4.000	102422.4	210.3	200.3	-21535.728	-20512.840
2-(23)	-1.626～ -1.126	4.000	102422.4	200.3	190.3	-20512.840	-19488.211
2-(24)	-1.126～ -0.626	4.000	102422.4	190.3	180.5	-19488.211	-18483.325
2-(25)	-0.626～ -0.350	4.000	102422.4	180.5	175.2	-18483.325	-17944.099
2-(26)	-0.350～ -0.126	4.000	102422.4	175.2	171.0	-17944.099	-17517.280
2-(27)	-0.126～ 0.000	4.000	102422.4	171.0	168.7	-17517.280	-17282.015



2) Equivalent Load for Ground Settlement

【Seismic Condition】

Span1 Name of Span: [Land Side]

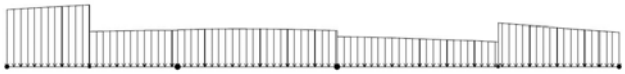
Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-11.126～-10.876	4.000	240601.5	235.7	239.3	-56699.575	-57564.825
1-(2)	-10.876～-10.626	4.000	240601.5	239.3	242.7	-57564.825	-58399.588
1-(3)	-10.626～-10.126	4.000	240601.5	242.7	249.2	-58399.588	-59966.389
1-(4)	-10.126～ -9.626	4.000	240601.5	249.2	255.5	-59966.389	-61479.874
2-(5)	-9.626～ -9.126	1.900	138209.4	255.5	260.3	-35316.053	-35976.450
2-(6)	-9.126～ -8.626	1.900	138209.4	260.3	262.6	-35976.450	-36295.762
2-(7)	-8.626～ -8.126	1.900	138209.4	262.6	262.8	-36295.762	-36315.934
2-(8)	-8.126～ -8.026	1.900	138209.4	262.8	262.5	-36315.934	-36283.575

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(9)	-8.026～ -7.526	1.900	141093.9	262.5	268.1	-37040.841	-37823.289
1-(10)	-7.526～ -7.026	1.900	141093.9	268.1	270.2	-37823.289	-38120.907
1-(11)	-7.026～ -6.526	1.900	141093.9	270.2	269.8	-38120.907	-38065.034
1-(12)	-6.526～ -6.026	1.900	141093.9	269.8	267.1	-38065.034	-37682.970
1-(13)	-6.026～ -5.526	1.900	141093.9	267.1	262.1	-37682.970	-36981.400
1-(14)	-5.526～ -5.126	1.900	141093.9	262.1	256.6	-36981.400	-36197.929

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(15)	-5.126～ -4.626	1.900	117726.1	256.6	252.6	-30202.857	-29737.955
1-(16)	-4.626～ -4.126	1.900	117726.1	252.6	246.6	-29737.955	-29034.614
1-(17)	-4.126～ -3.626	1.900	117726.1	246.6	238.2	-29034.614	-28046.560
1-(18)	-3.626～ -3.126	1.900	117726.1	238.2	228.8	-28046.560	-26939.135
1-(19)	-3.126～ -2.626	1.900	117726.1	228.8	222.4	-26939.135	-26182.707
2-(20)	-2.626～ -2.200	1.900	117726.1	222.4	211.7	-26182.707	-24925.776
2-(21)	-2.200～ -2.126	4.000	204844.8	211.7	210.3	-43371.154	-43071.457
2-(22)	-2.126～ -1.626	4.000	204844.8	210.3	200.3	-43071.457	-41025.680
2-(23)	-1.626～ -1.126	4.000	204844.8	200.3	190.3	-41025.680	-38976.421
2-(24)	-1.126～ -0.626	4.000	204844.8	190.3	180.5	-38976.421	-36966.650
2-(25)	-0.626～ -0.350	4.000	204844.8	180.5	175.2	-36966.650	-35888.199
2-(26)	-0.350～ -0.126	4.000	204844.8	175.2	171.0	-35888.199	-35034.560
2-(27)	-0.126～ 0.000	4.000	204844.8	171.0	168.7	-35034.560	-34564.030



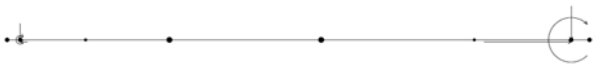
3.3.3 Point Load from Breast Walls

1) Normal Condition (Case Number: 1)

Case of Normal Condition 1

Name of Normal Load: [Gate Piers and Breast Walls (Normal) 1]

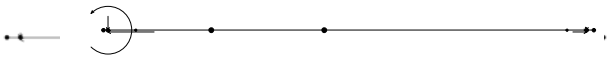
Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-40.40	93.20	-47.97
3	Right Breast Wall	10.776	497.78	193.79	-257.58



2) Seismic Condition (Total Number: 2)

Case of Seismic Conditon 1 [Land Side →River Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-5.53	9.09	-20.15
3	Right Breast Wall	10.776	455.98	105.29	-155.60



Case of Seimic Condition 2 [River Side→Land Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-62.33	9.09	-6.90
3	Right Breast Wall	10.776	329.91	105.29	-53.46



3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
2	Fixed Load Data 2	Water Weight (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Engaging Load (Normal)1	Gate Structure ･Breast Wall (Normal)1	1.0000
6	Arbitrary Load (Normal)1	Surcharge in Normal Condition	1.0000

2) Seismic Condition

1) Case 1 [Seismic Condition: Land Side→River Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Dead Load)1	Gate Structure ･Breast Wall (Dead Load)1	1.0000
6	Ingaging Load (Seismic)1	Seismic Load :Land Side →River Side	1.0000

2) Case 2 [Seismic Condition: River Side→Land Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Seismic)2	Seismic Load :Land Side →River Side	1.0000
6	Ingaging Load (Dead Load)2	Gate Structure ･Breast Wall (Dead Load)2	1.0000

3.4 Displacement between Sluiceway and Adjoining Levee

3.4.1 Normal Condition

1) Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-7.7	-7.6	240.8	235.7	5.1	40.0	○	616.509
2	0.250	-7.7	-7.6	243.1	239.3	3.8	40.0	○	461.193
3	0.500	-7.7	-7.6	245.4	242.7	2.7	40.0	○	321.121
4	1.000	-7.7	-7.7	250.0	249.2	0.8	40.0	○	92.339
5	1.500	-7.7	-7.7	254.6	255.5	-0.9	-50.0	○	-109.786
6	2.000	-7.7	-6.4	259.2	260.3	-1.1	-50.0	○	-74.674
7	2.500	-7.7	-5.1	263.8	262.6	1.2	19.0	○	84.259
8	3.000	-7.7	-3.8	268.4	262.8	5.7	19.0	○	392.762
9	3.100	-7.7	-3.6	269.4	262.5	6.8	19.0	○	472.659

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground Spring (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	0.1	-3.6	271.2	262.5	8.7	19.0	○	611.173
2	0.500	0.1	-2.3	270.0	268.1	2.0	19.0	○	138.564
3	1.000	0.1	-1.0	268.9	270.2	-1.3	-50.0	○	-91.630
4	1.500	0.1	0.3	267.7	269.8	-2.1	-50.0	○	-145.080
5	2.000	0.1	1.6	266.6	267.1	-0.5	-50.0	○	-35.436
6	2.500	0.1	2.9	265.4	262.1	3.3	19.0	○	233.961
7	2.900	0.1	3.9	264.5	256.6	7.9	19.0	○	560.586

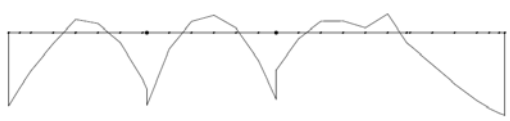
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	14.7	3.9	261.9	256.6	5.3	19.0	○	314.682
2	0.500	14.7	5.2	253.5	252.6	0.9	19.0	○	51.015
3	1.000	14.7	6.5	245.0	246.6	-1.6	-50.0	○	-93.432
4	1.500	14.7	7.7	236.6	238.2	-1.6	-50.0	○	-95.524
5	2.000	14.7	7.7	228.2	228.8	-0.6	-50.0	○	-37.930
6	2.500	14.7	7.6	219.8	222.4	-2.6	-50.0	○	-155.834
7	2.926	14.7	7.6	212.6	211.7	0.8	19.0	○	86.895
8	3.000	14.7	7.6	211.3	210.3	1.1	40.0	○	108.982
9	3.500	14.7	7.5	202.9	200.3	2.6	40.0	○	268.622
10	4.000	14.7	7.5	194.5	190.3	4.2	40.0	○	430.006
11	4.500	14.7	7.4	186.0	180.5	5.6	40.0	○	571.648
12	4.776	14.7	7.4	181.4	175.2	6.2	40.0	○	634.366
13	5.000	14.7	7.4	177.6	171.0	6.6	40.0	○	674.454
14	5.126	14.7	7.3	175.5	168.7	6.8	40.0	○	692.183

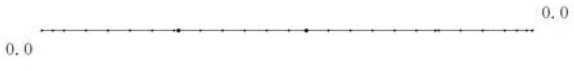
Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-6.9	-7.6	240.0	235.7	4.3	40.0	○	522.562
2	0.250	-6.9	-7.6	242.4	239.3	3.1	40.0	○	374.881
3	0.500	-6.9	-7.6	244.7	242.7	2.0	40.0	○	242.444
4	1.000	-6.9	-7.7	249.5	249.2	0.2	40.0	○	28.931
5	1.500	-6.9	-7.7	254.2	255.5	-1.3	-50.0	○	-157.924
6	2.000	-6.9	-6.4	259.0	260.3	-1.4	-50.0	○	-93.554
7	2.500	-6.9	-5.1	263.7	262.6	1.1	19.0	○	74.150
8	3.000	-6.9	-3.8	268.4	262.8	5.7	19.0	○	391.424
9	3.100	-6.9	-3.6	269.4	262.5	6.8	19.0	○	473.076

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	0.1	-3.6	271.1	262.5	8.5	19.0	○	601.594
2	0.500	0.1	-2.3	269.9	268.1	1.8	19.0	○	128.985
3	1.000	0.1	-1.0	268.7	270.2	-1.4	-50.0	○	-101.209
4	1.500	0.1	0.3	267.6	269.8	-2.2	-50.0	○	-154.659
5	2.000	0.1	1.6	266.4	267.1	-0.6	-50.0	○	-45.015
6	2.500	0.1	2.9	265.3	262.1	3.2	19.0	○	224.382
7	2.900	0.1	3.9	264.4	256.6	7.8	19.0	○	551.006

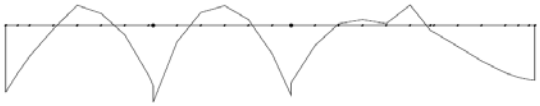
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	8.9	3.9	264.2	256.6	7.6	19.0	○	449.667
2	0.500	8.9	5.2	255.3	252.6	2.7	19.0	○	158.259
3	1.000	8.9	6.5	246.4	246.6	-0.2	-50.0	○	-13.930
4	1.500	8.9	7.7	237.5	238.2	-0.7	-50.0	○	-43.762
5	2.000	8.9	7.7	228.6	228.8	-0.2	-50.0	○	-13.911
6	2.500	8.9	7.6	219.7	222.4	-2.7	-50.0	○	-159.559
7	2.926	8.9	7.6	212.1	211.7	0.4	19.0	○	39.283
8	3.000	8.9	7.6	210.8	210.3	0.5	40.0	○	54.226
9	3.500	8.9	7.5	201.9	200.3	1.6	40.0	○	165.586
10	4.000	8.9	7.5	193.0	190.3	2.7	40.0	○	278.688
11	4.500	8.9	7.4	184.1	180.5	3.6	40.0	○	372.046
12	4.776	8.9	7.4	179.2	175.2	4.0	40.0	○	408.109
13	5.000	8.9	7.4	175.2	171.0	4.2	40.0	○	426.564
14	5.126	8.9	7.3	173.0	168.7	4.2	40.0	○	432.125

Displacement Diagram



Reaction Force of Ground



Reaction Force



2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-7.2	-7.6	241.1	235.7	5.4	40.0	○	649.554
2	0.250	-7.2	-7.6	243.3	239.3	4.1	40.0	○	491.169
3	0.500	-7.2	-7.6	245.6	242.7	2.9	40.0	○	348.027
4	1.000	-7.2	-7.7	250.2	249.2	0.9	40.0	○	113.105
5	1.500	-7.2	-7.7	254.7	255.5	-0.8	-50.0	○	-95.160
6	2.000	-7.2	-6.4	259.3	260.3	-1.0	-50.0	○	-69.799
7	2.500	-7.2	-5.1	263.9	262.6	1.2	19.0	○	85.607
8	3.000	-7.2	-3.8	268.4	262.8	5.7	19.0	○	390.582
9	3.100	-7.2	-3.6	269.3	262.5	6.8	19.0	○	469.775

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	0.1	-3.6	271.1	262.5	8.5	19.0	○	601.594
2	0.500	0.1	-2.3	269.9	268.1	1.8	19.0	○	128.985
3	1.000	0.1	-1.0	268.7	270.2	-1.4	-50.0	○	-101.209
4	1.500	0.1	0.3	267.6	269.8	-2.2	-50.0	○	-154.659
5	2.000	0.1	1.6	266.4	267.1	-0.6	-50.0	○	-45.015
6	2.500	0.1	2.9	265.3	262.1	3.2	19.0	○	224.382
7	2.900	0.1	3.9	264.4	256.6	7.8	19.0	○	551.006

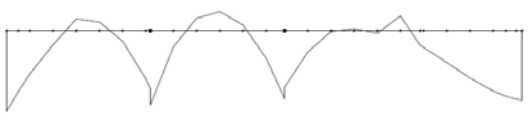
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	8.4	3.9	264.3	256.6	7.8	19.0	○	457.018
2	0.500	8.4	5.2	255.5	252.6	2.9	19.0	○	172.195
3	1.000	8.4	6.5	246.7	246.6	0.1	19.0	○	6.591
4	1.500	8.4	7.7	238.0	238.2	-0.3	-50.0	○	-16.657
5	2.000	8.4	7.7	229.2	228.8	0.3	19.0	○	19.780
6	2.500	8.4	7.6	220.4	222.4	-2.0	-50.0	○	-119.284
7	2.926	8.4	7.6	212.9	211.7	1.2	19.0	○	119.123
8	3.000	8.4	7.6	211.6	210.3	1.3	40.0	○	135.761
9	3.500	8.4	7.5	202.8	200.3	2.5	40.0	○	258.577
10	4.000	8.4	7.5	194.0	190.3	3.7	40.0	○	383.133
11	4.500	8.4	7.4	185.2	180.5	4.8	40.0	○	487.943
12	4.776	8.4	7.4	180.4	175.2	5.2	40.0	○	530.327
13	5.000	8.4	7.4	176.4	171.0	5.4	40.0	○	553.912
14	5.126	8.4	7.3	174.2	168.7	5.5	40.0	○	562.357

Displacement Diagram



Reaction Force of Ground



Reaction Force



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	-1.367	108.183	14.333
3	0.250	79.427	-78.217	110.273
4	0.500	78.316	-6.958	100.356
5	1.000	76.844	43.347	114.224
6	1.500	76.161	-14.074	125.758
7	2.000	68.564	-84.889	101.260
8	2.500	46.237	-118.872	47.010
9	3.000	9.180	-35.997	1.866
10	3.100	0.001	0.001	0.000

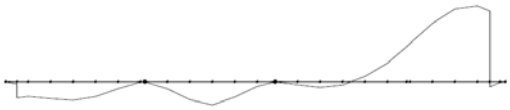
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	3.100	-0.001	0.000	0.000
2	3.600	36.277	151.055	47.610
3	4.100	57.517	126.409	121.771
4	4.600	63.703	-61.549	157.580
5	5.100	54.710	-143.057	104.144
6	5.600	30.430	-129.806	30.316
7	6.000	-0.001	0.000	0.000

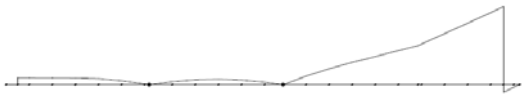
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	6.000	0.001	0.000	0.000
2	6.500	99.054	55.045	19.255
3	7.000	185.458	8.061	38.042
4	7.500	259.536	-75.558	21.213
5	8.000	327.810	-145.301	-35.200
6	8.500	396.581	-230.122	-126.598
7	8.926	455.567	-283.673	-239.146
8	9.000	473.458	-284.986	-260.177
9	9.500	594.849	-248.446	-396.866
10	10.000	717.101	-131.649	-495.257
11	10.500	840.213	60.904	-515.899
12	10.776	908.538	195.395	-480.929
13	10.776	-87.017	-192.184	34.231
14	11.000	-31.378	-71.518	4.529
15	11.126	-0.003	0.000	0.000

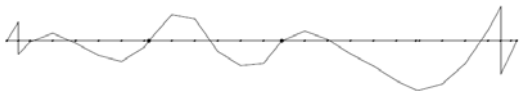
Bending Moment



Axial Force



Shear Force



3.5.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition　Land Side →River Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	6.411	87.673	11.725
3	0.250	11.935	-4.617	72.975
4	0.500	18.603	48.214	79.112
5	1.000	32.689	67.910	112.567
6	1.500	47.563	-11.792	130.464
7	2.000	48.903	-88.583	105.415
8	2.500	35.513	-123.757	48.820
9	3.000	7.393	-37.289	1.932
10	3.100	0.001	0.001	0.000

Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	3.100	-0.001	0.000	0.000
2	3.600	36.277	151.055	47.610
3	4.100	57.517	126.409	121.771
4	4.600	63.703	-61.549	157.580
5	5.100	54.710	-143.057	104.144
6	5.600	30.430	-129.806	30.316
7	6.000	-0.001	0.000	0.000

Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	6.000	0.001	0.000	0.000
2	6.500	59.109	108.165	32.987
3	7.000	105.568	103.455	89.355
4	7.500	139.701	51.263	128.532
5	8.000	168.030	2.100	141.127
6	8.500	196.856	-72.987	126.315
7	8.926	221.809	-126.804	80.929
8	9.000	229.413	-130.119	71.427
9	9.500	281.299	-117.938	6.868
10	10.000	334.046	-44.377	-36.291
11	10.500	387.653	86.064	-28.038
12	10.776	417.612	178.182	8.161
13	10.776	-38.363	-130.178	23.111
14	11.000	-13.863	-48.130	3.043
15	11.126	-0.003	0.000	0.000

Bending Moment



Axial Force



Shear Force



Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	0.541	119.171	15.723
3	0.250	62.865	-141.639	174.783
4	0.500	63.663	-60.209	150.300
5	1.000	66.009	7.983	142.150
6	1.500	69.143	-34.825	139.791
7	2.000	63.739	-97.087	107.135
8	2.500	43.605	-124.397	48.532
9	3.000	8.741	-36.729	1.902
10	3.100	0.001	0.001	0.000

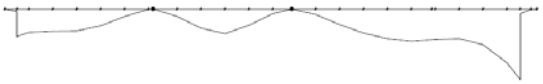
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	3.100	-0.001	0.000	0.000
2	3.600	36.277	151.055	47.610
3	4.100	57.517	126.409	121.771
4	4.600	63.703	-61.549	157.580
5	5.100	54.710	-143.057	104.144
6	5.600	30.430	-129.806	30.316
7	6.000	-0.001	0.000	0.000

Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	6.000	0.001	0.000	0.000
2	6.500	49.777	118.172	35.388
3	7.000	86.903	125.883	99.764
4	7.500	111.702	88.526	153.763
5	8.000	130.699	56.611	189.201
6	8.500	150.193	1.185	206.459
7	8.926	167.193	-33.975	196.582
8	9.000	172.395	-31.340	194.171
9	9.500	208.041	23.450	189.479
10	10.000	244.549	143.818	228.541
11	10.500	281.915	325.263	343.467
12	10.776	302.909	447.332	449.789
13	10.776	-26.995	-169.998	30.139
14	11.000	-9.770	-62.702	3.964
15	11.126	-0.003	0.000	0.000

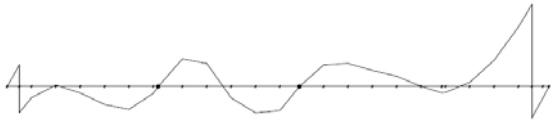
Bending Moment



Axial Force



Shear Force



3.6 Design of Flexible Joint

Opening

Opening = (Lateral Displacement of Span in Right Side) - (Lateral Displacement of Span in Left Side)

Bending Angle

θ = ｜θ1 - θ2｜ - Initial Bending Angle

Thus、

θ1: Angle of Displacement (Left Side) (rad)

θ2: Angle of Displacement (Right Side) (rad)

θ: Average Angle of Displacement (rad)

Unevenness

Unevenness = (Vertical Displacement of Span in Right Side) - (Vertical Displacement of Span in Left Side)

3.6.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Check of Opening Allowable Opening: 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-7.7	
Span (2- 1)	0.1- (-7.7)	7.8 OK
Span (3- 2)	14.7- (0.1)	14.5 OK
EP	14.7	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.52829 -0.00922	0.13220 0.00231	0.66049 0.01153
Span (3- 2)	0.00000 0.00000	0.13220 0.00231	0.96582 0.01686	0.83362 0.01455

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-240.8	
Span (2- 1)	-271.2-(-269.4)	1.8 OK
Span (3- 2)	-261.9-(-264.5)	2.6 OK
EP	-175.5	

3.6.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-6.9	
Span (2- 1)	0.1- (-6.9)	7.0 OK
Span (3- 2)	8.9- (0.1)	8.7 OK
EP	8.9	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.54284 -0.00947	0.13220 0.00231	0.67503 0.01178
Span (3- 2)	0.00000 0.00000	0.13220 0.00231	1.01982 0.01780	0.88762 0.01549

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-240.0	
Span (2- 1)	-271.1- (-269.4)	1.7 OK
Span (3- 2)	-264.2- (-264.4)	0.2 OK
EP	-173.0	

Calculation Case2 - Load: [Seismic Condition Land Side →River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-7.2	
Span (2- 1)	0.1- (-7.2)	7.3 OK
Span (3- 2)	8.4- (0.1)	8.2 OK
EP	8.4	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.52244 -0.00912	0.13220 0.00231	0.65464 0.01143
Span (3- 2)	0.00000 0.00000	0.13220 0.00231	1.00700 0.01758	0.87480 0.01527

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-241.1	
Span (2- 1)	-271.1-(-269.3)	1.7 OK
Span (3- 2)	-264.3-(-264.4)	0.0 OK
EP	-174.2	

3.7 Stress Intensity Analysis

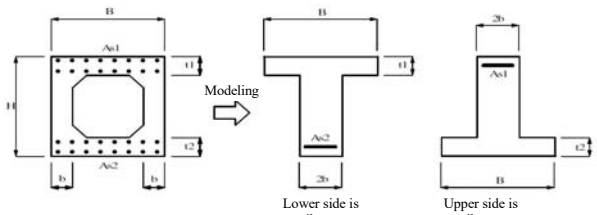
3.7.1 Calculation Condition

It is considered that double reinforced section which bending moment is acting on.
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.
Position of Neutral Axis

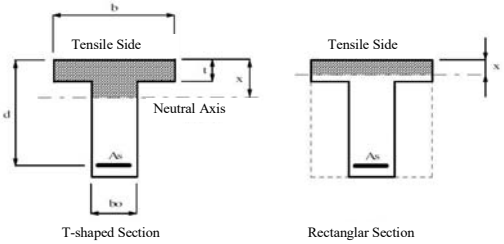
$$x=\frac{n\cdot(As\cdot d+As'\cdot d')+B\cdot t^2/2}{n\cdot(As+As')+B\cdot t}$$

Thus,

x : Position of Neutral Axis (mm)
n : Ratio of Young modulus = 9.0
As : Area of Re-bar in tensile side (mm^2)
As' : Area of Re-bar in compressive side (mm^2)
d : Effective Height of Beam (mm)
d' : Distance from the compressive edge of concrete to the centric of Re-bar (mm)
B : Width of Flange (mm)
t : Thickness of Flange (mm)



The stress calculation is conducted as follows based on the position of neutral axis
1) In case the neutral axis is in web, the section is considered as T-shape.
2) In case the neutral axis is in top slab or Bottom slab, the section is considered as rectangle.



Calculation Condition (In Case Bottom Slab is Tensile)
Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation Section
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.265	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.265	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.281	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.300	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side As(mm^2)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side As' (mm^2)
1- 1	2.000	2.000	1.716	2780.4	0.273	2780.4
1- 2	1.900	1.900	1.645	2780.4	0.244	2780.4
2- 1	1.900	1.900	1.659	2780.4	0.244	2780.4
3- 1	1.900	1.900	1.645	4011.0	0.244	4011.0
3- 2	2.000	2.000	1.716	4011.0	0.273	4011.0

Calculation Condition (In Case Top Slab is Tensile)
Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.265	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.265	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.281	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.300	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side	Position of Re-bar in Compressive	Area of Re-bar in Tensile Side
1- 1	2.000	2.000	1.727	2780.4	0.284	2780.4
1- 2	1.900	1.900	1.656	2780.4	0.255	2780.4
2- 1	1.900	1.900	1.656	2780.4	0.241	2780.4
3- 1	1.900	1.900	1.656	4011.0	0.255	4011.0
3- 2	2.000	2.000	1.727	4011.0	0.284	4011.0

3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	125.758	0.000	110.273	14.333
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	244.4		213.8	27.3
	Top Slab Inside	Aq2	mm^2	325.8		285.1	36.4
	Bottom Slab Inside	Aq3	mm^2	325.8		285.1	36.4
	Bottom Slab Outside	Aq4	mm^2	244.4		213.8	27.3
Neutral Axis		X	m	0.199	----	0.199	0.199
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.39	----	0.34	0.04
		σs	N/mm^2	29.73	----	26.07	3.39
		σs'	N/mm^2	-1.93	----	-1.69	-0.22
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		
		req	mm^2	760.2	----	665.3	84.8
		inp	mm^2	2780.4	----	2780.4	2780.4

Calculation Case1: Normal Condition

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	125.758	0.000	125.758	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	253.9		253.9	
	Top Slab Inside	Aq2	mm^2	338.5		338.5	
	Bottom Slab Inside	Aq3	mm^2	338.5		338.5	
	Bottom Slab Outside	Aq4	mm^2	253.9		253.9	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.43	----	0.43	----
		σs	N/mm^2	30.87	----	30.87	----
		σs'	N/mm^2	-2.11	----	-2.11	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	789.8	----	789.8	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Normal Condition

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	157.580	0.000	157.580	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	115.0 D16- 8	115.0 D16- 8	115.0 D16- 8	115.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	314.0		314.0	
	Top Slab Inside	Aq2	mm^2	418.7		418.7	
	Bottom Slab Inside	Aq3	mm^2	418.7		418.7	
	Bottom Slab Outside	Aq4	mm^2	314.0		314.0	
Neutral Axis		X	m	0.199	----	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.53	----	0.53	----
		σs	N/mm^2	38.03	----	38.03	----
		σs'	N/mm^2	-2.62	----	-2.62	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	977.0	----	977.0	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Normal Condition

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	38.042	-239.146	-239.146	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	75.7	488.8	488.8	
	Top Slab Inside	Aq2	mm^2	100.9	651.7	651.7	
	Bottom Slab Inside	Aq3	mm^2	100.9	651.7	651.7	
	Bottom Slab Outside	Aq4	mm^2	75.7	488.8	488.8	
Neutral Axis		X	m	0.233	0.234	0.234	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.11	0.68	0.68	----
		σs	N/mm^2	6.55	41.23	41.23	----
		σs'	N/mm^2	-0.60	-3.11	-3.11	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2				----
		req	mm^2	235.4	1520.7	1520.7	----
		inp	mm^2	4011.0	4011.0	4011.0	----

Calculation Case1: Normal Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	34.231	-515.899	-480.929	34.231
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	65.5	1034.4	962.3	65.5
	Top Slab Inside	Aq2	mm^2	87.4	1379.2	1283.1	87.4
	Bottom Slab Inside	Aq3	mm^2	87.4	1379.2	1283.1	87.4
	Bottom Slab Outside	Aq4	mm^2	65.5	1034.4	962.3	65.5
Neutral Axis		X	m	0.234	0.236	0.236	0.234
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.09	1.34	1.25	0.09
		σs	N/mm^2	5.68	85.63	79.82	5.68
		σs'	N/mm^2	-0.50	-6.17	-5.76	-0.50
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	203.8	3218.1	2993.9	203.8
		inp	mm^2	4011.0	4011.0	4011.0	4011.0

3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	130.464	0.000	130.464	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	190.1		190.1	
	Top Slab Inside	Aq2	mm^2	253.5		253.5	
	Bottom Slab Inside	Aq3	mm^2	253.5		253.5	
	Bottom Slab Outside	Aq4	mm^2	190.1		190.1	
Neutral Axis		X	m	0.199	----	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.41	----	0.41	----
		σs	N/mm^2	30.84	----	30.84	----
		σs'	N/mm^2	-2.00	----	-2.00	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	591.5	----	591.5	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	130.464	0.000	105.415	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	197.5		159.1	
	Top Slab Inside	Aq2	mm^2	263.3		212.2	
	Bottom Slab Inside	Aq3	mm^2	263.3		212.2	
	Bottom Slab Outside	Aq4	mm^2	197.5		159.1	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.44	----	0.36	----
		σs	N/mm^2	32.02	----	25.87	----
		σs'	N/mm^2	-2.19	----	-1.77	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	614.4	----	495.0	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	157.580	0.000	157.580	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	115.0 D16- 8	115.0 D16- 8	115.0 D16- 8	115.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	235.3		235.3	
	Top Slab Inside	Aq2	mm^2	313.7		313.7	
	Bottom Slab Inside	Aq3	mm^2	313.7		313.7	
	Bottom Slab Outside	Aq4	mm^2	235.3		235.3	
Neutral Axis		X	m	0.199	----	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.53	----	0.53	----
		σs	N/mm^2	38.03	----	38.03	----
		σs'	N/mm^2	-2.62	----	-2.62	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	732.0	----	732.0	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Seismic Condition　　Land Side→River Side

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	141.127	0.000	80.929	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	213.9		121.8	
	Top Slab Inside	Aq2	mm^2	285.2		162.4	
	Bottom Slab Inside	Aq3	mm^2	285.2		162.4	
	Bottom Slab Outside	Aq4	mm^2	213.9		121.8	
Neutral Axis		X	m	0.233	----	0.233	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.40	----	0.23	----
		σs	N/mm^2	24.29	----	13.93	----
		σs'	N/mm^2	-2.23	----	-1.28	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	665.4	----	378.8	----
		inp	mm^2	4011.0	----	4011.0	----

Calculation Case1: Seismic Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	80.928	-36.291	8.161	23.111
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	117.2	52.2	11.6	33.1
	Top Slab Inside	Aq2	mm^2	156.3	69.6	15.5	44.2
	Bottom Slab Inside	Aq3	mm^2	156.3	69.6	15.5	44.2
	Bottom Slab Outside	Aq4	mm^2	117.2	52.2	11.6	33.1
Neutral Axis		X	m	0.234	0.236	0.234	0.234
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.21	0.09	0.02	0.06
		σs	N/mm^2	13.42	6.02	1.35	3.83
		σs'	N/mm^2	-1.17	-0.43	-0.12	-0.34
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	364.7	162.3	36.2	103.1
		inp	mm^2	4011.0	4011.0	4011.0	4011.0

2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	174.783	0.000	139.791	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	255.8		203.9	
	Top Slab Inside	Aq2	mm^2	341.1		271.9	
	Bottom Slab Inside	Aq3	mm^2	341.1		271.9	
	Bottom Slab Outside	Aq4	mm^2	255.8		203.9	
Neutral Axis		X	m	0.199	----	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.54	----	0.43	----
		σs	N/mm^2	41.32	----	33.05	----
		σs'	N/mm^2	-2.68	----	-2.15	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	795.9	----	634.4	----
		inp	mm^2	2780.4	----	2780.4	----

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	139.791	0.000	139.791	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	211.8		211.8	
	Top Slab Inside	Aq2	mm^2	282.4		282.4	
	Bottom Slab Inside	Aq3	mm^2	282.4		282.4	
	Bottom Slab Outside	Aq4	mm^2	211.8		211.8	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.48	----	0.48	----
		σs	N/mm^2	34.31	----	34.31	----
		σs'	N/mm^2	-2.34	----	-2.34	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	659.0	----	659.0	----
		inp	mm^2	2780.4	----	2780.4	----

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	157.580	0.000	157.580	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	115.0 D16- 8	115.0 D16- 8	115.0 D16- 8	115.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	235.3		235.3	
	Top Slab Inside	Aq2	mm^2	313.7		313.7	
	Bottom Slab Inside	Aq3	mm^2	313.7		313.7	
	Bottom Slab Outside	Aq4	mm^2	235.3		235.3	
Neutral Axis		X	m	0.199	----	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.53	----	0.53	----
		σs	N/mm^2	38.03	----	38.03	----
		σs'	N/mm^2	-2.62	----	-2.62	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	732.0	----	732.0	----
		inp	mm^2	2780.4	----	2780.4	----

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	206.459	0.000	196.582	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	314.8		299.5	
	Top Slab Inside	Aq2	mm^2	419.7		399.3	
	Bottom Slab Inside	Aq3	mm^2	419.7		399.3	
	Bottom Slab Outside	Aq4	mm^2	314.8		299.5	
Neutral Axis		X	m	0.233	----	0.233	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.59	----	0.56	----
		σs	N/mm^2	35.54	----	33.84	----
		σs'	N/mm^2	-3.27	----	-3.11	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	979.4	----	931.8	----
		inp	mm^2	4011.0	----	4011.0	----

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	449.789	0.000	449.789	30.139
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	670.8		670.8	43.3
	Top Slab Inside	Aq2	mm^2	894.4		894.4	57.7
	Bottom Slab Inside	Aq3	mm^2	894.4		894.4	57.7
	Bottom Slab Outside	Aq4	mm^2	670.8		670.8	43.3
Neutral Axis		X	m	0.234	----	0.234	0.234
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	1.18	----	1.18	0.08
		σs	N/mm^2	74.57	----	74.57	5.00
		σs'	N/mm^2	-6.52	----	-6.52	-0.44
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		
		req	mm^2	2086.9	----	2086.9	134.7
		inp	mm^2	4011.0	----	4011.0	4011.0

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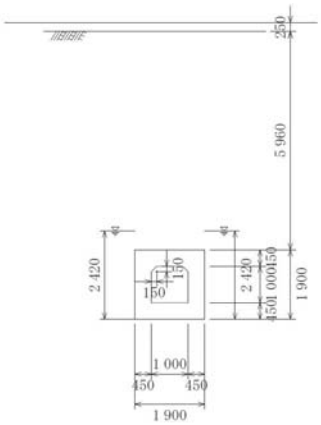
2.2.2.2 SLUICEWAY TYPE B

(2) BOX - TRANSVERSE

1 Calculation of Box Culvert in Transverse Direction

1.1 Design Condition

1.1.1 Dimension



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil(Wet)	γt	kN/m³	19.00
Soil(Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Outside of Top Slab	Diameter	Pitch	Area (mm²)	Inside of Top Slab	Diameter	Pitch	Area (mm²)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
	—	——			—	——	
Right Corner	D16	247	804.0	Right Corner	D16	250	794.4

Outside of Sidewall	Diameter	Pitch	Area (mm²)	Inside of Sidewall	Diameter	Pitch	Area (mm²)
Left Sidewall	D16	250	794.4	Left Sidewall	D13	250	506.8
	—	——			—	——	
Right Sidewall	D16	250	794.4	Right Sidewall	D13	250	506.8
	—	——			—	——	

Outside of Top Slab	Diameter	Pitch	Area (mm²)	Inside of Top Slab	Diameter	Pitch	Area (mm²)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
	—	——			—	——	
Right Corner	D16	250	794.4	Right Corner	D16	250	794.4

■Cover

Location		Cover(mm)	Location		Cover(mm)
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Midwall		———	———		——

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Top Slab	100	0.0
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Load

■Surcharge

	(kN/m²)
Surcharge	10.000
Snow Load	0.000

■Dead Load (Water Level)

Case	External Water Level(m)	Internal Water Level(m)
1	2.420	0.000

External Water Level: Height from Bottom Surface of Bottom Slab
Internal Water Level: Height from Top Surface of Bottom Slab

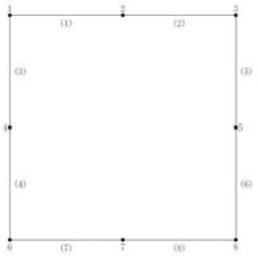
■Live Load

Intensity of Distribution Load Qw(kN/m²)	10.000

1.2 Cross-section Calculation

1.2.1 Model

1) Frame Dimension



2) Coordinate

No	X(m)	Y(m)
1	0.000	1.450
2	0.725	1.450
3	1.450	1.450
4	0.000	0.725
5	1.450	0.725
6	0.000	0.000
7	0.725	0.000
8	1.450	0.000

3) Member Material and Sectional Characteristics

Member	Number	Point Number i Edge	Point Number j Edge	Area (m²)	Geometric Moment of Inertia (m⁴)	Young Modules (kN/m²)
Left Side of Top Slab	1	1	2	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Top Slab	2	2	3	4.500000E-001	7.593750E-003	2.310000E+007
Upper Side of Left Side Wall	3	1	4	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Left Side Wall	4	4	6	4.500000E-001	7.593750E-003	2.310000E+007
Upper side of Right Wall	5	3	5	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Right Wall	6	5	8	4.500000E-001	7.593750E-003	2.310000E+007
Left Side of Bottom Slap	7	6	7	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slap	8	7	8	4.500000E-001	7.593750E-003	2.310000E+007

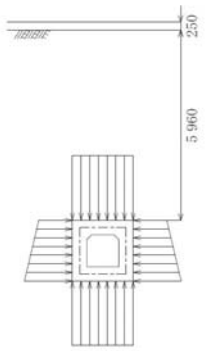
4) Supporting Point

Point	Horizontal (kN/m)	Vertical (kN/m)	Rotate (kN.m/rad)
9	-1	-1	0
13	0	-1	0

Note) -1 : Fixed, 0 : Free

1.2.2 Load

1) Dead Load (case-1) [RWL]



Weight of Box Culvert

(1) Top Slab
w = 0.450 × 24.00 = 10.80 (kN/m²)

(2) Left Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

(3) Right Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level) = 1.000 × 0.250 × 22.60 = 5.65 (kN/m²)
Embankment (Above Water Level) =1.000 × 5.440 × 19.00 = 103.36 (kN/m²)
Embankment (Below Water Level) =1.000 × 0.520 × 10.20 = 5.30 (kN/m²)
Water Pressure = 0.520 × 9.80 = 5.10 (kN/m²)

Σwd = 119.41 (kN/m²)

(2) Surcharge Load at Road
Surcharge = 10.000 (kN/m²)
Snow Load= 0.00 (kN/m²)

Σqd = 10.000 (kN/m²)

(3) Load Acting on Top Slab
Uniformly Distributed Load
w = 119.41 + 10.00 = 129.41 (kN/m²)

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

pi = Ko×(qd + Yo×γa + Zu×γ + (Zo - Zu)×γ') + (Zo - Zu)×γw

Ko: Coefficient of Earth Pressure at Rest = 0.500
Zo: Depth of Calculation Point from Embankment Top(m)

(1)Left Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	5.960	67.25
p_2	Center of Top Slab	6.185	70.61
p_4	Center of Bottom Slab	7.635	92.21
p_5	Bottom Surface of Bottom Slab	7.860	95.56

(2)Right Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	5.960	67.25
p_2	Center of Top Slab	6.185	70.61
p_4	Center of Bottom Slab	7.635	92.21
p_5	Bottom Surface of Bottom Slab	7.860	95.56

Uplift and Buoyancy
This Act on Bottom Slab Upward

$$U = 2.420 \times 1.900 \times 9.80 = 45.06 \ (kN/m)$$

$$w = \frac{-45.06}{1.900} = -23.72 \ (kN/m^2)$$

Summary of Acting Forces

Item			V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/
Weight of Body		Top Slab	21.06		0.950		20.01
		Left Side Wall	10.80		0.225		2.43
		Right Side Wall	10.80		1.675		18.09
Surcharge		Distribution Load	245.88		0.950		233.59
Earth Pressure and Water Pressure	Left Side Wall	Distribution		154.68		0.895	138.42
	Right Side Wall	Distribution		-154.68		0.895	-138.42
Uplift/Buoyancy			-45.06		0.950		-42.81
Total			243.48				231.30

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity
Me = ΣV × e = 0.00 (kN.m/m)

$$Me = \Sigma V \times e = 0.00 \ (kN.m/m)$$

$$q1 = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 128.15 \ (kN/m^2)$$

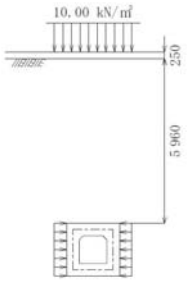
$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 128.15 \ (kN/m^2)$$

$$q1' = q1 + \frac{qr - q1}{B} \times \frac{T}{2} = 128.15 \ (kN/m^2)$$

$$qr' = qr + \frac{q1 - qr}{B} \times \frac{T}{2} = 128.15 \ (kN/m^2)$$

Thus, T : Thickness of Side Wall
ql : Subgrade Reaction Intensity on Left Edge
qr : Subgrade Reaction Intensity on Right Edge
ql': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface qL= 10.000 (kN/m²)

Load

(1)Vertical Load Effecting Top Slab
wl = qL= 10.00 (kN/m²)

(2)Horizontal Load Acting on Left Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

(3)Horizontal Load Effecting on Right Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

Summary of Acting Force

		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Top Slab	Distribution	19.00		0.950		18.05
Left Side Wall	Distribution		9.50		0.950	9.03
Right Side Wall	Distribution		-9.50		0.950	-9.03
Total		19.00				18.05

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$ql = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$ql' = ql + \frac{qr - ql}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

$$qr' = qr + \frac{ql - qr}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

Thus、T : Thickness of Side Wall
ql : Subgrade Reaction Intensity on Left Edge
qr : Subgrade Reaction Intensity on Right Edge
ql': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

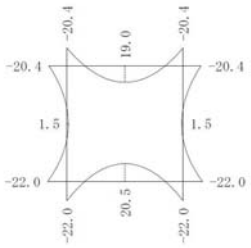
Dead Load + Live Load

Load Number	Beginning Member Number	End Member Number	Load Intensity at i Edge	Load Intensity at j Edge	Distance from i Edge (m)	Distance from j Edge (m)	Load Width (m)
14	1	2	-10.80	-10.80	0.000	0.000	1.450
14	3	4	-10.80	-10.80	0.225	0.225	1.000
14	5	6	-10.80	-10.80	0.225	0.225	1.000
14	1	2	-129.41	-129.41	0.000	0.000	1.450
13	3	4	70.61	92.21	0.000	0.000	1.450
13	5	6	-70.61	-92.21	0.000	0.000	1.450
14	7	8	23.72	23.72	0.000	0.000	1.450
14	1	2	-10.00	-10.00	0.000	0.000	1.450
13	3	4	5.00	5.00	0.000	0.000	1.450
13	5	6	-5.00	-5.00	0.000	0.000	1.450
14	7	8	138.15	138.15	0.000	0.000	1.450

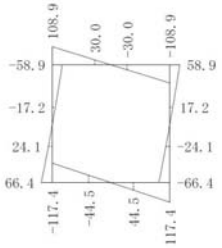
Load Number
13: Member Distribution Load (X Direction)
14: Member Distribution Load (Y Direction)

1.2.4 Calculation Results of Frame Analysis

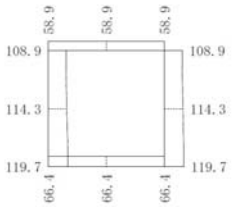
Bending Moment



Shear Force



Axial Force



1.2.5 Stress Intensity Calculation

■Bending Stress Intensity

Top Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-20.444	19.033	-20.444
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	424.8	0.0	424.8
	Internal	mm^2	0.0	394.9	0.0
Re-Bar	External	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 247 D— @— 804.0
	Internal	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
Neutral Axis	X	m	0.065	0.065	0.065
Stress Intensity	σc	N/mm^2	1.86	1.73	1.85
	σs	N/mm^2	76.07	70.82	75.18
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	566.4	526.5	566.4
	inp	mm^2	794.4	794.4	804.0
Case	——	——	Dead-1+Live-1	Dead-1+Liva-1	Dead-1+Liev-1

※Axial force is not considered.

Left Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-20.444	1.470	-22.035
Axial Force	N	kN	108.902	114.302	119.702
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar Arrangement	External	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
	Internal	mm^2	D13 @ 250 D— @— 506.8	D13 @ 250 D— @— 506.8	D13 @ 250 D— @— 506.8
Neutral Axis	X	m	0.184	1.414	0.189
Stress Intensity	σc	N/mm^2	1.28	0.30	1.36
	σs	N/mm^2	11.03	0.00	11.14
	σs'	N/mm^2	0.00	-2.01	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	794.4	506.8	794.4
Case	——	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Right Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-20.444	1.470	-22.035
Axial Force	N	kN	108.902	114.302	119.702
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar	External	mm^2	D16 @ 247 D— @— 804.0	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
	Internal	mm^2	D13 @ 250 D— @— 506.8	D13 @ 250 D— @— 506.8	D13 @ 250 D— @— 506.8
Neutral Axis	X	m	0.184	1.414	0.189
Stress Intensity	σc	N/mm^2	1.28	0.30	1.36
	σs	N/mm^2	10.96	0.00	11.14
	σs'	N/mm^2	0.00	-2.01	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	804.0	506.8	794.4
Case	——	———	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Bottom Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-22.035	20.505	-22.035
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	115.0	115.0	115.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	494.6	0.0	494.6
	Internal	mm^2	0.0	426.1	0.0
Re-Bar	External	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
	Internal	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
Neutral Axis	X	m	0.062	0.065	0.062
Stress Intensity	σc	N/mm^2	2.25	1.87	2.25
	σs	N/mm^2	88.29	76.29	88.29
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	659.5	568.2	659.5
	inp	mm^2	794.4	794.4	794.4
Case	——	———	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

■Shear Stress Intensity

$$\tau m = \frac{S}{b \times d} \leqq \tau a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm2)	τa (N/mm2)	Cases	L (m)
Top Slap	Left τ Point	30.042	360.0	0.083	0.457	Dead-1+Live-1	0.525
	Right τ Point	-30.042	360.0	0.083	0.457	Dead-1+Live-1	0.525
Left Side Wall	Upper τ Point	-17.192	360.0	0.048	0.457	Dead-1+Live-1	0.525
	Lower τ Point	24.118	360.0	0.067	0.495	Dead-1+Live-1	0.450
Right Side Wall	Upper τ Point	17.192	360.0	0.048	0.457	Dead-1+Live-1	0.525
	Lower τ Point	-24.118	360.0	0.067	0.495	Dead-1+Live-1	0.450
Bottom Slab	Left τ Point	-44.512	360.0	0.124	0.478	Dead-1+Live-1	0.450
	Right τ Point	44.512	360.0	0.124	0.478	Dead-1+Live-1	0.450

Note) τ Point: Check point for shear stress intensity
L: Distance from grid point of corner

2.2.2.2 SLUICEWAY TYPE B

(3) BREAST WALL - LAND SIDE

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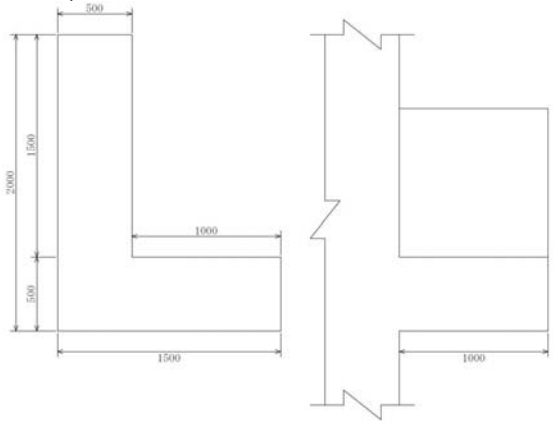
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1 Calculation of Land Side Breast Wall

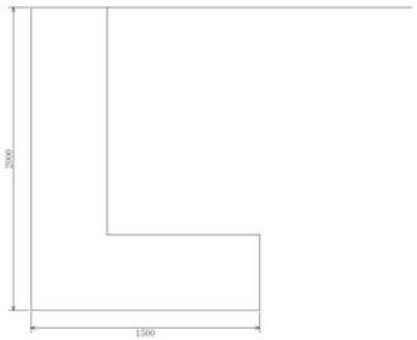
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm^2/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D19	250	1146.0
	Bottom Face	115.0	D19	250	1146.0

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

1.1.3 **Loads**

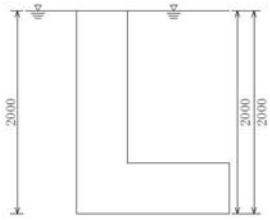
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

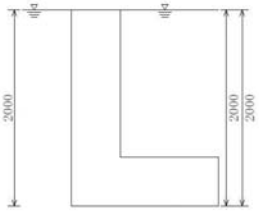
	(m)
Toe	2.000
Heel	2.000



1-2) Seismic Condition Number of Cases [1]

<Case 1>

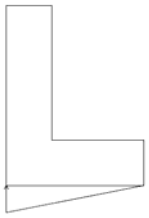
	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front



2) Subgrade Reaction

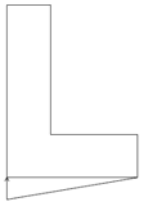
2-1) Normal <Case 1>

	(kN/m²), (m)
Toe	154.13
Heel	0.00
Load Width	1.500



2-2) Seismic <Case 1>

	(kN/m²), (m)
Toe	130.64
Heel	0.00
Load Width	1.500



3) Surcharge Load

Normal	kN/m²	10.00
Seismic	kN/m²	5.00

4) Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 **Load**

(1) **Normal Condition-1**

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W = 0.000 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (0.000+ 10.00× 1.500)/ 1.500

= 10.000 (kN/m²)

Earth Pressure at the Top

p1 = q0'・Ko = 10.000× 0.500 = 5.000 (kN/m²)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.000+ 5.000

= 5.000 (kN/m²)

Earth Pressure at Junction

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500×(20.00- 9.80)× 1.500+ 5.000

= 12.650 (kN/m²)

Design Earth Pressure

P = p3

= 12.650 (kN/m²)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

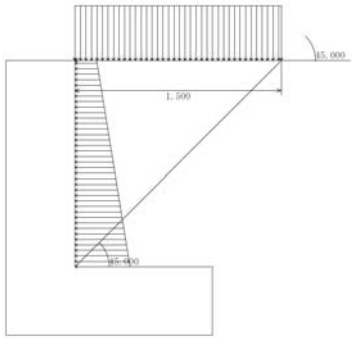
q_0 : Surcharge (kN/m²)

w_{qo} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 1.500× 9.80 = 14.700 (kN/m²)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m²)

(2) **Seismic Condition-1**

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.500 × 24.00 × 0.20 = 2.400

Thus、

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m³)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	0.000	(m)
Embankment Height under the water level surface	h2	=	1.500	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γt	=	19.00	(kN/m^3)
Unit Weight of Soil (Saturated)	γsat	=	20.00	(kN/m^3)
Unit Weight of Water	γw	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	1.863	(m)
Width of Converted Load	B	=	1.863	(m)
Internal Friction Angle of Soil	φ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh	=	0.345	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}$ (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}$ (kh')	=	19.026	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ + 0.00^\circ + 11.310^\circ\ )\times\sin(\ 30.00^\circ + 0.00^\circ\ )}{\cos(\ 0.00^\circ - 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}}$$

$\cot(\xi_{EA}-\alpha) = 0.85094$

Thus,

$$\cot(\xi_{EA}-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604(^\circ\ )$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ + 0.00^\circ + 19.026^\circ\ )\times\sin(\ 30.00^\circ + 0.00^\circ\ )}{\cos(\ 0.00^\circ - 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 19.026^\circ\ )}}$$

$\cot(\xi_{EA}'-\alpha) = 1.24217$

Thus,

$$\cot(\xi_{EA}'-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA}')} = 1.24217$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{1.24217}\right) = 38.836(^\circ\ )$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ - 11.310^\circ - 0.00^\circ\ )}{\cos(\ 11.310^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )}$$
$$\times\frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ + 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}{\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )\times\cos(\ 0.00^\circ - 0.00^\circ\ )}}\right]^2}$$

$= 0.4733$

In case $\varphi-\alpha-\theta_o < 0$, $\sin(\varphi-\alpha-\theta_o) = 0$.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ - 19.026^\circ - 0.00^\circ\ )}{\cos(\ 19.026^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ + 19.026^\circ + 0.00^\circ\ )}$$
$$\times\frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ + 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 19.026^\circ\ )}{\cos(\ 0.00^\circ + 19.026^\circ + 0.00^\circ\ )\times\cos(\ 0.00^\circ - 0.00^\circ\ )}}\right]^2}$$

$= 0.6214$

In case $\varphi-\alpha-\theta_o' < 0$, $\sin(\varphi-\alpha-\theta_o') = 0$.

Weight of Embankment W = 0.000 (kN/m)

Converted Load q0' = (W + q0 · wq0) / B = (0.000+ 5.00× 1.863) / 1.863 = 5.000 (kN/m^2)

Earth Pressure at the Top

$P1 = q0' \cdot K_{EA} = 5.000\times 0.4733 = 2.366$ (kN/m^2)

Earth Pressure at Water Level

$P2 = K_{EA}\cdot\gamma_t\cdot h1 + p1$
$= 0.4733\times 19.00\times 0.000+ 2.366$
$= 2.366$ (kN/m^2)

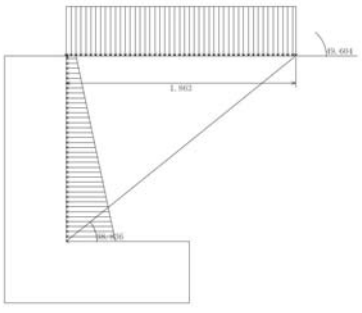
Earth Pressure at Junction

$P3 = K_{EA}'\cdot(\gamma_{sat}-\gamma_w)\cdot h2+p2$
$= 0.6214\times(\ 20.00- 9.80)\times 1.500+ 2.366$
$= 11.874$ (kN/m^2)

Design Earth Pressure

$P_{IE} = P3\cdot\cos\delta = 11.874\times\cos(\ 0.00^\circ\ )$
$= 11.874$ (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

Ph = hh · γ_w= 1.500× 9.80 = 14.700 (kN/m^2)

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m^2)	L (m)	P·l^2/2 (kN.m/m)
Water Pressure	14.70	1.000	7.35
Earth Pressure	12.65	1.000	6.32
Σ	27.35	----	13.68
Bending Moment M (kN.m/m) Σ(P·l^2/2) = 13.68			
Shear Force S (kN/m) Σ(P·l) = 27.35			

2) Seismic Condition-1

	P (kN/m^2)	L (m)	P·l^2/2 (kN.m/m)
Inertia force	2.40	1.000	1.20
Water Pressure	14.70	1.000	7.35
Earth Pressure	11.87	1.000	5.94
Σ	28.97	----	14.49
Bending Moment M (kN.m/m) Σ(P·l^2/2) = 14.49			
Shear Force S (kN/m) Σ(P·l) = 28.97			

1.2.3 **Stress Calculation**

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Front	mm^2	D16 - 4.00 = 794.4
	Back	mm^2	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	13.68
Re-bar	d1 As1	mm mm^2	410.0 794.4
Required Area of Re-bar	Back	mm^2	246.4
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm^2	1.01
	σs	N/mm^2	44.51
Allowable Value	σca	N/mm^2	8.20
	σsa	N/mm^2	140.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	328.5
	inp	mm^2	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	14.49
Re-bar	d1 As1	mm mm^2	410.0 794.4
Required Area of Re-bar	Back	mm^2	195.7
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm^2	1.07
	σs	N/mm^2	47.15
Allowable Value	σca	N/mm^2	12.30
	σsa	N/mm^2	186.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	261.0
	inp	mm^2	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	27.35
Re-bar	d1 As1	mm mm^2	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.067
Allowable Value	τa	N/mm^2	0.360
	τa2	N/mm^2	1.600

■Seismic Condition-1

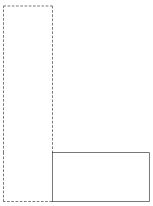
	Symbol	Unit	Junction
Shear Force	S	kN	28.97
Re-bar	d1 As1	mm mm^2	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.071
Allowable Value	τa	N/mm^2	0.540
	τa2	N/mm^2	2.400

1.3 **Calculation of Heel Slab**

1.3.1 **Load**

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

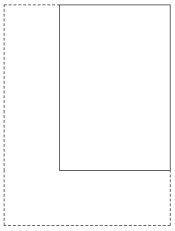
Thus,

Sw : Weight of Body (kN/m^2)

h : Height of Bottom Slab (m)

γ_s : Unit Weight of Concrete (kN/m^3)

1-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γt : Wet Unit Weight of Soil (kN/m^3)

γsat : Unit Weight of Soil underwater (kN/m^3)

1-3) Subgrade Reaction Force

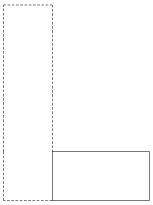
	Intensity of subgrade reaction (kN/m^2)
Base	102.75
Edge	0.00

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

(2) **) Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

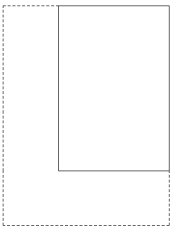
Thus、

Sw : Weight of Wall (kN/m^2)

H : Height of Bottom Slab (m)

γ_s : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	87.09
Edge	0.00

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

1.3.2 Summary of Cross-Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	102.75	1.000	51.38
Surcharge	-10.00	1.000	-5.00
Σ	70.35	----	35.18
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = -35.18		
Shear Force S (kN/m)	Σ(P・l) = 70.35		

1-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	0.00	1.000	0.00
Surcharge	-10.00	1.000	-5.00
Σ	-32.40	----	-16.20
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = -16.20		
Shear Force S (kN/m)	Σ(P・l) = -32.40		

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	87.09	1.000	43.55
Surcharge	-5.00	1.000	-2.50
Σ	59.69	----	29.85
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 29.85		
Shear Force S (kN/m)	Σ(P・l) = 59.69		

2-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	0.00	1.000	0.00
Surcharge	-5.00	1.000	-2.50
Σ	-27.40	----	-13.70
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = -13.70		
Shear Force S (kN/m)	Σ(P・l) = -27.40		

1.3.3 Stress Intensity Calculation

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Upper	mm^2	D19 - 4.00 = 1146.0
	Lower	mm^2	D19 - 4.00 = 1146.0

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	35.18	-16.20
Re-bar	d1 As1	mm mm^2	385.0 1146.0	90.0 1146.0
Required Area of Re-bar	Upper	mm^2		292.7
	Lower	mm^2	690.4	
Neutral Axis	X	m	0.079	0.082
Stress Intensity	σc	N/mm^2	2.47	1.03
	σs	N/mm^2	85.61	36.95
Allowable Value	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	920.6	390.2
	inp	mm^2	1146.0	1146.0

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	29.85	-13.70
Re-bar	d1 As1	mm mm^2	385.0 1146.0	90.0 1146.0
Required Area of Re-bar	Upper	mm^2		185.0
	Lower	mm^2	436.1	
Neutral Axis	X	m	0.079	0.082
Stress Intensity	σc	N/mm^2	2.10	0.87
	σs	N/mm^2	72.64	31.25
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	581.5	246.6
	inp	mm^2	1146.0	1146.0

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	70.35	-32.40
Re-bar	d1 As1	mm mm^2	385.0 1146.0	90.0 1146.0
Effective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.183	0.079
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	59.69	-27.40
Re-bar	d1 As1	mm mm^2	385.0 1146.0	90.0 1146.0
Effective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.155	0.067
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400

2.2.2.2 SLUICEWAY TYPE B

(4) BREAST WALL - RIVER SIDE

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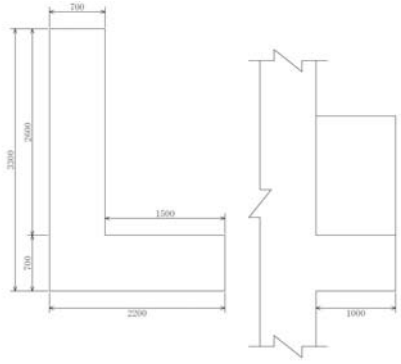
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1 Calculation of River Side Breast Wall

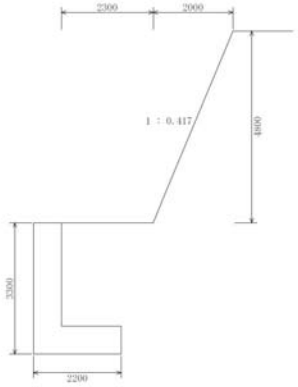
1.1 Design Condition

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm^2/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D16	250	794.4
	Bottom Face	115.0	D16	250	794.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.3 **Loads**

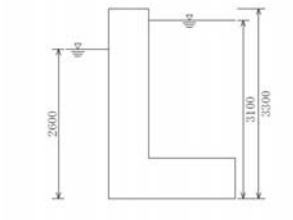
■Basic Load

1)Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

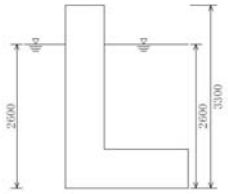
	(m)
Toe	2.600
Heel	3.100



1-2) Seismic Condition Number of Cases [1]

<Case 1>

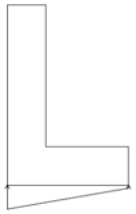
	(m)
Toe	2.600
Heel	2.600
Direction	Back → Front



2)Subgrade Reaction

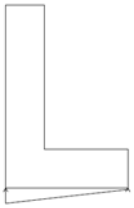
2-1) Normal <Case 1>

	(kN/m²),(m)
Toe	173.05
Heel	21.72
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m²),(m)
Toe	108.03
Heel	9.82
Load Width	0.000



3)Surcharge Load

Normal	kN/m²	10.00
Seismic	kN/m²	5.00

4)Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 **Load**

(1) **Normal Condition-1**

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W = 155.040 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (155.040+ 10.00× 3.100)/ 2.600

= 71.554 (kN/m²)

Earth Pressure at the Top

p1 = q0'・Ko = 71.554× 0.500 = 35.777 (kN/m²)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.200+ 35.777

= 37.677 (kN/m²)

Earth Pressure at Bottom Surface of Base

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500×(20.00- 9.80)× 2.400+ 37.677

= 49.917 (kN/m²)

Design Earth Pressure

P = p3

= 49.917 (kN/m²)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

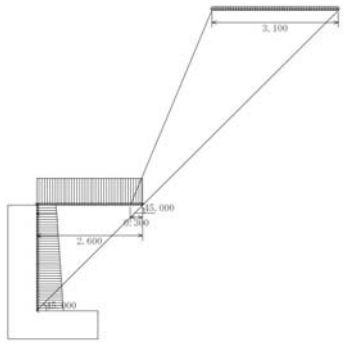
q_0 : Surcharge (kN/m²)

w_{qo} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Loads Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 2.400× 9.80 = 23.520 (kN/m²)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

(2) **Seismic Condition-1**

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.700 × 24.00 × 0.20 = 3.360

Thus、

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m³)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	0.700	(m)
Embankment Height under the water level surface	h2	=	1.900	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γt	=	19.00	(kN/m^3)
Unit Weight of Soil (Dry)	γsat	=	20.00	(kN/m^3)
Unit Weight of Water	γw	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	2.442	(m)
Width of Converted Load	B	=	2.657	(m)
Internal Friction Angle of Soil	φ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δE_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	Kh'	=	0.299	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}(kh)$	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}(kh')$	=	16.638	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{ES}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_0)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_0)}}$$

$$= -\tan(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ ) + \sec(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ ) \times\sqrt{\frac{\cos(\ 0.00^\circ + 0.00^\circ + 11.310^\circ\ )\times\sin(\ 30.00^\circ + 0.00^\circ\ )}{\cos(\ 0.00^\circ - 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}}$$

$$\cot(\xi_{ES}-\alpha) = 0.85094$$

Thus,

$$\cot(\xi_{ES}-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{ES})} = 0.85094$$

$$\xi_{ES} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$K_{ES} = \frac{\cos^2(\phi-\theta_0-\theta)}{\cos\theta_0\cdot\cos^2\theta\cdot\cos(\theta+\theta_0+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_0)}{\cos(\theta+\theta_0+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ - 11.310^\circ - 0.00^\circ\ )}{\cos(\ 11.310^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )} \times \frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ + 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}{\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )\times\cos(\ 0.00^\circ - 0.00^\circ\ )}}\right]^2}$$

$$= 0.4733$$

However、φ-α-θ.' < 0 のときは sin(φ-α-θ.')

Weight of Embankment W

$$W = 127.653\ (\text{kN/m})$$

Converted Load q0'

$$q0' = (W + q0\cdot wq0)\ /\ B = (127.653 + 5.00\times 2.442)\ /\ 2.657 = 52.631\ (\text{kN/m}^2)$$

Earth Pressure at the Top

$P1 = q0'\cdot K_{EA} = 52.631\times 0.4733 = 24.908\ (\text{kN/m}^2)$

Earth Pressure at Water Level

$P2 = K_{EA}\cdot\gamma_t\cdot h1 + p1$

$= 0.4733\times 19.00\times 0.700 + 24.908$

$= 31.203\ (\text{kN/m}^2)$

Earth Pressure at Junction

$P3 = K_{EA}\cdot(\gamma_{sat}-\gamma_w)\cdot h2 + p2$

$= 0.5681\times(20.00 - 9.80)\times 1.900 + 31.203$

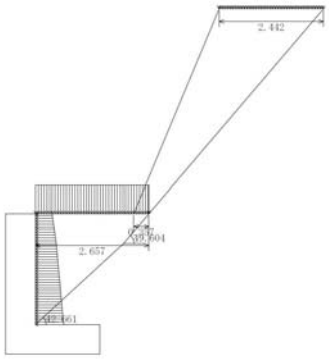
$= 42.212\ (\text{kN/m}^2)$

Design Earth Pressure

$P_{HE} = P3\cdot\cos\delta = 42.212\times\cos(0.00^\circ)$

$= 42.212\ (\text{kN/m}^2)$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$Ph = hh\cdot\gamma_w = 1.900\times 9.80 = 18.620\ (\text{kN/m}^2)$

Thus、

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m^2)	L (m)	P·l^2/2 (kN.m/m)
Water Pressure	23.52	1.000	11.76
Earth Pressure	49.92	1.000	24.96
Σ	73.44	----	36.72
Bending Moment M (kN.m/m) Σ(P·l^2/2) = 36.72			
Shear Force S (kN/m) Σ(P·l) = 73.44			

2) Seismic Condition-1

	P (kN/m^2)	L (m)	P·l^2/2 (kN.m/m)
Inertia force	3.36	1.000	1.68
Water Pressure	18.62	1.000	9.31
Earth Pressure	42.21	1.000	21.11
Σ	64.19	----	32.10
Bending Moment M (kN.m/m) Σ(P·l^2/2) = 32.10			
Shear Force S (kN/m) Σ(P·l) = 64.19			

1.2.3 Stress Calculation

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Front	mm^2	D16 - 4.00 = 794.4
	Back	mm^2	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	36.72
Re-bar	d1 As1	mm mm^2	610.0 794.4
Required Area of Re-bar	Back	mm^2	446.1
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm^2	1.46
	σs	N/mm^2	79.53
Allowable Value	σca	N/mm^2	8.20
	σsa	N/mm^2	140.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	594.7
	inp	mm^2	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	32.10
Re-bar	d1 As1	mm mm^2	610.0 794.4
Required Area of Re-bar	Back	mm^2	291.5
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm^2	1.28
	σs	N/mm^2	69.52
Allowable Value	σca	N/mm^2	12.30
	σsa	N/mm^2	186.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	388.7
	inp	mm^2	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	73.44
Re-bar	d1 As1	mm mm^2	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.120
Allowable Value	τa	N/mm^2	0.360
	τa2	N/mm^2	1.600

■Seismic Condition-1

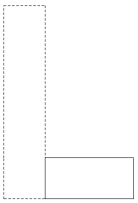
	Symbol	Unit	Junction
Shear Force	S	kN	64.19
Re-bar	d1 As1	mm mm^2	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.105
Allowable Value	τa	N/mm^2	0.540
	τa2	N/mm^2	2.400

1.3 Calculation of Bottom Slab

1.3.1 **Load**

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

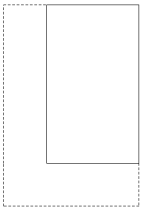
Thus,

Sw : Weight of Body (kN/m^2)

h :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

1-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.200× 19.00 + 2.400× 20.00 = 51.800

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.200× 19.00 + 2.400× 20.00 = 51.800

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

1-3) Subgrade Reaction Force

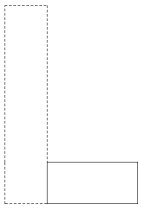
	Intensity of subgrade reaction (kN/m^2)
Base	124.90
Edge	21.72

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.759× 9.80	27.039
Edge	3.100× 9.80	30.380

(2) **Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

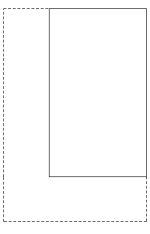
Thus、

Sw : Weight of Body (kN/m2)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.700× 19.00 + 1.900× 20.00 = 51.300

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.700× 19.00 + 1.900× 20.00 = 51.300

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	76.78
Edge	9.82

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.600× 9.80	25.480
Edge	2.600× 9.80	25.480

1.3.2 **Summary of Cross-Sectional Force**

1) Normal Condition-1

1-1) Junction Section

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.80	1.000	-25.90
Uplift Force	27.04	1.000	13.52
Intensity of Subgrade Reaction	124.90	1.000	62.45
Σ	83.34	----	41.67
Bending Moment M (kN.m/m) Σ(P・l²/2) = 41.67			
Shear Force S (kN/m) Σ(P・l) = 83.34			

1-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.80	1.000	-25.90
Uplift Force	30.38	1.000	15.19
Intensity of Subgrade Reaction	21.72	1.000	10.86
Σ	-16.50	----	-8.25
Bending Moment M (kN.m/m) Σ(P・l²/2) = -8.25			
Shear Force S (kN/m) Σ(P・l) = -16.50			

2) Seismic Condition-1

2-1) Base

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.30	1.000	-25.65
Uplift Force	25.48	1.000	12.74
Intensity of Subgrade Reaction	76.78	1.000	38.39
Σ	34.16	----	17.08
Bending Moment M (kN.m/m) Σ(P・l²/2) = 17.08			
Shear Force S (kN/m) Σ(P・l) = 34.16			

2-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.30	1.000	-25.65
Uplift Force	25.48	1.000	12.74
Intensity of Subgrade Reaction	9.82	1.000	4.91
Σ	-32.80	----	-16.40
Bending Moment M (kN.m/m) Σ(P・l²/2) = -16.40			
Shear Force S (kN/m) Σ(P・l) = -32.80			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Upper	mm²	D16 - 4.00 =794.4
	Lower	mm²	D16 - 4.00 =794.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	41.67	-8.25
Re-bar	d1 As1	mm mm²	585.0 794.4	90.0 794.4
Required Area of Re-bar	Upper	mm²		98.3
	Lower	mm²	530.0	
Neutral Axis	X	m	0.085	0.087
Stress Intensity	σc	N/mm²	1.77	0.33
	σs	N/mm²	94.20	17.87
Allowable Value	σca	N/mm²	8.20	8.20
	σsa	N/mm²	140.00	140.00
Minimum of Re-bar Area	min	mm²		
	req	mm²	706.6	131.1
	inp	mm²	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	17.08	-16.40
Re-bar	d1 As1	mm mm²	585.0 794.4	90.0 794.4
Required Area of Re-bar	Upper	mm²		147.7
	Lower	mm²	160.6	
Neutral Axis	X	m	0.085	0.087
Stress Intensity	σc	N/mm²	0.73	0.65
	σs	N/mm²	38.62	35.52
Allowable Value	σca	N/mm²	12.30	12.30
	σsa	N/mm²	186.00	186.00
Minimum of Re-bar Area	min	mm²		
	req	mm²	214.2	196.9
	inp	mm²	794.4	794.4

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	83.34	-16.50
Re-bar	d1 As1	mm mm²	585.0 794.4	90.0 794.4
Effective Height	d	mm	585.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.142	0.027
Allowable Value	τa	N/mm²	0.360	0.360
	τa2	N/mm²	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	34.16	-32.80
Re-bar	d1 As1	mm mm²	585.0 794.4	90.0 794.4
Effective Height	d	mm	585.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.058	0.054
Allowable Value	τa	N/mm²	0.540	0.540
	τa2	N/mm²	2.400	2.400

2.2.2.3 SLUICEWAY TYPE C

(1) BOX - LONGITUDINAL

Structural Calculation of Sluiceway Type-C

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1 Design Condition

1.1 Design Condition

1.1.1 Basic Condition

1) Culvert Shape: Rectanglar

2) Culvert Type: Double Holes

3) Allowable Displacement

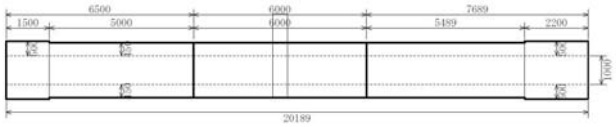
Residual Settlement	: 300.0 (mm)	
Residual Settlement for Rigid Support		: 50.0 (mm)
Relative Displacement	Base Width	: 1.0 (%)
		± : 50.0 (mm)

4) Type of Joint : Flexible Joint

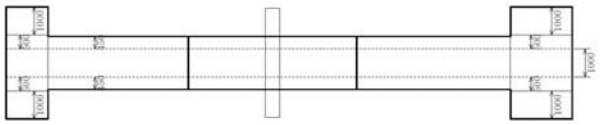
5) Allowable Opening: 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

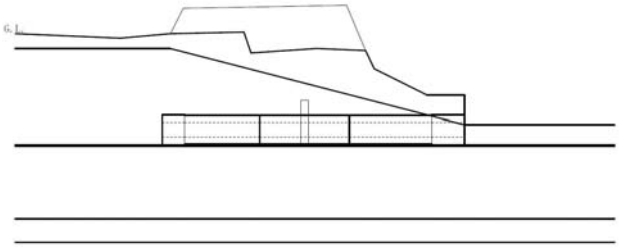
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Leeve Cross-section



1.2 Shape of Culvert Body

1.2.1 Span and Block

1) Spans

Number of Spans : 3
Total Length of Spans : 20.189 (m)

Span No	Name of Span	Length of Span (m)	Number of Blocks
1	Land Side	6.500	2
2	Center	6.000	1
3	River Side	7.689	2

2) Blocks

Span/ Block	Length of Block (m)	Depth for Subgrade Reaction(m)
1- 1	1.500	12.000
1- 2	5.000	5.700
2- 1	6.000	5.700
3- 1	5.489	5.700
3- 2	2.200	12.000

1.2.2 Sectional Dimension

1) Dimension (Block)

Span/ Block	Left Inside Width	Inside Height Y2 (m)
1- 1	1.000	1.000
1- 2	1.000	1.000
2- 1	1.000	1.000
3- 1	1.000	1.000
3- 2	1.000	1.000

Span/ Block	Thickness of Left Side Wall X1(m)	Thickness of Top Slab Y1(m)	Thickness of Bottom Slab Y3(m)	Height of Overhang Y4(m)	Length of Left Overhang B1(m)
1- 1	0.500	0.500	0.500	0.500	1.000
1- 2	0.450	0.450	0.450	0.000	0.000
2- 1	0.450	0.450	0.450	0.000	0.000
3- 1	0.450	0.450	0.450	0.000	0.000
3- 2	0.500	0.500	0.500	0.700	1.000

1.3 Reinforcement

Main Re-bar

Span No	Block No	Flange		Reinforcing Bar				
		Portion	b (mm)	t (mm)	Outside Diameter@Pitch (Number)	Outside Cover (mm)	Inside Diameter@Pitch (Number)	Inside Cover (mm)
1	1	Top Slab	2000.0	500.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	2000.0	500.0	D16@250(6)	115.0	D16@250(8)	90.0
	2	Top Slab	1900.0	450.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	1900.0	450.0	D16@250(6)	115.0	D16@250(8)	90.0
2	1	Top Slab	1900.0	450.0	D19@250(6)	90.0	D19@250(8)	90.0
		Bottom Slab	1900.0	450.0	D19@250(6)	115.0	D19@250(8)	90.0
3	1	Top Slab	1900.0	450.0	D22@250(6)	90.0	D22@250(8)	90.0
		Bottom Slab	1900.0	450.0	D22@250(6)	115.0	D22@250(8)	90.0
	2	Top Slab	2000.0	500.0	D22@250(6)	90.0	D22@250(8)	90.0
		Bottom Slab	2000.0	500.0	D22@250(6)	115.0	D22@250(8)	90.0

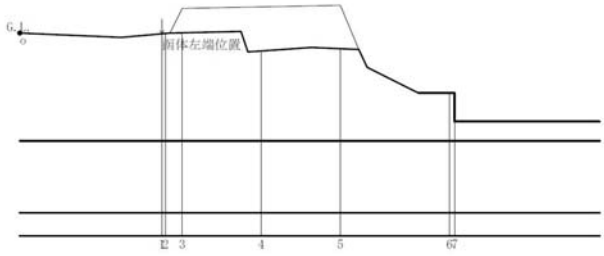
2 Settlement and Lateral Displacement

2.1 Immediate Settlement

2.1.1 Settlemet Calculation Points

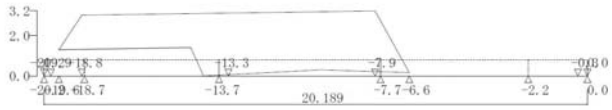
Settlemet Calculation Points

No	Calculation Point (m)	Name
1	-20.188	Box end (land side)
2	-19.938	Breast wall (land side)
3	-18.789	Levee end (land side)
4	-13.339	Levee center
5	-7.889	Levee end (river side)
6	-0.350	Breast wall (river side)
7	0.000	Box end (river side)



2.1.2 Summery of Immediate Settlement

No	Calculation Point (m)	Name	Immediate Settlement (mm)
1	-20.188	Box end (land side)	4.1
2	-19.938	Breast wall (land side)	5.6
3	-18.789	Levee end (land side)	11.1
4	-13.339	Levee center	26.8
5	-7.889	Levee end (river side)	22.0
6	-0.350	Breast wall (river side)	0.0
7	0.000	Box end (river side)	0.0



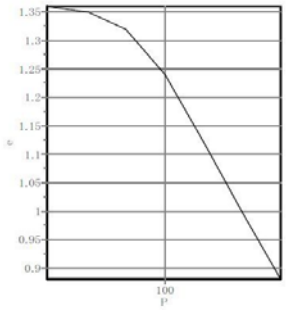


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

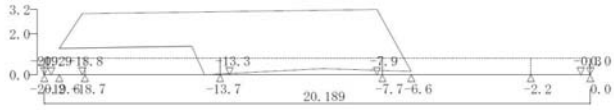
No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/ m³)	Unit Weight (Saturated) (kN/ m³)	Pre-Consolidation Stress q0 (kN/m²)	Elastic Modulus Es (kN/m²)
1	As	Sand	7.422	17.500	18.500	0.0	6900.0
2	Ac	Clay	12.372	15.500	16.500	0.0	5400.0
3	Dc2	Clay	13.952	17.500	18.500	0.0	15700.0

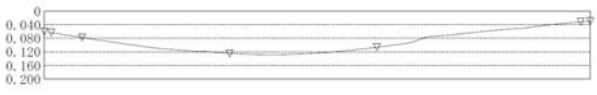
No	Concolidation Pressure P(kN/m²)	Void Ratio e
1	12.0000	1.3600
2	25.0000	1.3500
3	50.0000	1.3200
4	100.0000	1.2400
5	200.0000	1.1200
6	400.0000	1.0000
7	800.0000	0.8800



2.2.2 Summery of Consolidation Settlement

No	Calculation Point (mm)	Name	Consolidation Settlement (mm)
1	-20.188	Box end (land side)	60.6
2	-19.938	Breast wall (land side)	63.6
3	-18.789	Levee end (land side)	77.7
4	-13.339	Levee center	124.6
5	-7.889	Levee end (river side)	106.5
6	-0.350	Breast wall (river side)	31.5
7	0.000	Box end (river side)	29.1



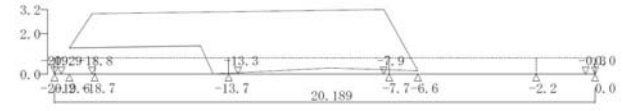


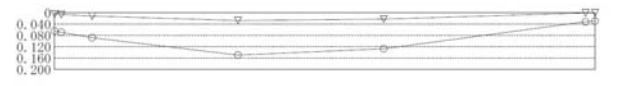
2.3 Residual Settlement

2.3.1 Sumarry of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vaue	Judge
1	-20.188	Box end (land side)	4.1	59.7	0.0	63.9	300.000	OK
2	-19.938	Breast wall (land side)	5.6	62.6	0.0	68.2	300.000	OK
3	-18.789	Levee end (land side)	11.1	76.6	0.0	87.7	300.000	OK
4	-13.339	Levee center	26.8	122.3	0.0	149.1	300.000	OK
5	-7.889	Levee end (river side)	22.0	104.7	0.0	126.7	300.000	OK
6	-0.350	Breast wall (river side)	0.0	31.3	0.0	31.3	300.000	OK
7	0.000	Box end (river side)	0.0	29.0	0.0	29.0	300.000	OK

The maximum of residual settlement is above 50.0(mm), herence the foundation is taken as flexible





▽ : Immediate Settlement

○ : Residual Settlement

3 Calculation of Box Culvert regarding Longitudal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B}\cdot\frac{d^4w}{dx^4}+k_v(w-w_g)=q \text{ (Swag)}$$

$$\frac{EA}{U}\cdot\frac{d^2u}{dx^2}+k_s(u-u_g)=p \text{ (Displacement in axial direction of Box Culvert)}$$

Thus,

w : Displacement of Box Culvert (Swag : cm {m})
w_g : Displacement of the Ground (Residual Settlement : cm {m})
k_v : Modulus of Sub grade Reaction in Vertical Direction (kgf/cm³) {kN/m³}
B : Width of Box Culvert (cm) {m}
EI : Rigidity of Box Culvert (kgf･cm²) {kN･m²}
q : Vertical External Force (kgf/cm²) {kN/m²}
u : Displacement on axial direction of Box Culvert (cm) {m}
u_g : Displacement of Ground (Lateral Displacement ; cm {m})
k_s : Modulus of Lateral Shear Sub grade Reaction (kgf/cm³) {kN/m³}
U : Circumference of Box Culvert (cm) {m}
EA : Rigidity of Box Culvert in axial direction (kgf) {kN}
p : Axial External Force (kgf/cm²){kN/m²}

3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{om}=\frac{\log\frac{(B+2h_n\cdot\tan\theta)\cdot L}{(L+2h_n\cdot\tan\theta)\cdot B}}{\sum\frac{1}{E_i}\log\frac{(B+2h_i\cdot\tan\theta)(L+2h_{i-1}\cdot\tan\theta)}{(L+2h_i\cdot\tan\theta)(B+2h_{i-1}\cdot\tan\theta)}}$$

In case of B=L

$$E_{om}=\frac{-\frac{1}{B+2h_n\cdot\tan\theta}+\frac{1}{B}}{\sum\frac{1}{E_i}\left(-\frac{1}{B+2h_i\cdot\tan\theta}+\frac{1}{B+2h_{i-1}\cdot\tan\theta}\right)}$$

Thus

Eom ; Converted Modulus of Deformation
B ; Loading Width = Width of Culvert
L ; Loading Length = Length of a span
hn ; Depth for Calculation
hn ; Depth from the ground to the bottom Elevation of Each Layer（m）
Ei ; Converted Modulus of Deformation of Each Layer(kN/m²)
θ ; Angle of Load Dispersion（θ=30°）

Span1-Block1 Land Side

B			4.000 (m)
L			6.500 (m)
hn			12.000 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	4.850	4.850	21600.0
2	7.150	12.000	62800.0
Total	12.000		
Eom	26529.8 (kN/m²)		

※Layer Thickness and Depths are the values based on subgrade Surface.

Span1-Block2 Land Side

B			1.900 (m)
L			6.500 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	4.850	4.850	21600.0
2	0.850	5.700	62800.0
Total	5.700		
Eom	22431.0 (kN/m²)		

※Layer Thickness and Depths are values Calculated from the subgrade

Span2-Block1 Center

B			1.900 (m)
L			6.000 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	4.850	4.850	21600.0
2	0.850	5.700	62800.0
Total	5.700		
Eom	22412.7 (kN/m²)		

※Layer and Depth is the values from the subgrade

Span3-Block1 River Side

B			1.900 (m)
L			7.689 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	4.850	4.850	21600.0
2	0.850	5.700	62800.0
Total	5.700		
Eom	22468.7 (kN/m²)		

※Layer and Depth is the values from the subgrade

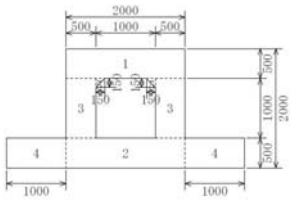
Span3-Block2 River Side

B			4.000 (m)
L			7.689 (m)
hn			12.000 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	4.850	4.850	21600.0
2	7.150	12.000	62800.0
Total	12.000		
Eom	26782.8 (kN/m²)		

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

Span1-Block1　Land Side

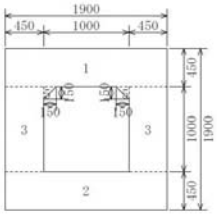


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.023	1.450	0.0326	0.0473	0.00003
Total	4.023		3.2826	4.2348	0.14586

Yg = Σ(Ai・Yi)/ΣAi = 3.2826 / 4.023 = 0.8161 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 4.2348 + 0.14586 - 0.6660・4.023= 1.70183 (m^4)

Span1-Block2　Land Side

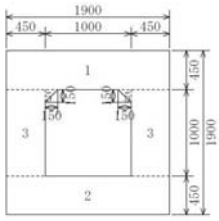


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.633 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.633= 1.00722 (m^4)

Span2-Block1　Center

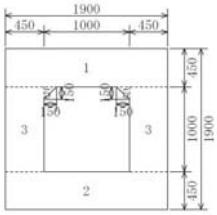


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.633 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.633= 1.00722 (m^4)

Span3-Block1　River Side

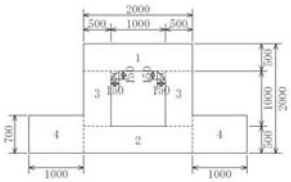


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.633 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.633 = 1.00722 (m^4)

Span3-Block2　River Side



Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.400	0.350	0.4900	0.1715	0.05717
5	0.023	1.450	0.0326	0.0473	0.00003
Total	4.423		3.5226	4.3438	0.18219

Yg = Σ(Ai・Yi)/ΣAi = 3.5226 / 4.423 = 0.7965 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 4.3438 + 0.18219 - 0.6344・4.423= 1.72015 (m^4)

3.2.3 Table of Modulus of Subgarade Reaction

Coefficient of Lateral Shear Reaction of Soil

$k_s = \lambda \cdot k_v$

Thus、

ks: Coefficient of Lateral Shear Reaction of Soil (kN/m2)

λ ; Ratio between the coefficient of Lateral Shear Reaction of Soil and Vertical Sub grade Reaction (=0.333)

kv : Coefficient of Vertical Sub grade Reaction

3.2.4 List of Modulus of Subgrade Reaction

Calculated Value

Normal Condition

Span Block	Position (m)	B (m)	k_v (kN/m^3)	k_s (kN/m^3)	k_v・B (kN/m^2)	k_s・B (kN/m^2)
1-1	-20.189～-18.689	4.000	10564.3	3517.9	42257.1	14071.6
1-2	-18.689～-13.689	1.900	11808.5	3932.2	22436.1	7471.2
2-1	-13.689～-7.689	1.900	12158.3	4048.7	23100.8	7692.6
3-1	-7.689～-2.200	1.900	11106.2	3698.4	21101.7	7026.9
3-2	-2.200～0.000	4.000	10013.9	3334.6	40055.5	13338.5

Seismic Condition

Span Block	Position (m)	B (m)	k_v (kN/m^3)	k_s (kN/m^3)	k_v・B (kN/m^2)	k_s・B (kN/m^2)
1-1	-20.189～-18.689	4.000	21128.5	7035.8	84514.1	28143.2
1-2	-18.689～-13.689	1.900	23616.9	7864.4	44872.2	14942.4
2-1	-13.689～ -7.689	1.900	24316.6	8097.4	46201.6	15385.1
3-1	-7.689～ -2.200	1.900	22212.3	7396.7	42203.4	14053.7
3-2	-2.200～ 0.000	4.000	20027.8	6669.2	80111.0	26677.0

Used Value

Normal Condition

Span Block	Position (m)	k_v・B (kN/m^2)	k_s・B (kN/m^2)
1-1	-20.189～-18.689	43346.0	14434.2
1-2	-18.689～-13.689	23100.8	7692.6
2-1	-13.689～ -7.689	21837.5	7271.9
3-1	-7.689～ -2.200	21626.2	7201.5
3-2	-2.200～ 0.000	40923.5	13627.5

Seismic Condition

Span Block	Position (m)	Reduction Ratio DE	k_v・B (kN/m^2)	k_s・B (kN/m^2)
1-1	-20.189～-18.689	1.000	86691.9	28868.4
1-2	-18.689～-13.689	1.000	46201.6	15385.1
2-1	-13.689～ -7.689	1.000	43675.0	14543.8
3-1	-7.689～ -2.200	1.000	43252.4	14403.0
3-2	-2.200～ 0.000	1.000	81847.0	27255.0

3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

W = (A1 + A2 + A3)･γc (kN/m)

A1: Cross Sectional Area (Excluding Hunch) (m^2)

A2: Area of Upper Side Hunch (m^2)

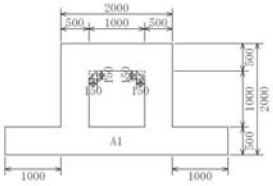
A3: Area of Lower Side Hunch (m^2)

γc: Unit Weight (Concrete) (kN/m^3)

Span No. 1-1 Land Side

W = (4.000 + 0.023 + 0.000)･ 24.000

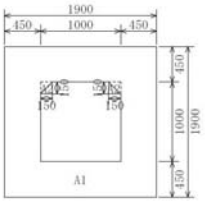
= 96.540 (kN/m)



Span No. 1-2 Land Side

W = (2.610 + 0.023 + 0.000)･ 24.000

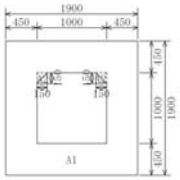
= 63.180 (kN/m)



Span No. 2-1 Center

W = (2.610 + 0.023 + 0.000)･ 24.000

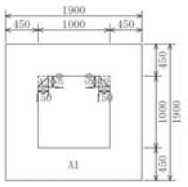
= 63.180 (kN/m)



Span No. 3-1 River Side

W = (2.610 + 0.023 + 0.000)･ 24.000

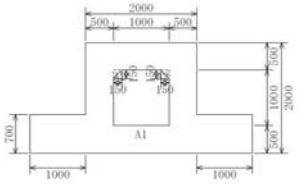
= 63.180 (kN/m)



Span No. 3-2 River Side

W = (4.400 + 0.023 + 0.000)･ 24.000

= 106.140 (kN/m)



2) Seepage Cutoff Wall Body Weight

A1 = X1･L2

A2 = L1･Y1･2

W = (A1 + A2)･B･γc (kN)

X1: Top Slab Width (m)

Y1: Side Wall Height (m)

L1: Side Wall Width (m)

L2: Top Slab Height (m)

A1: Top Slab Area (m^2)

A2: Side Wall Area (m^2)

B: Thickness (m)

γc: Unit Weight (Concrete) (kN/m^3)

SpanNo.2-SpanDistance from Base Point (3.000)

A1 = 3.900･ 1.000

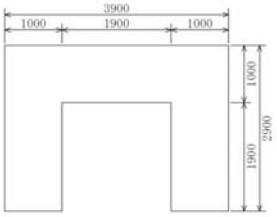
= 3.900 (m^2)

A2 = 1.000･ 1.900･2

= 3.800 (m^2)

W = (3.900 + 3.800)･ 0.500･ 24.00

= 92.400 (kN)



3.3.2 Ground Displacement Load (Settlement、Lateral Displacement)

1) Equivalent Load for Ground Settlement

【Normal Condition】

Span1 Name of Span: [Land Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-20.189～-19.939	4.000	43346.0	63.8	68.2	-2767.222	-2956.303
1-(2)	-19.939～-19.689	4.000	43346.0	68.2	72.5	-2956.303	-3144.376
1-(3)	-19.689～-19.189	4.000	43346.0	72.5	81.6	-3144.376	-3537.494
1-(4)	-19.189～-18.689	4.000	43346.0	81.6	89.2	-3537.494	-3864.937
2-(5)	-18.689～-18.189	1.900	23100.8	89.2	96.8	-2059.780	-2236.045
2-(6)	-18.189～-17.689	1.900	23100.8	96.8	104.8	-2236.045	-2421.909
2-(7)	-17.689～-17.189	1.900	23100.8	104.8	112.3	-2421.909	-2594.056
2-(8)	-17.189～-16.689	1.900	23100.8	112.3	119.2	-2594.056	-2754.165
2-(9)	-16.689～-16.189	1.900	23100.8	119.2	125.6	-2754.165	-2902.411
2-(10)	-16.189～-15.689	1.900	23100.8	125.6	130.5	-2902.411	-3015.175
2-(11)	-15.689～-15.189	1.900	23100.8	130.5	134.2	-3015.175	-3099.530
2-(12)	-15.189～-14.689	1.900	23100.8	134.2	143.5	-3099.530	-3315.829
2-(13)	-14.689～-14.189	1.900	23100.8	143.5	143.8	-3315.829	-3321.748
2-(14)	-14.189～-13.689	1.900	23100.8	143.8	146.6	-3321.748	-3386.698

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(15)	-13.689～-13.189	1.900	21837.5	146.6	149.9	-3201.491	-3274.147
1-(16)	-13.189～-12.689	1.900	21837.5	149.9	151.8	-3274.147	-3315.732
1-(17)	-12.689～-12.189	1.900	21837.5	151.8	152.4	-3315.732	-3328.648
1-(18)	-12.189～-11.689	1.900	21837.5	152.4	152.4	-3328.648	-3329.022
1-(19)	-11.689～-11.189	1.900	21837.5	152.4	152.1	-3329.022	-3322.519
1-(20)	-11.189～-10.689	1.900	21837.5	152.1	150.8	-3322.519	-3294.017
1-(21)	-10.689～-10.189	1.900	21837.5	150.8	149.5	-3294.017	-3263.872
1-(22)	-10.189～ -9.689	1.900	21837.5	149.5	148.0	-3263.872	-3231.344
1-(23)	-9.689～ -9.189	1.900	21837.5	148.0	143.9	-3231.344	-3143.173
1-(24)	-9.189～ -8.689	1.900	21837.5	143.9	138.9	-3143.173	-3032.228
1-(25)	-8.689～ -8.189	1.900	21837.5	138.9	132.0	-3032.228	-2883.494
1-(26)	-8.189～ -7.689	1.900	21837.5	132.0	122.8	-2883.494	-2680.614

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(27)	-7.689～ -7.189	1.900	21626.2	122.8	113.5	-2654.673	-2454.247
1-(28)	-7.189～ -6.689	1.900	21626.2	113.5	102.9	-2454.247	-2225.049
1-(29)	-6.689～ -6.189	1.900	21626.2	102.9	83.6	-2225.049	-1806.996
1-(30)	-6.189～ -5.689	1.900	21626.2	83.6	73.9	-1806.996	-1598.234
1-(31)	-5.689～ -5.189	1.900	21626.2	73.9	69.1	-1598.234	-1494.109
1-(32)	-5.189～ -4.689	1.900	21626.2	69.1	65.0	-1494.109	-1405.563
1-(33)	-4.689～ -4.189	1.900	21626.2	65.0	60.8	-1405.563	-1315.689
1-(34)	-4.189～ -3.689	1.900	21626.2	60.8	56.7	-1315.689	-1225.465
1-(35)	-3.689～ -3.189	1.900	21626.2	56.7	53.5	-1225.465	-1156.247
1-(36)	-3.189～ -2.689	1.900	21626.2	53.5	51.1	-1156.247	-1105.210
1-(37)	-2.689～ -2.200	1.900	21626.2	51.1	47.1	-1105.210	-1018.555
2-(38)	-2.200～ -2.189	4.000	40923.5	47.1	47.0	-1927.423	-1922.827
2-(39)	-2.189～ -1.689	4.000	40923.5	47.0	42.1	-1922.827	-1724.016
2-(40)	-1.689～ -1.189	4.000	40923.5	42.1	37.7	-1724.016	-1543.967
2-(41)	-1.189～ -0.900	4.000	40923.5	37.7	35.4	-1543.967	-1448.062
2-(42)	-0.900～ -0.689	4.000	40923.5	35.4	33.8	-1448.062	-1381.673
2-(43)	-0.689～ -0.189	4.000	40923.5	33.8	30.2	-1381.673	-1235.949
2-(44)	-0.189～ 0.000	4.000	40923.5	30.2	29.0	-1235.949	-1184.916



2) Equivalent Load for Ground Settlement

【Seismic Condition】

Span1 Name of Span: [Land Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-20.189～-19.939	4.000	86691.9	63.8	68.2	-5534.443	-5912.606
1-(2)	-19.939～-19.689	4.000	86691.9	68.2	72.5	-5912.606	-6288.752
1-(3)	-19.689～-19.189	4.000	86691.9	72.5	81.6	-6288.752	-7074.989
1-(4)	-19.189～-18.689	4.000	86691.9	81.6	89.2	-7074.989	-7729.873
2-(5)	-18.689～-18.189	1.900	46201.6	89.2	96.8	-4119.560	-4472.089
2-(6)	-18.189～-17.689	1.900	46201.6	96.8	104.8	-4472.089	-4843.818
2-(7)	-17.689～-17.189	1.900	46201.6	104.8	112.3	-4843.818	-5188.111
2-(8)	-17.189～-16.689	1.900	46201.6	112.3	119.2	-5188.111	-5508.331
2-(9)	-16.689～-16.189	1.900	46201.6	119.2	125.6	-5508.331	-5804.822
2-(10)	-16.189～-15.689	1.900	46201.6	125.6	130.5	-5804.822	-6030.350
2-(11)	-15.689～-15.189	1.900	46201.6	130.5	134.2	-6030.350	-6199.059
2-(12)	-15.189～-14.689	1.900	46201.6	134.2	143.5	-6199.059	-6631.657
2-(13)	-14.689～-14.189	1.900	46201.6	143.5	143.8	-6631.657	-6643.497
2-(14)	-14.189～-13.689	1.900	46201.6	143.8	146.6	-6643.497	-6773.396

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(15)	-13.689～-13.189	1.900	43675.0	146.6	149.9	-6402.983	-6548.294
1-(16)	-13.189～-12.689	1.900	43675.0	149.9	151.8	-6548.294	-6631.464
1-(17)	-12.689～-12.189	1.900	43675.0	151.8	152.4	-6631.464	-6657.295
1-(18)	-12.189～-11.689	1.900	43675.0	152.4	152.4	-6657.295	-6658.044
1-(19)	-11.689～-11.189	1.900	43675.0	152.4	152.1	-6658.044	-6645.037
1-(20)	-11.189～-10.689	1.900	43675.0	152.1	150.8	-6645.037	-6588.034
1-(21)	-10.689～-10.189	1.900	43675.0	150.8	149.5	-6588.034	-6527.744
1-(22)	-10.189～ -9.689	1.900	43675.0	149.5	148.0	-6527.744	-6462.688
1-(23)	-9.689～ -9.189	1.900	43675.0	148.0	143.9	-6462.688	-6286.346
1-(24)	-9.189～ -8.689	1.900	43675.0	143.9	138.9	-6286.346	-6064.457
1-(25)	-8.689～ -8.189	1.900	43675.0	138.9	132.0	-6064.457	-5766.989
1-(26)	-8.189～ -7.689	1.900	43675.0	132.0	122.8	-5766.989	-5361.228

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(27)	-7.689～ -7.189	1.900	43252.4	122.8	113.5	-5309.346	-4908.494
1-(28)	-7.189～ -6.689	1.900	43252.4	113.5	102.9	-4908.494	-4450.098
1-(29)	-6.689～ -6.189	1.900	43252.4	102.9	83.6	-4450.098	-3613.992
1-(30)	-6.189～ -5.689	1.900	43252.4	83.6	73.9	-3613.992	-3196.469
1-(31)	-5.689～ -5.189	1.900	43252.4	73.9	69.1	-3196.469	-2988.219
1-(32)	-5.189～ -4.689	1.900	43252.4	69.1	65.0	-2988.219	-2811.125
1-(33)	-4.689～ -4.189	1.900	43252.4	65.0	60.8	-2811.125	-2631.377
1-(34)	-4.189～ -3.689	1.900	43252.4	60.8	56.7	-2631.377	-2450.930
1-(35)	-3.689～ -3.189	1.900	43252.4	56.7	53.5	-2450.930	-2312.495
1-(36)	-3.189～ -2.689	1.900	43252.4	53.5	51.1	-2312.495	-2210.421
1-(37)	-2.689～ -2.200	1.900	43252.4	51.1	47.1	-2210.421	-2037.109
2-(38)	-2.200～ -2.189	4.000	81847.0	47.1	47.0	-3854.846	-3845.654
2-(39)	-2.189～ -1.689	4.000	81847.0	47.0	42.1	-3845.654	-3448.031
2-(40)	-1.689～ -1.189	4.000	81847.0	42.1	37.7	-3448.031	-3087.934
2-(41)	-1.189～ -0.900	4.000	81847.0	37.7	35.4	-3087.934	-2896.124
2-(42)	-0.900～ -0.689	4.000	81847.0	35.4	33.8	-2896.124	-2763.345
2-(43)	-0.689～ -0.189	4.000	81847.0	33.8	30.2	-2763.345	-2471.898
2-(44)	-0.189～ 0.000	4.000	81847.0	30.2	29.0	-2471.898	-2369.832



3.3.3 Point Load from Breast Walls

1) Normal Condition (Case Number: 1)

Case of Normal Condition 1

Name of Normal Load: [Gate Piers and Breast Walls (Normal) 1]

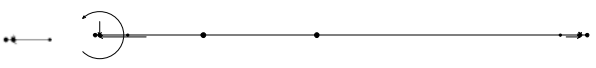
Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	19.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-40.40	93.20	-47.97
3	Right Breast Wall	19.289	466.72	150.06	-282.66



2) Seismic Condition (Total Number: 2)

Case of Seismic Conditon 1 [Land Side →River Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	19.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-5.53	9.09	-20.15
3	Right Breast Wall	19.289	440.71	101.15	-155.98



Case of Seimic Condition 2 [River Side→Land Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	19.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-62.33	9.09	-6.90
3	Right Breast Wall	19.289	314.27	101.15	-47.54



3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
2	Fixed Load Data 2	Water Weight (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Engaging Load (Normal)1	Gate Structure ・Breast Wall (Normal)1	1.0000
6	Arbitrary Load (Normal)1	Surcharge in Normal Condition	1.0000

2) Seismic Condition

1) Case 1 [Seismic Condition: Land Side→River Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Arbitrary Load (Seismic)1	Surcharge in Seismic Condition	1.0000
6	Ingaging Load (Dead Load)1	Gate Structure ・Breast Wall (Dead Load)1	1.0000
7	Ingaging Load (Seismic)1	Seismic Load :Land Side →River Side	1.0000

2) Case 2 [Seismic Condition: River Side→Land Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Dead Load)2	Seismic Load	1.0000
6	Ingaging Load (Dead Load)2	Gate Structure ・Breast Wall (Dead Load)2	1.0000
7	Arbitrary Load (Seismic)1	Surcharge in Seismic Condition	1.0000

3.4 Displacement between Sluiceway and Adjoining Levee

3.4.1 Normal Condition

1) Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-17.0	-20.0	73.5	63.8	9.7	40.0	○	419.348
2	0.250	-17.0	-20.1	76.8	68.2	8.6	40.0	○	370.914
3	0.500	-17.0	-20.1	80.0	72.5	7.5	40.0	○	323.489
4	1.000	-17.0	-19.7	86.5	81.6	4.9	40.0	○	211.666
5	1.500	-17.0	-19.1	93.0	89.2	3.8	19.0	○	165.519
6	2.000	-17.0	-18.0	99.5	96.8	2.7	19.0	○	61.861
7	2.500	-17.0	-16.8	106.0	104.8	1.1	19.0	○	25.909
8	3.000	-17.0	-15.7	112.5	112.3	0.2	19.0	○	3.675
9	3.500	-17.0	-14.6	118.9	119.2	-0.3	-50.0	○	-6.523
10	4.000	-17.0	-13.5	125.4	125.6	-0.2	-50.0	○	-4.857
11	4.500	-17.0	-12.3	131.9	130.5	1.4	19.0	○	32.290
12	5.000	-17.0	-11.2	138.4	134.2	4.2	19.0	○	97.846
13	5.500	-17.0	-10.0	144.9	143.5	1.4	19.0	○	31.458
14	6.000	-17.0	-8.3	151.4	143.8	7.6	19.0	○	175.448
15	6.500	-17.0	-6.2	157.9	146.6	11.3	19.0	○	260.409

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground Spring (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	6.3	-6.2	160.7	146.6	14.1	19.0	○	307.164
2	0.500	6.3	-4.1	159.0	149.9	9.0	19.0	○	197.194
3	1.000	6.3	-2.0	157.3	151.8	5.4	19.0	○	118.295
4	1.500	6.3	0.1	155.5	152.4	3.1	19.0	○	68.065
5	2.000	6.3	2.2	153.8	152.4	1.4	19.0	○	30.376
6	2.500	6.3	4.3	152.1	152.1	0.0	-50.0	○	-0.436
7	3.000	6.3	6.4	150.4	150.8	-0.4	-50.0	○	-9.250
8	3.500	6.3	8.5	148.7	149.5	-0.8	-50.0	○	-16.422
9	4.000	6.3	10.6	147.0	148.0	-1.0	-50.0	○	-21.211
10	4.500	6.3	12.6	145.3	143.9	1.4	19.0	○	29.643
11	5.000	6.3	14.7	143.6	138.9	4.7	19.0	○	103.269
12	5.500	6.3	16.8	141.9	132.0	9.8	19.0	○	214.685
13	6.000	6.3	18.4	140.2	122.8	17.4	19.0	○	380.247

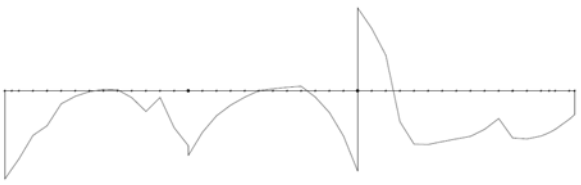
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	32.9	18.4	104.6	122.8	-18.2	-50.0	○	-393.529
2	0.500	32.9	19.4	99.8	113.5	-13.7	-50.0	○	-295.560
3	1.000	32.9	20.4	95.1	102.9	-7.8	-50.0	○	-168.818
4	1.500	32.9	20.4	90.3	83.6	6.8	19.0	○	146.779
5	2.000	32.9	20.3	85.6	73.9	11.7	19.0	○	253.086
6	2.500	32.9	20.1	80.9	69.1	11.8	19.0	○	254.758
7	3.000	32.9	20.0	76.1	65.0	11.1	19.0	○	240.853
8	3.500	32.9	19.8	71.4	60.8	10.6	19.0	○	228.277
9	4.000	32.9	19.7	66.7	56.7	10.0	19.0	○	216.053
10	4.500	32.9	19.6	61.9	53.5	8.5	19.0	○	182.825
11	5.000	32.9	19.4	57.2	51.1	6.1	19.0	○	131.418
12	5.489	32.9	19.3	52.5	47.1	5.5	19.0	○	223.078
13	5.500	32.9	19.3	52.4	47.0	5.5	40.0	○	223.409
14	6.000	32.9	19.2	47.7	42.1	5.6	40.0	○	228.372
15	6.500	32.9	19.0	43.0	37.7	5.2	40.0	○	214.574
16	6.789	32.9	19.0	40.2	35.4	4.8	40.0	○	198.437
17	7.000	32.9	18.9	38.2	33.8	4.5	40.0	○	183.023
18	7.500	32.9	18.8	33.5	30.2	3.3	40.0	○	134.902
19	7.689	32.9	18.7	31.7	29.0	2.8	40.0	○	112.662

Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-15.7	-20.0	71.9	63.8	8.0	40.0	○	348.192
2	0.250	-15.7	-20.1	75.2	68.2	7.0	40.0	○	302.631
3	0.500	-15.7	-20.1	78.5	72.5	6.0	40.0	○	258.079
4	1.000	-15.7	-19.7	85.1	81.6	3.5	40.0	○	152.003
5	1.500	-15.7	-19.1	91.7	89.2	2.6	19.0	○	111.602
6	2.000	-15.7	-18.0	98.4	96.8	1.6	19.0	○	36.188
7	2.500	-15.7	-16.8	105.0	104.8	0.1	19.0	○	3.299
8	3.000	-15.7	-15.7	111.6	112.3	-0.7	-50.0	○	-15.873
9	3.500	-15.7	-14.6	118.2	119.2	-1.0	-50.0	○	-23.008
10	4.000	-15.7	-13.5	124.8	125.6	-0.8	-50.0	○	-18.280
11	4.500	-15.7	-12.3	131.5	130.5	0.9	19.0	○	21.929
12	5.000	-15.7	-11.2	138.1	134.2	3.9	19.0	○	90.547
13	5.500	-15.7	-10.0	144.7	143.5	1.2	19.0	○	27.221
14	6.000	-15.7	-8.3	151.3	143.8	7.5	19.0	○	174.273
15	6.500	-15.7	-6.2	158.0	146.6	11.4	19.0	○	262.296

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	6.3	-6.2	160.2	146.6	13.6	19.0	○	297.584
2	0.500	6.3	-4.1	158.5	149.9	8.6	19.0	○	187.615
3	1.000	6.3	-2.0	156.8	151.8	5.0	19.0	○	108.715
4	1.500	6.3	0.1	155.1	152.4	2.7	19.0	○	58.486
5	2.000	6.3	2.2	153.4	152.4	1.0	19.0	○	20.796
6	2.500	6.3	4.3	151.7	152.1	-0.5	-50.0	○	-10.015
7	3.000	6.3	6.4	150.0	150.8	-0.9	-50.0	○	-18.829
8	3.500	6.3	8.5	148.3	149.5	-1.2	-50.0	○	-26.001
9	4.000	6.3	10.6	146.6	148.0	-1.4	-50.0	○	-30.790
10	4.500	6.3	12.6	144.9	143.9	0.9	19.0	○	20.063
11	5.000	6.3	14.7	143.1	138.9	4.3	19.0	○	93.690
12	5.500	6.3	16.8	141.4	132.0	9.4	19.0	○	205.105
13	6.000	6.3	18.4	139.7	122.8	17.0	19.0	○	370.667

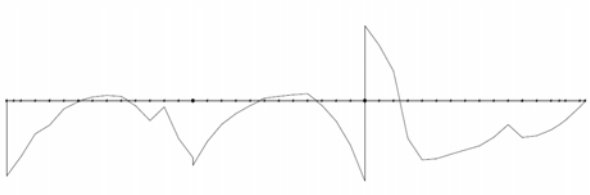
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	22.6	18.4	106.7	122.8	-16.0	-50.0	○	-346.112
2	0.500	22.6	19.4	101.7	113.5	-11.8	-50.0	○	-255.074
3	1.000	22.6	20.4	96.6	102.9	-6.3	-50.0	○	-135.264
4	1.500	22.6	20.4	91.6	83.6	8.0	19.0	○	173.402
5	2.000	22.6	20.3	86.5	73.9	12.6	19.0	○	272.777
6	2.500	22.6	20.1	81.5	69.1	12.4	19.0	○	267.517
7	3.000	22.6	20.0	76.4	65.0	11.4	19.0	○	246.680
8	3.500	22.6	19.8	71.3	60.8	10.5	19.0	○	227.172
9	4.000	22.6	19.7	66.3	56.7	9.6	19.0	○	208.015
10	4.500	22.6	19.6	61.2	53.5	7.8	19.0	○	167.853
11	5.000	22.6	19.4	56.2	51.1	5.1	19.0	○	109.512
12	5.489	22.6	19.3	51.2	47.1	4.1	19.0	○	168.790
13	5.500	22.6	19.3	51.1	47.0	4.1	40.0	○	168.832
14	6.000	22.6	19.2	46.1	42.1	3.9	40.0	○	160.670
15	6.500	22.6	19.0	41.0	37.7	3.3	40.0	○	133.747
16	6.789	22.6	19.0	38.1	35.4	2.7	40.0	○	110.022
17	7.000	22.6	18.9	35.9	33.8	2.2	40.0	○	89.069
18	7.500	22.6	18.8	30.9	30.2	0.7	40.0	○	27.820
19	7.689	22.6	18.7	29.0	29.0	0.0	40.0	○	0.617

Displacement Diagram



Reaction Force of Ground



Reaction Force



2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-16.2	-20.0	74.2	63.8	10.3	40.0	○	447.169
2	0.250	-16.2	-20.1	77.3	68.2	9.1	40.0	○	396.438
3	0.500	-16.2	-20.1	80.5	72.5	8.0	40.0	○	346.716
4	1.000	-16.2	-19.7	86.9	81.6	5.3	40.0	○	230.299
5	1.500	-16.2	-19.1	93.3	89.2	4.1	19.0	○	179.558
6	2.000	-16.2	-18.0	99.7	96.8	2.9	19.0	○	66.894
7	2.500	-16.2	-16.8	106.1	104.8	1.2	19.0	○	28.494
8	3.000	-16.2	-15.7	112.5	112.3	0.2	19.0	○	3.812
9	3.500	-16.2	-14.6	118.8	119.2	-0.4	-50.0	○	-8.834
10	4.000	-16.2	-13.5	125.2	125.6	-0.4	-50.0	○	-9.616
11	4.500	-16.2	-12.3	131.6	130.5	1.1	19.0	○	25.082
12	5.000	-16.2	-11.2	138.0	134.2	3.8	19.0	○	88.190
13	5.500	-16.2	-10.0	144.4	143.5	0.8	19.0	○	19.354
14	6.000	-16.2	-8.3	150.8	143.8	7.0	19.0	○	160.896
15	6.500	-16.2	-6.2	157.1	146.6	10.5	19.0	○	243.408

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	6.3	-6.2	160.2	146.6	13.6	19.0	○	297.584
2	0.500	6.3	-4.1	158.5	149.9	8.6	19.0	○	187.615
3	1.000	6.3	-2.0	156.8	151.8	5.0	19.0	○	108.715
4	1.500	6.3	0.1	155.1	152.4	2.7	19.0	○	58.486
5	2.000	6.3	2.2	153.4	152.4	1.0	19.0	○	20.796
6	2.500	6.3	4.3	151.7	152.1	-0.5	-50.0	○	-10.015
7	3.000	6.3	6.4	150.0	150.8	-0.9	-50.0	○	-18.829
8	3.500	6.3	8.5	148.3	149.5	-1.2	-50.0	○	-26.001
9	4.000	6.3	10.6	146.6	148.0	-1.4	-50.0	○	-30.790
10	4.500	6.3	12.6	144.9	143.9	0.9	19.0	○	20.063
11	5.000	6.3	14.7	143.1	138.9	4.3	19.0	○	93.690
12	5.500	6.3	16.8	141.4	132.0	9.4	19.0	○	205.105
13	6.000	6.3	18.4	139.7	122.8	17.0	19.0	○	370.667

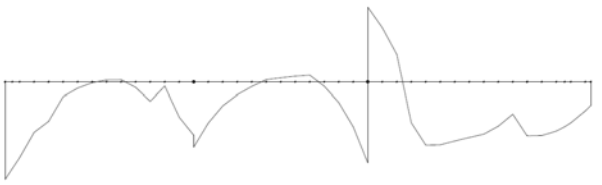
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	21.7	18.4	106.9	122.8	-15.9	-50.0	○	-343.812
2	0.500	21.7	19.4	102.0	113.5	-11.5	-50.0	○	-249.264
3	1.000	21.7	20.4	97.1	102.9	-5.8	-50.0	○	-125.946
4	1.500	21.7	20.4	92.2	83.6	8.6	19.0	○	186.229
5	2.000	21.7	20.3	87.3	73.9	13.4	19.0	○	289.113
6	2.500	21.7	20.1	82.4	69.1	13.3	19.0	○	287.362
7	3.000	21.7	20.0	77.5	65.0	12.5	19.0	○	270.033
8	3.500	21.7	19.8	72.6	60.8	11.7	19.0	○	254.034
9	4.000	21.7	19.7	67.7	56.7	11.0	19.0	○	238.385
10	4.500	21.7	19.6	62.8	53.5	9.3	19.0	○	201.732
11	5.000	21.7	19.4	57.9	51.1	6.8	19.0	○	146.898
12	5.489	21.7	19.3	53.1	47.1	6.0	19.0	○	246.027
13	5.500	21.7	19.3	53.0	47.0	6.0	40.0	○	246.216
14	6.000	21.7	19.2	48.1	42.1	6.0	40.0	○	244.690
15	6.500	21.7	19.0	43.2	37.7	5.5	40.0	○	224.401
16	6.789	21.7	19.0	40.4	35.4	5.0	40.0	○	204.511
17	7.000	21.7	18.9	38.3	33.8	4.6	40.0	○	186.357
18	7.500	21.7	18.8	33.4	30.2	3.2	40.0	○	131.742
19	7.689	21.7	18.7	31.6	29.0	2.6	40.0	○	107.047

Displacement Diagram



Reaction Force of Ground



Reaction Force



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	10.995	72.253	9.284
3	0.250	91.789	-114.147	105.224
4	0.500	103.036	-53.877	84.468
5	1.000	124.202	26.852	80.045
6	1.500	141.564	68.089	104.744
7	2.000	147.455	69.227	139.625
8	2.500	149.018	54.790	171.381
9	3.000	146.254	25.806	191.995
10	3.500	139.163	-11.286	195.840
11	4.000	127.747	-50.510	180.359
12	4.500	112.005	-80.032	146.951
13	5.000	91.939	-83.877	104.609
14	5.500	67.450	-87.931	63.044
15	6.000	37.396	-72.584	19.915
16	6.500	0.001	0.000	0.000

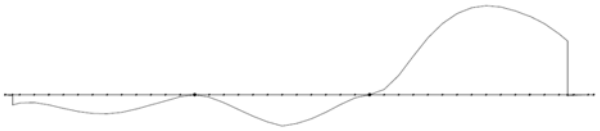
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	6.500	0.000	0.000	0.000
2	7.000	41.835	89.710	24.719
3	7.500	76.031	132.202	81.840
4	8.000	102.590	142.412	151.541
5	8.500	121.512	130.643	220.590
6	9.000	132.796	101.748	279.329
7	9.500	136.442	62.947	320.687
8	9.500	136.443	-29.453	320.687
9	10.000	132.450	-72.250	295.410
10	10.500	120.848	-118.038	247.938
11	11.000	101.700	-152.310	179.291
12	11.500	75.046	-155.462	100.814
13	12.000	40.884	-112.353	31.538
14	12.500	-0.001	0.000	0.000

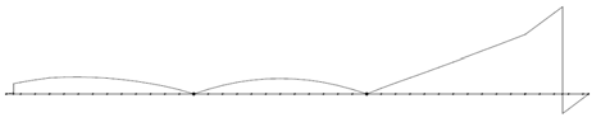
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	12.500	0.001	0.000	0.000
2	13.000	50.398	-208.652	-54.204
3	13.500	97.246	-361.126	-199.289
4	14.000	142.289	-403.016	-396.899
5	14.500	187.550	-339.429	-584.725
6	15.000	233.307	-248.848	-731.829
7	15.500	279.560	-161.325	-834.083
8	16.000	326.307	-80.423	-894.258
9	16.500	373.547	-5.720	-915.539
10	17.000	421.276	57.619	-901.871
11	17.500	469.495	99.800	-861.445
12	17.989	517.125	125.176	-806.169
13	17.989	517.129	125.137	-806.169
14	18.000	519.161	126.713	-807.044
15	18.000	519.167	126.948	-807.044
16	18.500	612.248	182.034	-729.901
17	19.000	706.249	234.910	-625.376
18	19.289	760.998	261.147	-553.584
19	19.289	-172.437	-38.973	11.736
20	19.500	-132.278	-23.145	5.240
21	20.000	-36.458	-1.524	0.077
22	20.189	-0.003	0.000	0.000

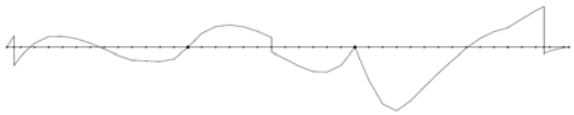
Bending Moment



Axial Force



Shear Force



3.5.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side →River Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	15.514	57.560	7.432
3	0.250	21.038	-34.730	68.682
4	0.500	36.802	11.560	66.018
5	1.000	67.006	66.464	87.739
6	1.500	93.404	84.722	126.381
7	2.000	104.111	77.369	167.392
8	2.500	110.490	55.958	201.413
9	3.000	112.542	21.518	221.184
10	3.500	110.267	-19.513	221.837
11	4.000	103.667	-61.160	201.573
12	4.500	92.741	-91.586	162.551
13	5.000	77.491	-94.819	114.522
14	5.500	57.818	-96.743	67.955
15	6.000	32.580	-77.749	21.269
16	6.500	0.001	0.000	0.000

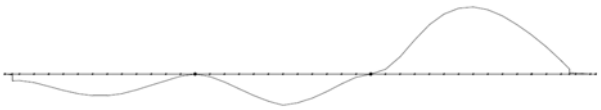
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	6.500	0.000	0.000	0.000
2	7.000	41.835	89.710	24.719
3	7.500	76.031	132.202	81.840
4	8.000	102.590	142.412	151.541
5	8.500	121.512	130.643	220.590
6	9.000	132.796	101.748	279.329
7	9.500	136.442	62.947	320.687
8	9.500	136.443	-29.453	320.687
9	10.000	132.450	-72.250	295.410
10	10.500	120.848	-118.038	247.938
11	11.000	101.700	-152.310	179.291
12	11.500	75.046	-155.462	100.814
13	12.000	40.884	-112.353	31.538
14	12.500	-0.001	0.000	0.000

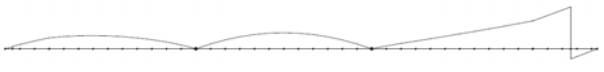
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	12.500	0.001	0.000	0.000
2	13.000	24.874	-187.447	-48.799
3	13.500	46.197	-321.198	-178.498
4	14.000	65.715	-346.845	-351.980
5	14.500	85.452	-269.497	-508.176
6	15.000	105.685	-167.635	-617.391
7	15.500	126.413	-71.313	-676.735
8	16.000	147.636	15.907	-690.220
9	16.500	169.350	94.446	-662.274
10	17.000	191.556	159.141	-598.081
11	17.500	214.250	200.195	-507.072
12	17.989	236.917	222.068	-403.462
13	17.989	236.921	222.025	-403.463
14	18.000	237.891	223.295	-400.499
15	18.000	237.896	223.527	-400.500
16	18.500	282.677	262.812	-278.821
17	19.000	328.378	295.192	-138.836
18	19.289	355.209	307.439	-51.605
19	19.289	-85.496	14.649	-13.535
20	19.500	-65.720	19.271	-9.885
21	20.000	-18.200	11.000	-1.118
22	20.189	-0.003	0.000	0.000

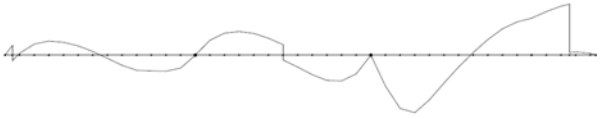
Bending Moment



Axial Force



Shear Force



Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	12.104	81.939	10.507
3	0.250	74.428	-178.871	169.567
4	0.500	86.783	-109.521	133.778
5	1.000	110.167	-12.453	105.718
6	1.500	129.746	42.696	114.344
7	2.000	136.819	52.193	138.672
8	2.500	139.564	44.821	163.731
9	3.000	137.982	21.609	180.859
10	3.500	132.072	-11.004	183.779
11	4.000	121.838	-47.042	169.289
12	4.500	107.278	-74.671	138.142
13	5.000	88.394	-77.917	98.684
14	5.500	65.086	-82.665	59.979
15	6.000	36.214	-69.305	19.041
16	6.500	0.001	0.000	0.000

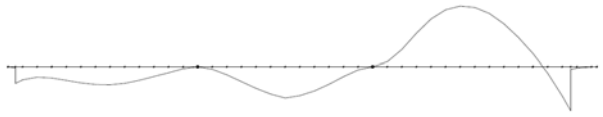
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	6.500	0.000	0.000	0.000
2	7.000	41.835	89.710	24.719
3	7.500	76.031	132.202	81.840
4	8.000	102.590	142.412	151.541
5	8.500	121.512	130.643	220.590
6	9.000	132.796	101.748	279.329
7	9.500	136.442	62.947	320.687
8	9.500	136.443	-29.453	320.687
9	10.000	132.450	-72.250	295.410
10	10.500	120.848	-118.038	247.938
11	11.000	101.700	-152.310	179.291
12	11.500	75.046	-155.462	100.814
13	12.000	40.884	-112.353	31.538
14	12.500	-0.001	0.000	0.000

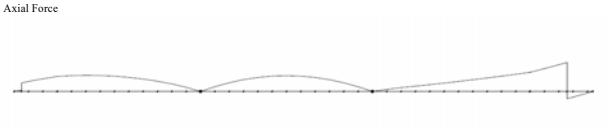
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	12.500	0.001	0.000	0.000
2	13.000	18.324	-183.188	-47.796
3	13.500	33.098	-311.193	-173.990
4	14.000	46.066	-329.608	-340.724
5	14.500	59.253	-243.543	-486.185
6	15.000	72.936	-131.479	-579.934
7	15.500	87.115	-23.468	-618.339
8	16.000	101.788	76.926	-604.671
9	16.500	116.952	170.125	-542.612
10	17.000	132.608	250.965	-436.605
11	17.500	148.753	309.649	-295.339
12	17.989	165.013	350.201	-133.697
13	17.989	165.017	350.165	-133.697
14	18.000	165.714	352.258	-130.528
15	18.000	165.720	352.506	-130.528
16	18.500	198.106	430.773	65.268
17	19.000	231.412	504.941	299.564
18	19.289	251.079	542.623	451.064
19	19.289	-63.186	-70.567	25.494
20	19.500	-48.640	-46.783	13.177
21	20.000	-13.515	-7.650	0.651
22	20.189	-0.003	0.000	0.000

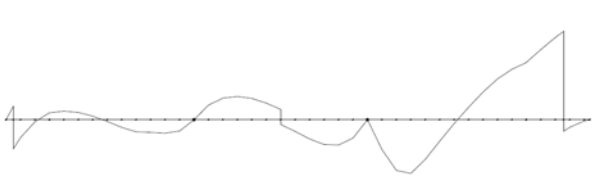
Bending Moment



Axial Force



Shear Force



3.6 Design of Flexible Joint

Opening

Opening = (Lateral Displacement of Span in Right Side) - (Lateral Displacement of Span in Left Side)

Bending Angle

θ = ¦ θ1 - θ2¦ - Initial Bending Angle

Thus、

θ1: Angle of Displacement (Left Side) (rad)

θ2: Angle of Displacement (Right Side) (rad)

θ: Average Angle of Displacement (rad)

Unevenness

Unevenness = (Vertical Displacement of Span in Right Side) - (Vertical Displacement of Span in Left Side)

3.6.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Check of Opening Allowable Opening: 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-17.0	
Span (2- 1)	6.3- (-17.0)	23.3 OK
Span (3- 2)	32.9- (6.3)	26.6 OK
EP	32.9	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.74363 -0.01298	0.19580 0.00342	0.93943 0.01640
Span (3- 2)	0.00000 0.00000	0.19583 0.00342	0.54289 0.00948	0.34706 0.00606

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-73.5	
Span (2- 1)	-160.7- (-157.9)	2.8 OK
Span (3- 2)	-104.6- (-140.2)	35.6 OK
EP	-31.7	

3.6.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-15.7	
Span (2- 1)	6.3- (-15.7)	22.0 OK
Span (3- 2)	22.6- (6.3)	16.3 OK
EP	22.6	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.75882 -0.01324	0.19580 0.00342	0.95462 0.01666
Span (3- 2)	0.00000 0.00000	0.19583 0.00342	0.57962 0.01012	0.38379 0.00670

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-71.9	
Span (2- 1)	-160.2- (-158.0)	2.3 OK
Span (3- 2)	-106.7- (-139.7)	33.0 OK
EP	-29.0	

Calculation Case2 - Load: [Seismic Condition Land Side →River Side]

Check for Opening Allowable Opening 100.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-16.2	
Span (2- 1)	6.3- (-16.2)	22.5 OK
Span (3- 2)	21.7- (6.3)	15.4 OK
EP	21.7	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.73149 -0.01277	0.19580 0.00342	0.92729 0.01618
Span (3- 2)	0.00000 0.00000	0.19583 0.00342	0.56103 0.00979	0.36520 0.00637

Check for Unevenness Allowable Unevenness 100.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-74.2	
Span (2- 1)	-160.2- (-157.1)	3.1 OK
Span (3- 2)	-106.9- (-139.7)	32.9 OK
EP	-31.6	

3.7 Stress Intensity Analysis

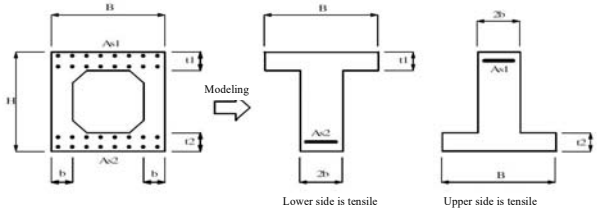
3.7.1 Calculation Condition

It is considered that double reinforced section which bending moment is acting on.
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.
Position of Neutral Axis

$$x=\frac{n\cdot(As\cdot d+As'\cdot d')+B\cdot t^2/2}{n\cdot(As+As')+B\cdot t}$$

Thus,

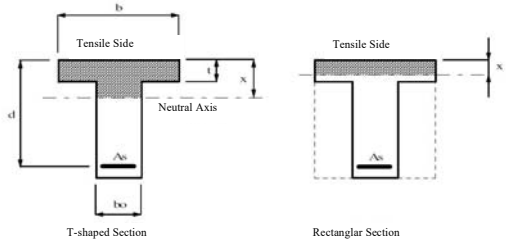
x : Position of Neutral Axis (mm)
n : Ratio of Young modulus = 9.0
As : Area of Re-bar in tensile side (mm^2)
As' : Area of Re-bar in compressive side (mm^2)
d : Effective Height of Beam (mm)
d' : Distance from the compressive edge of concrete to the centric of Re-bar (mm)
B : Width of Flange (mm)
t : Thickness of Flange (mm)



Lower side is tensile Upper side is tensile

The stress calculation is conducted as follows based on the position of neutral axis

1) In case the neutral axis is in web, the section is considered as T-shape.
2) In case the neutral axis is in top slab or Bottom slab, the section is considered as rectangle.



T-shaped Section Rectanglar Section

Calculation Condition (In Case Bottom Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation Section
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.265	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.281	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.299	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.316	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side As(mm^2)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side As' (mm^2)
1- 1	2.000	2.000	1.716	2780.4	0.273	2780.4
1- 2	1.900	1.900	1.645	2780.4	0.244	2780.4
2- 1	1.900	1.900	1.645	4011.0	0.244	5419.4
3- 1	1.900	1.900	1.645	5419.4	0.244	5419.4
3- 2	2.000	2.000	1.716	5419.4	0.273	5419.4

Calculation Condition (In Case Top Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.265	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.281	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.299	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.316	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side	Position of Re-bar in Compressive	Area of Re-bar in Tensile Side
1- 1	2.000	2.000	1.727	2780.4	0.284	2780.4
1- 2	1.900	1.900	1.656	2780.4	0.255	2780.4
2- 1	1.900	1.900	1.656	4011.0	0.255	4011.0
3- 1	1.900	1.900	1.656	5419.4	0.255	5419.4
3- 2	2.000	2.000	1.727	5419.4	0.284	5419.4

3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	105.224	0.000	104.744	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	203.9		203.0	
	Top Slab Inside	Aq2	mm^2	271.9		270.6	
	Bottom Slab Inside	Aq3	mm^2	271.9		270.6	
	Bottom Slab Outside	Aq4	mm^2	203.9		203.0	
Neutral Axis		X	m	0.199	----	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.33	----	0.33	----
		σs	N/mm^2	24.87	----	24.76	----
		σs'	N/mm^2	-1.62	----	-1.61	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	634.4	----	631.5	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Normal Condition

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	195.840	0.000	171.381	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	398.5		347.8	
	Top Slab Inside	Aq2	mm^2	531.3		463.7	
	Bottom Slab Inside	Aq3	mm^2	531.3		463.7	
	Bottom Slab Outside	Aq4	mm^2	398.5		347.8	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.67	----	0.58	----
		σs	N/mm^2	48.07	----	42.07	----
		σs'	N/mm^2	-3.28	----	-2.87	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	1239.6	----	1082.1	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Normal Condition

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	320.687	0.000	320.687	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	659.5		659.5	
	Top Slab Inside	Aq2	mm^2	879.3		879.3	
	Bottom Slab Inside	Aq3	mm^2	879.3		879.3	
	Bottom Slab Outside	Aq4	mm^2	659.5		659.5	
Neutral Axis		X	m	0.233	----	0.233	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.92	----	0.92	----
		σs	N/mm^2	55.20	----	55.20	----
		σs'	N/mm^2	-5.07	----	-5.07	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	2051.8	----	2051.8	----
		inp	mm^2	4011.0	----	4011.0	----

Calculation Case1: Normal Condition

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-915.539	-806.169	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		1946.4	1706.0	
	Top Slab Inside	Aq2	mm^2		2595.2	2274.7	
	Bottom Slab Inside	Aq3	mm^2		2595.2	2274.7	
	Bottom Slab Outside	Aq4	mm^2		1946.4	1706.0	
Neutral Axis		X	m	----	0.266	0.266	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	2.26	1.99	----
		σs	N/mm^2	----	118.11	104.00	----
		σs'	N/mm^2	----	-11.55	-10.17	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2	----	4470.4		----
		req	mm^2	----	6055.5	5307.6	----
		inp	mm^2	----	5419.4	5419.4	----

Calculation Case1: Normal Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	11.736	-807.044	-553.584	11.736
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	22.3	1642.1	1112.4	22.3
	Top Slab Inside	Aq2	mm^2	29.7	2189.5	1483.2	29.7
	Bottom Slab Inside	Aq3	mm^2	29.7	2189.5	1483.2	29.7
	Bottom Slab Outside	Aq4	mm^2	22.3	1642.1	1112.4	22.3
Neutral Axis		X	m	0.267	0.268	0.268	0.267
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.03	1.82	1.25	0.03
		σs	N/mm^2	1.46	100.26	68.77	1.46
		σs'	N/mm^2	-0.16	-9.35	-6.41	-0.16
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	69.4	5108.9	3460.8	69.4
		inp	mm^2	5419.4	5419.4	5419.4	5419.4

3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	126.381	0.000	126.381	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	184.1		184.1	
	Top Slab Inside	Aq2	mm^2	245.4		245.4	
	Bottom Slab Inside	Aq3	mm^2	245.4		245.4	
	Bottom Slab Outside	Aq4	mm^2	184.1		184.1	
Neutral Axis		X	m	0.199	----	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.39	----	0.39	----
		σs	N/mm^2	29.88	----	29.88	----
		σs'	N/mm^2	-1.94	----	-1.94	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	572.7	----	572.7	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	221.837	0.000	221.184	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	338.7		337.7	
	Top Slab Inside	Aq2	mm^2	451.6		450.2	
	Bottom Slab Inside	Aq3	mm^2	451.6		450.2	
	Bottom Slab Outside	Aq4	mm^2	338.7		337.7	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.76	----	0.75	----
		σs	N/mm^2	54.45	----	54.29	----
		σs'	N/mm^2	-3.72	----	-3.71	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	1053.7	----	1050.6	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	320.687	0.000	320.687	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	493.2		493.2	
	Top Slab Inside	Aq2	mm^2	657.6		657.6	
	Bottom Slab Inside	Aq3	mm^2	657.6		657.6	
	Bottom Slab Outside	Aq4	mm^2	493.2		493.2	
Neutral Axis		X	m	0.233	----	0.233	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.92	----	0.92	----
		σs	N/mm^2	55.20	----	55.20	----
		σs'	N/mm^2	-5.07	----	-5.07	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	1534.4	----	1534.4	----
		inp	mm^2	4011.0	----	4011.0	----

Calculation Case1: Seismic Condition　Land Side→River Side

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-690.220	-403.462	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		1083.4	624.1	
	Top Slab Inside	Aq2	mm^2		1444.6	832.2	
	Bottom Slab Inside	Aq3	mm^2		1444.6	832.2	
	Bottom Slab Outside	Aq4	mm^2		1083.4	624.1	
Neutral Axis		X	m	----	0.266	0.266	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	1.70	1.00	----
		σs	N/mm^2	----	89.04	52.05	----
		σs'	N/mm^2	----	-8.71	-5.09	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	3370.7	1941.8	----
		inp	mm^2	----	5419.4	5419.4	----

Calculation Case1: Seismic Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	0.000	-403.463	-51.605	-13.535
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		600.3	74.4	19.3
	Top Slab Inside	Aq2	mm^2		800.5	99.2	25.8
	Bottom Slab Inside	Aq3	mm^2		800.5	99.2	25.8
	Bottom Slab Outside	Aq4	mm^2		600.3	74.4	19.3
Neutral Axis		X	m	----	0.268	0.268	0.268
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	0.91	0.12	0.03
		σs	N/mm^2	----	50.12	6.41	1.68
		σs'	N/mm^2	----	-4.67	-0.60	-0.16
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2	----			
		req	mm^2	----	1867.7	231.5	60.2
		inp	mm^2	----	5419.4	5419.4	5419.4

2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	169.567	0.000	114.344	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	248.1		166.3	
	Top Slab Inside	Aq2	mm^2	330.8		221.8	
	Bottom Slab Inside	Aq3	mm^2	330.8		221.8	
	Bottom Slab Outside	Aq4	mm^2	248.1		166.3	
Neutral Axis		X	m	0.199	----	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.53	----	0.36	----
		σs	N/mm^2	40.09	----	27.03	----
		σs'	N/mm^2	-2.60	----	-1.76	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	771.8	----	517.5	----
		inp	mm^2	2780.4	----	2780.4	----

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	183.779	0.000	163.731	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	279.7		248.7	
	Top Slab Inside	Aq2	mm^2	372.9		331.6	
	Bottom Slab Inside	Aq3	mm^2	372.9		331.6	
	Bottom Slab Outside	Aq4	mm^2	279.7		248.7	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.63	----	0.56	----
		σs	N/mm^2	45.11	----	40.19	----
		σs'	N/mm^2	-3.08	----	-2.74	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	870.1	----	773.7	----
		inp	mm^2	2780.4	----	2780.4	----

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	320.687	0.000	320.687	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	493.2		493.2	
	Top Slab Inside	Aq2	mm^2	657.6		657.6	
	Bottom Slab Inside	Aq3	mm^2	657.6		657.6	
	Bottom Slab Outside	Aq4	mm^2	493.2		493.2	
Neutral Axis		X	m	0.233	----	0.233	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.92	----	0.92	----
		σs	N/mm^2	55.20	----	55.20	----
		σs'	N/mm^2	-5.07	----	-5.07	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	1534.4	----	1534.4	----
		inp	mm^2	4011.0	----	4011.0	----

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-618.339	-133.697	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		967.5	202.5	
	Top Slab Inside	Aq2	mm^2		1290.0	270.0	
	Bottom Slab Inside	Aq3	mm^2		1290.0	270.0	
	Bottom Slab Outside	Aq4	mm^2		967.5	202.5	
Neutral Axis		X	m	----	0.266	0.266	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	1.53	0.33	----
		σs	N/mm^2	----	79.77	17.25	----
		σs'	N/mm^2	----	-7.80	-1.69	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	3010.0	629.9	----
		inp	mm^2	----	5419.4	5419.4	----

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	451.064	-133.697	451.064	25.494
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	672.8	194.9	672.8	36.6
	Top Slab Inside	Aq2	mm^2	897.0	259.8	897.0	48.8
	Bottom Slab Inside	Aq3	mm^2	897.0	259.8	897.0	48.8
	Bottom Slab Outside	Aq4	mm^2	672.8	194.9	672.8	36.6
Neutral Axis		X	m	0.267	0.268	0.267	0.267
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	1.02	0.30	1.02	0.06
		σs	N/mm^2	55.95	16.61	55.95	3.16
		σs'	N/mm^2	-6.11	-1.55	-6.11	-0.35
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	2093.1	606.3	2093.1	113.8
		inp	mm^2	5419.4	5419.4	5419.4	5419.4

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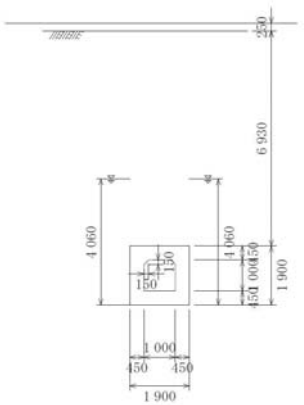
2.2.2.3 SLUICEWAY TYPE C

(2) BOX - TRANSVERSE

1 Calculation of Box Culvert in Transverse Direction

1.1 Design Condition

1.1.1 Dimension



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material			SD295	
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D16	247	804.0	Left Corner	D16	247	804.0
Center of Span	D16	247	804.0	Right Corner	D16	247	804.0
Right Corner	D16	247	804.0	Right Corner	D16	247	804.0

Outside of Sidewall	Diameter	Pitch	Area (mm^2)	Inside of Sidewall	Diameter	Pitch	Area (mm^2)
Left Sidewall	D16	247	804.0	Left Sidewall	D13	280	452.5
Right Sidewall	D16	247	804.0	Right Sidewall	D13	280	452.5

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D16	247	804.0	Left Corner	D16	247	804.0
Center of Span	D16	247	804.0	Right Corner	D16	247	804.0
Right Corner	D16	247	804.0	Right Corner	D16	247	804.0

■Cover

Location		Cover(mm)	Location		Cover(mm)
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Midwall		—	—		—

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Top Slab	100	0.0
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Load

■Surcharge

	(kN/m^2)
Surcharge	0.000
Snow Load	0.000

■Dead Load (Water Level)

Case	External Water Level(m)	Internal Water Level(m)
1	4.060	0.000

External Water Level: Height from Bottom Surface of Bottom Slab
Internal Water Level: Height from Top Surface of Bottom Slab

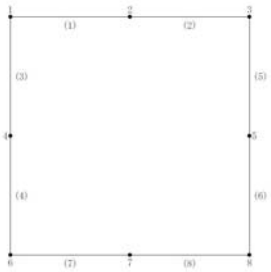
■Live Load

Intensity of Distribution Load Qw (kN/m^2)	10.000

1.2 Cross-section Calculation

1.2.1 Model

1) Frame Dimension



2) Coordinate

No	X(m)	Y(m)
1	0.000	1.450
2	0.725	1.450
3	1.450	1.450
4	0.000	0.725
5	1.450	0.725
6	0.000	0.000
7	0.725	0.000
8	1.450	0.000

3) Member Material and Sectional Characteristics

Member	Number	Point Number		Area (m^2)	Geometric Moment of Inertia (m^4)	Young Modules (kN/m^2)
		i Edge	j Edge			
Left Side of Top Slab	1	1	2	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Top Slab	2	2	3	4.500000E-001	7.593750E-003	2.310000E+007
Upper Side of Left Side Wall	3	1	4	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Left Side Wall	4	4	6	4.500000E-001	7.593750E-003	2.310000E+007
Upper side of Right Wall	5	3	5	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Right Wall	6	5	8	4.500000E-001	7.593750E-003	2.310000E+007
Left Side of Bottom Slap	7	6	7	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slap	8	7	8	4.500000E-001	7.593750E-003	2.310000E+007

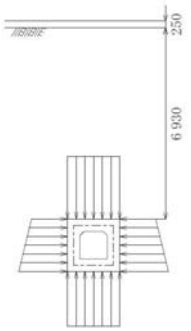
4) Supporting Point

Point	Horizontal (kN/m)	Vertical (kN/m)	Rotate (kN.m/rad)
9	-1	-1	0
13	0	-1	0

Note) -1: Fixed, 0: Free

1.2.2 Load

1) Dead Load (case-1) [RWL]



Weight of Box Culvert

(1) Top Slab
w = 0.450 × 24.00 = 10.80 (kN/m²)

(2) Left Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

(3) Right Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level) = 1.000 × 0.250 × 22.60 = 5.65 (kN/m²)
Embankment (Above Water Level) =1.000 × 4.770 × 19.00 = 90.63 (kN/m²)
Embankment (Below Water Level) =1.000 × 2.160 × 10.20 = 22.03 (kN/m²)
Water Pressure =2.160 × 9.80 = 21.17 (kN/m²)

Σwd = 139.48 (kN/m²)

(2) Surcharge Load at Road
Surcharge = 0.000 (kN/m²)
Snow Load= 0.00 (kN/m²)

Σqd = 0.000 (kN/m²)

(3) Load Acting on Top Slab
Uniformly Distributed Load
w = 139.48 + 0.00 = 139.48 (kN/m²)

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

$pi = Ko\times (qd + Yo\times\gamma a + Zu\times\gamma + (Zo - Zu)\times\gamma') + (Zo - Zu)\times\gamma w$

Ko: Coefficient of Earth Pressure at Rest = 0.500
Zo:Depth of Calculation Point from Embankment Top(m)

(1) Left Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	6.930	80.32
p_2	Center of Top Slab	7.155	83.68
P_3	Center of Bottom Slab	8.605	105.28
p_4	Bottom Surface of Bottom Slab	8.830	108.63

(2) Right Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	6.930	80.32
p_2	Center of Top Slab	7.155	83.68
p_3	Center of Bottom Slab	8.605	105.28
p_4	Bottom Surface of Bottom Slab	8.830	108.63

Uplift and Buoyancy
This Act on Bottom Slab Upward

$$U = 4.060 \times 1.900 \times 9.80 = 75.60 \ (kN/m)$$

$$w = \frac{-75.60}{1.900} = -39.79 \ (kN/m^2)$$

Summary of Acting Forces

Item			V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Weight of Body		Top Slab	21.06		0.950		20.01
		Left Side Wall	10.80		0.225		2.43
		Right Side Wall	10.80		1.675		18.09
Surcharge		Distribution Load	265.01		0.950		251.76
Earth Pressure and Water Pressure	Left Side Wall			179.51		0.903	162.02
	Right Side Wall			-179.51		0.903	-162.02
Uplift/Buoyancy			-75.60		0.950		-71.82
Total			232.07				220.47

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity
Me = ΣV × e = 0.00 (kN.m/m)

$$Me = \Sigma V \times e = 0.00 \ (kN.m/m)$$

$$q1 = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 122.14 \ (kN/m^2)$$

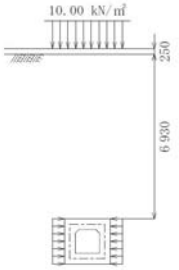
$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 122.14 \ (kN/m^2)$$

$$q1' = q1 + \frac{qr - q1}{B} \times \frac{T}{2} = 122.14 \ (kN/m^2)$$

$$qr' = qr + \frac{q1 - qr}{B} \times \frac{T}{2} = 122.14 \ (kN/m^2)$$

Thus, T : Thickness of Side Wall
q1 : Subgrade Reaction Intensity on Left Edge
qr : Subgrade Reaction Intensity on Right Edge
q1': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface qL= 10.000 (kN/m²)

Load

(1) Vertical Load Effecting Top Slab
wl = qL= 10.00 (kN/m²)

(2) Horizontal Load Acting on Left Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

(3) Horizontal Load Effecting on Right Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

Summary of Acting Force

		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Top Slab	Distribution	19.00		0.950		18.05
Left Side Wall	Distribution		9.50		0.950	9.03
Right Side Wall	Distribution		-9.50		0.950	-9.03
Total		19.00				18.05

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$ql = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$ql' = ql + \frac{qr - ql}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

$$qr' = qr + \frac{ql - qr}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

Thus、T : Thickness of Side Wall

ql : Subgrade Reaction Intensity on Left Edge

qr : Subgrade Reaction Intensity on Right Edge

ql': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

Dead Load + Live Load

Load Number	Beginning Member Number	End Member Number	Load Intensity at i Edge (kN/m)	Load Intensity at j Edge (kN/m)	Distance from i Edge (m)	Distance from j Edge (m)	Load Width (m)
14	1	2	-10.80	-10.80	0.000	0.000	1.450
14	3	4	-10.80	-10.80	0.225	0.225	1.000
14	5	6	-10.80	-10.80	0.225	0.225	1.000
14	1	2	-139.48	-139.48	0.000	0.000	1.450
13	3	4	83.68	105.28	0.000	0.000	1.450
13	5	6	-83.68	-105.28	0.000	0.000	1.450
14	7	8	39.79	39.79	0.000	0.000	1.450
14	1	2	-10.00	-10.00	0.000	0.000	1.450
13	3	4	5.00	5.00	0.000	0.000	1.450
13	5	6	-5.00	-5.00	0.000	0.000	1.450
14	7	8	132.14	132.14	0.000	0.000	1.450

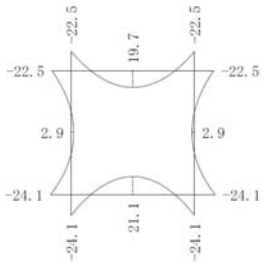
Load Number

13: Member Distribution Load (X Direction)

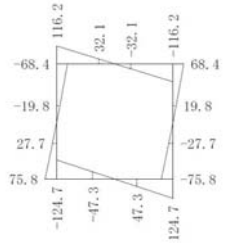
14: Member Distribution Load (Y Direction)

1.2.4 Calculation Results of Frame Analysis

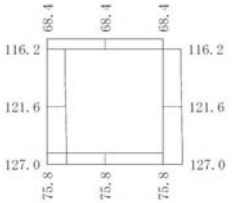
Bending Moment



Shear Force



Axial Force



1.2.5 Stress Intensity Calculation

■Bending Stress Intensity

Top Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-22.471	19.653	-22.471
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	467.9	0.0	467.9
	Internal	mm^2	0.0	408.0	0.0
Re-Bar	External	mm^2	D16 @ 247 D─@── 804.0	D16 @ 247 D─@── 804.0	D16 @ 247 D─@── 804.0
	Internal	mm^2	D16 @ 247 D─@── 804.0	D16 @ 247 D─@── 804.0	D16 @ 247 D─@── 804.0
Neutral Axis	X	m	0.065	0.065	0.065
Stress Intensity	σc	N/mm^2	2.03	1.78	2.03
	σs	N/mm^2	82.63	72.27	82.63
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	623.9	544.0	623.9
	inp	mm^2	804.0	804.0	804.0
Case	──	──	Dead-1+Live-1	Dead-1+Liva-1	Dead-1+Liev-1

※Axial force is not considered.

Left Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-22.471	2.878	-24.062
Axial Force	N	kN	116.203	121.603	127.003
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar Arrangement	External	mm^2	D16 @ 247 D—@— 804.0	D16 @ 247 D—@— 804.0	D16 @ 247 D—@— 804.0
	Internal	mm^2	D13 @ 280 D—@— 452.5	D13 @ 280 D—@— 452.5	D13 @ 280 D—@— 452.5
Neutral Axis	X	m	0.177	0.905	0.182
Stress Intensity	σc	N/mm^2	1.43	0.36	1.51
	σs	N/mm^2	13.23	0.00	13.29
	σs'	N/mm^2	0.00	-1.94	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	804.0	452.5	804.0
Case	—	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Right Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-22.471	2.878	-24.062
Axial Force	N	kN	116.203	121.603	127.003
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar	External	mm^2	D16 @ 247 D—@— 804.0	D16 @ 247 D—@— 804.0	D16 @ 247 D—@— 804.0
	Internal	mm^2	D13 @ 280 D—@— 452.5	D13 @ 280 D—@— 452.5	D13 @ 280 D—@— 452.5
Neutral Axis	X	m	0.177	0.905	0.182
Stress Intensity	σc	N/mm^2	1.43	0.36	1.51
	σs	N/mm^2	13.23	0.00	13.29
	σs'	N/mm^2	0.00	-1.94	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	804.0	452.5	804.0
Case	—	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Bottom Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-24.062	21.124	-24.062
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	115.0	115.0	115.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	541.3	0.0	541.3
	Internal	mm^2	0.0	439.3	0.0
Re-Bar	External	mm^2	D16 @ 247 D—@— 804.0	D16 @ 247 D—@— 804.0	D16 @ 247 D—@— 804.0
	Internal	mm^2	D16 @ 247 D—@— 804.0	D16 @ 247 D—@— 804.0	D16 @ 247 D—@— 804.0
Neutral Axis	X	m	0.063	0.065	0.063
Stress Intensity	σc	N/mm^2	2.44	1.91	2.44
	σs	N/mm^2	95.28	77.68	95.28
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	721.8	585.7	721.8
	inp	mm^2	804.0	804.0	804.0
Case	—	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

■Shear Stress Intensity

$$\tau m = \frac{S}{b \times d} \leqq \tau a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm^2)	τa (N/mm^2)	Cases	L (m)
Top Slap	Left τ Point	32.056	360.0	0.089	0.457	Dead-1+Live-1	0.525
	Right τ Point	-32.056	360.0	0.089	0.457	Dead-1+Live-1	0.525
Left Side Wall	Upper τ Point	-19.806	360.0	0.055	0.457	Dead-1+Live-1	0.525
	Lower τ Point	27.712	360.0	0.077	0.495	Dead-1+Live-1	0.450
Right Side Wall	Upper τ Point	19.806	360.0	0.055	0.457	Dead-1+Live-1	0.525
	Lower τ Point	-27.712	360.0	0.077	0.495	Dead-1+Live-1	0.450
Bottom Slab	Left τ Point	-47.281	360.0	0.131	0.478	Dead-1+Live-1	0.450
	Right τ Point	47.281	360.0	0.131	0.478	Dead-1+Live-1	0.450

Note) τ Point: Check point for shear stress intensity
L: Distance from grid point of corner

2.2.2.3 SLUICEWAY TYPE C

(3) BREAST WALL - LAND SIDE

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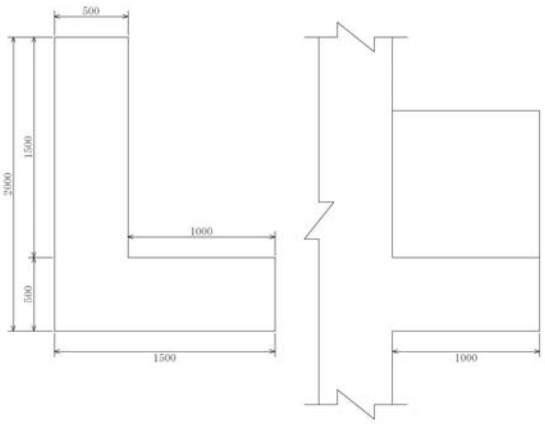
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1 Calculation of Land Side Breast Wall

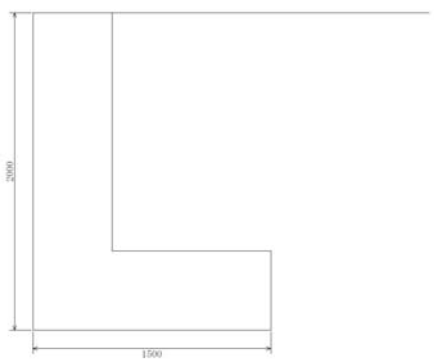
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φres	°	30
Peak Angle of Internal Friction	φpeak	°	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm^2/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D16	250	794.4
	Bottom Face	115.0	D16	250	794.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

1.1.4 Loads

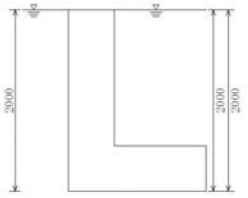
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

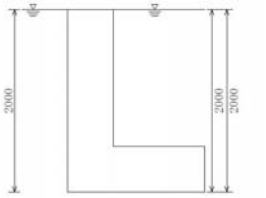
	(m)
Toe	2.000
Heel	2.000



1-2) Seismic Condition Number of Cases [1]

<Case 1>

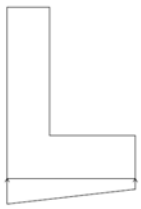
	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front



2) Subgrade Reaction

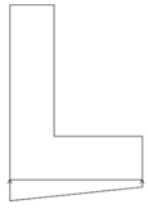
2-1) Normal <Case 1>

	(kN/m^2), (m)
Toe	95.78
Heel	40.25
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m^2), (m)
Toe	77.37
Heel	26.69
Load Width	0.000



3) Surcharge Load

Normal	kN/m^2	10.00
Seismic	kN/m^2	5.00

4) Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W = 0.000 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (0.000+ 10.00× 1.500)/ 1.500

= 10.000 (kN/m^2)

Earth Pressure at the Top

p1 = q0'・Ko = 10.000× 0.500 = 5.000 (kN/m^2)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.000+ 5.000

= 5.000 (kN/m^2)

Earth Pressure at Junction

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500×(20.00- 9.80)× 1.500+ 5.000

= 12.650 (kN/m^2)

Design Earth Pressure

P = p3

= 12.650 (kN/m^2)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

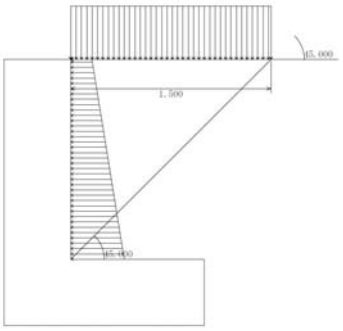
q_0 : Surcharge (kN/m^2)

w_{q0} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 1.500× 9.80 = 14.700 (kN/m^2)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

(2) **Seismic Condition-1**

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.500 × 24.00 × 0.20 = 2.400

Thus、

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	0.000	(m)
Embankment Height under the water level surface	h2	=	1.500	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_t	=	19.00	(kN/m^3)
Unit Weight of Soil (Saturated)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	1.863	(m)
Width of Converted Load	B	=	1.863	(m)
Internal Friction Angle of Soil	ϕ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh	=	0.345	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}$ (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}$ (kh')	=	19.026	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ + 0.00^\circ + 11.310^\circ\ )\times\sin(\ 30.00^\circ + 0.00^\circ\ )}{\cos(\ 0.00^\circ - 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}}$$

$$\cot(\xi_{EA}-\alpha) = 0.85094$$

Thus,

$$\cot(\xi_{EA}-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604(^\circ\ )$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ + 0.00^\circ + 19.026^\circ\ )\times\sin(\ 30.00^\circ + 0.00^\circ\ )}{\cos(\ 0.00^\circ - 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 19.026^\circ\ )}}$$

$$\cot(\xi_{EA}'-\alpha) = 1.24217$$

Thus,

$$\cot(\xi_{EA}'-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA}')} = 1.24217$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{1.24217}\right) = 38.836(^\circ\ )$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ - 11.310^\circ - 0.00^\circ\ )}{\cos(\ 11.310^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )} \times \frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ + 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}{\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )\times\cos(\ 0.00^\circ - 0.00^\circ\ )}}\right]^2}$$

$$= 0.4733$$

In case φ-α-θ_o< 0, sin(φ-α-θ_o) = 0.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ - 19.026^\circ - 0.00^\circ\ )}{\cos(\ 19.026^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ + 19.026^\circ + 0.00^\circ\ )} \times \frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ + 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 19.026^\circ\ )}{\cos(\ 0.00^\circ + 19.026^\circ + 0.00^\circ\ )\times\cos(\ 0.00^\circ - 0.00^\circ\ )}}\right]^2}$$

$$= 0.6214$$

In case φ-α-θ'$_o$< 0, sin(φ-α-θ'$_o$) = 0.

Weight of Embankment W $W = 0.000$ (kN/m)

Converted Load q0' $q0' = (W + q0\cdot wq0) / B$

$= (\ 0.000 + 5.00\times 1.863\ ) / 1.863$

$= 5.000$ (kN/m^2)

Earth Pressure at the Top

P1 = q0'・K_{EA} = 5.000× 0.4733 = 2.366 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 0.000+ 2.366

= 2.366 (kN/m^2)

Earth Pressure at Junction

P3 = K_{EA}・(γ_{sat} − γ_w)・h2 + p2

= 0.6214×(20.00- 9.80)× 1.500+ 2.366

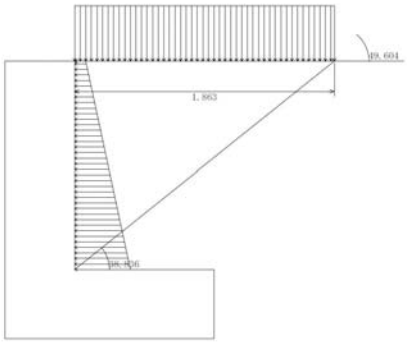
= 11.874 (kN/m^2)

Design Earth Pressure

P_{HE} = P3 ・cosδ= 11.874×cos(0.00°)

= 11.874 (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

Ph = hh・γ_w= 1.500× 9.80 = 14.700 (kN/m^2)

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

1.2.2 **Summary of Cross-sectional Internal Forces**

1) Normal Condition-1

	P(kN/m²)	l(m)	P・l²/2(kN.m/m)
Water Pressure	14.70	1.000	7.35
Earth Pressure	12.65	1.000	6.32
Σ	27.35	----	13.68
Bending Moment	M(kN.m/m)	Σ(P・l²/2) = 13.68	
Shear Force	S(kN/m)	Σ(P・l) = 27.35	

2) Seismic Condition-1

	P(kN/m²)	l(m)	P・l²/2(kN.m/m)
Inertia force	2.40	1.000	1.20
Water Pressure	14.70	1.000	7.35
Earth Pressure	11.87	1.000	5.94
Σ	28.97	----	14.49
Bending Moment	M(kN.m/m)	Σ(P・l²/2) = 14.49	
Shear Force	S(kN/m)	Σ(P・l) = 28.97	

1.2.3 **Stress Calculation**

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Front	mm²	D16 - 4.00 = 794.4
	Back	mm²	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	13.68
Re-bar	d1 As1	mm mm²	410.0 794.4
Required Area of Re-bar	Back	mm²	246.4
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm²	1.01
	σs	N/mm²	44.51
Allowable Value	σca	N/mm²	8.20
	σsa	N/mm²	140.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	328.5
	inp	mm²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	14.49
Re-bar	d1 As1	mm mm²	410.0 794.4
Required Area of Re-bar	Back	mm²	195.7
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm²	1.07
	σs	N/mm²	47.15
Allowable Value	σca	N/mm²	12.30
	σsa	N/mm²	186.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	261.0
	inp	mm²	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	27.35
Re-bar	d1 As1	mm mm²	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.067
Allowable Value	τa	N/mm²	0.360
	τa2	N/mm²	1.600

■Seismic Condition-1

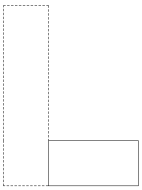
	Symbol	Unit	Junction
Shear Force	S	kN	28.97
Re-bar	d1 As1	mm mm²	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.071
Allowable Value	τa	N/mm²	0.540
	τa2	N/mm²	2.400

1.3 **Calculation of Heel Slab**

1.3.1 **Load**

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

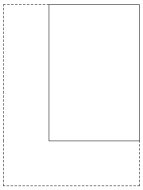
Thus,

Sw : Weight of Body (kN/m²)

h :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

1-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.00

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.00

Thus、

Pw1 :Wight of Embankment at basis (kN/m²)

Pw2 : Weight of Embankment at edge (kN/m²)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

1-3) Subgrade Reaction Force

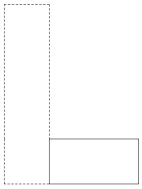
	Intensity of subgrade reaction (kN/m²)
Base	77.27
Edge	40.25

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

(2) **) Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

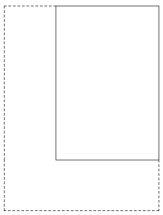
Thus、

Sw : Weight of Wall (kN/m^2)

H :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.00

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.00

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction (kN/m^2)
Base	60.48
Edge	26.69

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

1.3.2 Summary of Cross-Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	77.27	1.000	38.63
Surcharge	-10.00	1.000	-5.00
Σ	44.87	----	22.43
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 22.43		
Shear Force	S (kN/m) Σ(P・l) = 44.87		

1-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	40.25	1.000	20.13
Surcharge	-10.00	1.000	-5.00
Σ	7.85	----	3.93
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 3.93		
Shear Force	S (kN/m) Σ(P・l) = 7.85		

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	60.48	1.000	30.24
Surcharge	-5.00	1.000	-2.50
Σ	33.08	----	16.54
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 16.54		
Shear Force	S (kN/m) Σ(P・l) = 33.08		

2-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	26.69	1.000	13.35
Surcharge	-5.00	1.000	-2.50
Σ	-0.71	----	-0.35
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = -0.35		
Shear Force	S (kN/m) Σ(P・l) = -.0.71		

1.3.3 Stress Intensity Calculation

(1) Flexural Stress Intensity

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Upper	mm^2	D16 - 4.00 = 794.4
	Lower	mm^2	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	22.43	3.93
Re-bar	d1 As1	mm mm^2	385.0 794.4	385.0 794.4
Required Area of Re-bar	Lower	mm^2	435.5	74.2
Neutral Axis	X	m	0.067	0.067
Stress Intensity	σc	N/mm^2	1.84	0.32
	σs	N/mm^2	77.90	13.63
Allowable Value	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	580.7	99.0
	inp	mm^2	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	16.54	-0.35
Re-bar	d1 As1	mm mm^2	385.0 794.4	90.0 794.4
Required Area of Re-bar	Upper	mm^2		4.7
	Lower	mm^2	238.9	
Neutral Axis	X	m	0.067	0.070
Stress Intensity	σc	N/mm^2	1.35	0.03
	σs	N/mm^2	57.43	1.16
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	318.6	6.2
	inp	mm^2	794.4	794.4

(2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	44.87	7.85
Re-bar	d1 As1	mm mm^2	385.0 794.4	385.0 794.4
Effective Height	d	mm	385.0	385.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.117	0.020
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	33.08	-0.71
Re-bar	d1 As1	mm mm^2	385.0 794.4	90.0 794.4
Effective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.086	0.002
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400

2.2.2.3 SLUICEWAY TYPE C

(4) BREAST WALL - RIVER SIDE

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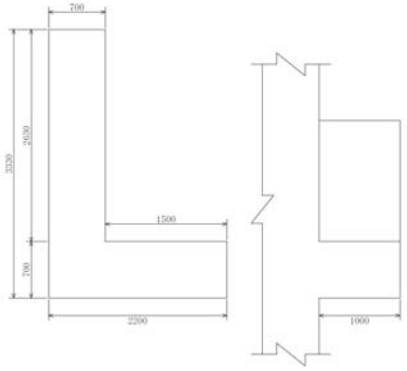
1.3.3 Stress Intensity Calculation....19

1 Calculation of River Side Breast Wall

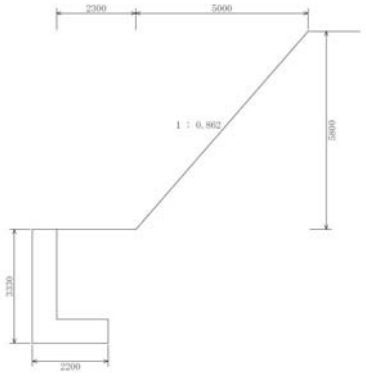
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φres	°	30
Peak Angle of Internal Friction	φpeak	°	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm^2/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D16	250	794.4
	Bottom Face	115.0	D16	250	794.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Side Wall	100.0	0.0
Bottom Slab	100.0	0.0

1.1.4 Loads

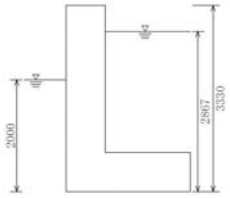
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

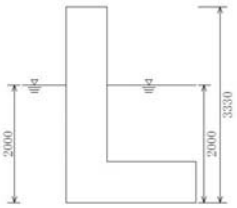
	(m)
Toe	2.000
Heel	2.867



1-2) Seismic Condition Number of Cases [1]

<Case 1>

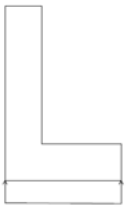
	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front



2) Subgrade Reaction

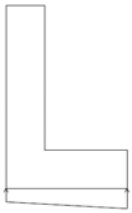
2-1) Normal <Case 1>

	(kN/m^2),(m)
Toe	69.59
Heel	72.12
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m^2),(m)
Toe	39.71
Heel	59.88
Load Width	0.000



3) Surcharge Load

Normal	kN/m^2	10.00
Seismic	kN/m^2	5.00

4) Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W =80.446 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load $q0' = (W+q0 \cdot wq0)/B$

$= (80.446+ 10.00\times 1.130)/ 2.630$

$= 34.884\ (kN/m^2)$

Earth Pressure at the Top

$p1 = q0' \cdot Ko = 34.884\times 0.500 = 17.442\ (kN/m^2)$

Earth Pressure at Water Level

$p2 = Ko \cdot \gamma_t \cdot h1+p1$

$= 0.500\times 19.00\times 0.463+ 17.442$

$= 21.841\ (kN/m^2)$

Earth Pressure at Junction

$p3 = Ko \cdot (\gamma_{sat}-\gamma_w) \cdot h2+p2$

$= 0.500\times(20.00- 9.80)\times 2.167+ 21.841$

$= 32.892\ (kN/m^2)$

Design Earth Pressure

$P = p3$

$= 32.892\ (kN/m^2)$

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

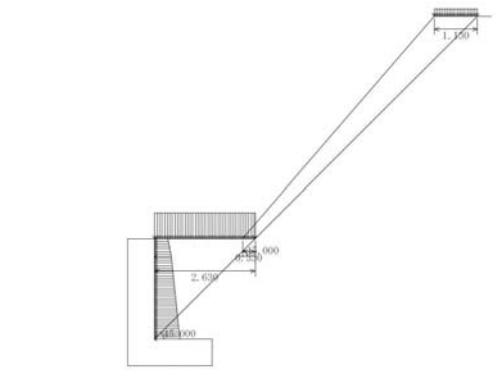
q_0 : Surcharge (kN/m^2)

w_{qo} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 2.167× 9.80 = 21.237 (kN/m^2)

Thus,

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

(2) **Seismic Condition-1**

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.700× 24.00× 0.20 = 3.360

Thus,

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_c : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	1.330	(m)
Embankment Height under the water level surface	H2	=	1.300	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γt	=	19.00	(kN/m^3)
Unit Weight of Soil (Saturated)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	0.037	(m)
Width of Converted Load	B	=	2.401	(m)
Internal Friction Angle of Soil	φ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh	=	0.259	(degree)
Compound Angle in Seismic Condition	θ_0= tan^{-1} (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	θ_0= tan^{-1} (kh')	=	14.496	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$$\cot(\xi_{EA}-\alpha) = 0.85094$$

Thus,

$$\cot(\xi_{EA}-0.00^\circ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 14.496^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 14.496^\circ)}}$$

$$\cot(\xi_{EA}'-\alpha) = 0.97654$$

Thus,

$$\cot(\xi_{EA}'-0.00^\circ) = \frac{1}{\tan(\xi_{EA}')} = 0.97654$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{0.97654}\right) = 45.680^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$$= 0.4733$$

In case φ-α-θ_o< 0, sin(φ-α-θ_o) = 0.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 14.496^\circ - 0.00^\circ)}{\cos(14.496^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 14.496^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 14.496^\circ)}{\cos(0.00^\circ + 14.496^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$$= 0.5266$$

In case φ-α-θ'$_o$< 0, sin(φ-α-θ'$_o$) = 0.

Weight of Embankment W

Converted Load q0'

W = 7.601 (kN/m)

q0' = (W + q0・wq0) / B

= (7.601+ 5.00× 0.037) / 2.401

= 3.242 (kN/m^2)

Earth Pressure at the Top

P1 = q0'・K_{EA} = 3.242× 0.4733 = 1.534 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 1.330+ 1.534

= 13.494 (kN/m^2)

Earth Pressure at Junction

P3 = K_{EA}・(γ_{sat} − γ_w)・h2 + p2

= 0.5266×(20.00- 9.80)× 1.300+ 13.494

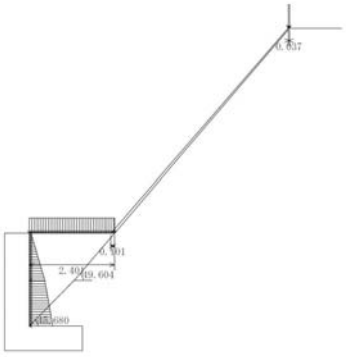
= 20.476 (kN/m^2)

Design Earth Pressure

P_{HE} = P3 ・cosδ= 46.159×cos(0.00°)

= 46.159 (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

Ph = hh・γ_w= 1.300× 9.80 = 12.740 (kN/m^2)

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

1.2.2 **Summary of Cross-sectional Internal Forces**

1) Normal Condition-1

	P(kN/m²)	l(m)	P・l²/2(kN.m/m)
Water Pressure	21.24	1.000	10.62
Earth Pressure	32.89	1.000	16.45
Σ	54.13	----	27.06
Bending Moment	M(kN.m/m)	Σ(P・l²/2) =	27.06
Shear Force	S(kN/m)	Σ(P・l) =	54.13

2) Seismic Condition-1

	P(kN/m²)	l(m)	P・l²/2(kN.m/m)
Inertia force	3.36	1.000	1.68
Water Pressure	12.74	1.000	6.37
Earth Pressure	20.48	1.000	10.24
Σ	36.58	----	18.29
Bending Moment	M(kN.m/m)	Σ(P・l²/2) =	18.29
Shear Force	S(kN/m)	Σ(P・l) =	36.58

1.2.3 **Stress Calculation**

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Front	mm²	D16 - 4.00 = 794.4
	Back	mm²	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	27.06
Re-bar	d1 As1	mm mm²	610.0 794.4
Required Area of Re-bar	Back	mm²	327.1
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm²	1.08
	σs	N/mm²	58.62
Allowable Value	σca	N/mm²	8.20
	σsa	N/mm²	140.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	436.1
	inp	mm²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	18.29
Re-bar	d1 As1	mm mm²	610.0 794.4
Required Area of Re-bar	Back	mm²	164.9
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm²	0.73
	σs	N/mm²	39.61
Allowable Value	σca	N/mm²	12.30
	σsa	N/mm²	186.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	219.8
	inp	mm²	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	54.13
Re-bar	d1 As1	mm mm²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.089
Allowable Value	τa	N/mm²	0.360
	τa2	N/mm²	1.600

■Seismic Condition-1

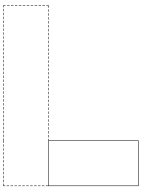
	Symbol	Unit	Junction
Shear Force	S	kN	36.58
Re-bar	d1 As1	mm mm²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.060
Allowable Value	τa	N/mm²	0.540
	τa2	N/mm²	2.400

1.3 **Calculation of Heel Slab**

1.3.1 **Load**

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

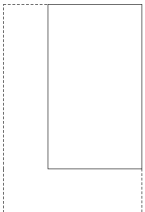
Thus,

Sw : Weight of Body (kN/m²)

h :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

1-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.463× 19.00 + 2.167× 20.00 = 52.137

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.463× 19.00 + 2.167× 20.00 = 52.137

Thus、

Pw1 :Wight of Embankment at basis (kN/m²)

Pw2 : Weight of Embankment at edge (kN/m²)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

1-3) Subgrade Reaction Force

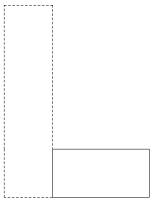
	Intensity of subgrade reaction (kN/m²)
Base	70.40
Edge	72.12

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.276× 9.80	22.303
Edge	2.867× 9.80	28.097

(2) **) Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

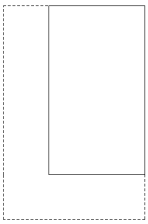
Thus、

Sw : Weight of Wall (kN/m2)

H :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 1.330× 19.00 + 1.300× 20.00 = 51.270

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 1.330× 19.00 + 1.300× 20.00 = 51.270

Thus、

Pw1 :Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	46.13
Edge	59.88

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

1.3.2 Summary of Cross Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P(kN/m^2)	l(m)	P・l^2/2(kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-52.14	1.000	-26.07
Uplift Force	22.30	1.000	11.15
Intensity of Subgrade Reaction	70.40	1.000	35.20
Σ	23.76	----	11.88
Bending Moment M(kN.m/m) Σ(P・l^2/2) = 11.88			
Shear Force S(kN/m) Σ(P・l) =23.76			

1-2) Edge

	P(kN/m^2)	l(m)	P・l^2/2(kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-52.14	1.000	-26.07
Uplift Force	28.10	1.000	14.05
Intensity of Subgrade Reaction	72.12	1.000	36.06
Σ	31.28	----	15.64
Bending Moment M(kN.m/m) Σ(P・l^2/2) = 15.64			
Shear Force S(kN/m) Σ(P・l) = 31.28			

2) Seismic Condition-1

2-1) Base

	P(kN/m^2)	l(m)	P・l^2/2(kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.27	1.000	-25.64
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	46.13	1.000	23.06
Σ	-2.34	----	-1.17
Bending Moment M(kN.m/m) Σ(P・l^2/2) = -1.17			
Shear Force S(kN/m) Σ(P・l) = -2.34			

2-2) Edge

	P(kN/m^2)	l(m)	P・l^2/2(kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.27	1.000	-25.64
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	59.88	1.000	29.94
Σ	11.41	----	5.71
Bending Moment M(kN.m/m) Σ(P・l^2/2) = 5.71			
Shear Force S(kN/m) Σ(P・l) = 11.41			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Upper	mm^2	D16 - 4.00 =794.4
	Lower	mm^2	D16 - 4.00 =794.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	11.88	15.64
Re-bar	d1	mm	585.0	585.0
	As1	mm^2	794.4	794.4
Required Area of Re-bar	Lower	mm^2	148.3	195.8
Neutral Axis	X	m	0.085	0.085
Stress Intensity	σc	N/mm^2	0.50	0.66
	σs	N/mm^2	26.86	35.36
Allowable Value	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	197.7	261.1
	inp	mm^2	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	-1.17	5.71
Re-bar	d1	mm	90.0	585.0
	As1	mm^2	794.4	794.4
Required Area of Re-bar	Upper	mm^2	10.4	
	Lower	mm^2		53.1
Neutral Axis	X	m	0.087	0.085
Stress Intensity	σc	N/mm^2	0.05	0.24
	σs	N/mm^2	2.54	12.90
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	13.8	70.8
	inp	mm^2	794.4	794.4

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	23.76	31.28
Re-bar	d1	mm	585.0	585.0
	As1	mm^2	794.4	794.4
Effective Height	d	mm	585.0	585.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.041	0.053
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	-2.34	11.41
Re-bar	d1	mm	90.0	585.0
	As1	mm^2	794.4	794.4
Effective Height	d	mm	610.0	585.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.004	0.020
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400

2.2.2.4 SLUICEWAY TYPE F

(1) BOX - LONGITUDINAL

Structural Calculation of Sluiceway Type-F

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1 Design Condition

1.1 Design Condition

1.1.1 Basic Condition

1) Culvert Shape:Rectanglar

2) Culvert Type: Double Holes

3) Allowable Displacement

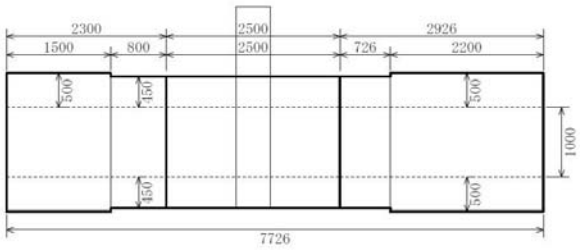
Residual Settlement : 300.0 (mm)
Residual Settlement for Rigid Support : 50.0 (mm)
Relative Displacement Base Width : 1.0 (%)
± : 50.0 (mm)

4) Type of Joint : Flexible Joint

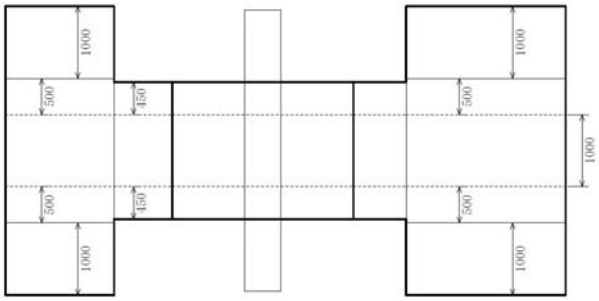
5) Allowable Opening : 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

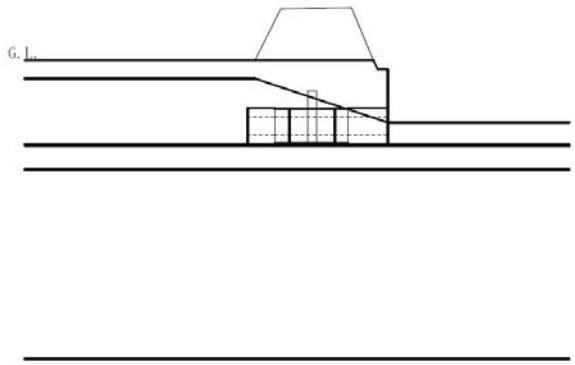
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Leeve Cross-section



1.2 Shape of Culvert Body

1.2.1 Span and Block

1) Spans

Number of Spans: 3
Total Length of Spans: 7.726 (m)

Span No	Name of Span	Length of Span (m)	Number of Blocks
1	Land Side	2.300	2
2	Center	2.500	1
3	River Side	2.926	2

2) Blocks

Span/ Block	Length of Block (m)	Depth for Subgrade Reaction(m)
1- 1	1.500	12.000
1- 2	0.800	5.700
2- 1	2.500	5.700
3- 1	0.726	5.700
3- 2	2.200	12.000

1.2.2 Sectional Dimension

1) Dimension (Block)

Span/ Block	Left Inside Width X2 (m)	Inside Height Y2 (m)
1- 1	1.000	1.000
1- 2	1.000	1.000
2- 1	1.000	1.000
3- 1	1.000	1.000
3- 2	1.000	1.000

Span/ Block	Thickness of Left Side Wall X1(m)	Thickness of Top Slab Y1(m)	Thickness of Bottom Slab Y3(m)	Height of Overhang Y4(m)	Length of Left Overhang B1(m)
1- 1	0.500	0.500	0.500	0.500	1.000
1- 2	0.450	0.450	0.450	0.000	0.000
2- 1	0.450	0.450	0.450	0.000	0.000
3- 1	0.450	0.450	0.450	0.000	0.000
3- 2	0.500	0.500	0.500	0.700	1.000

1.3 Reinforcement

Main Re-bar

Span No	Block No	Flange			Reinforcing Bar			
		Portion	b (mm)	t (mm)	Outside		Inside	
					Diameter@Pitch (Number)	Cover (mm)	Diameter@Pitch (Number)	Cover (mm)
1	1	Top Slab	2000.0	500.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	2000.0	500.0	D16@250(6)	115.0	D16@250(8)	90.0
	2	Top Slab	1900.0	450.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	1900.0	450.0	D16@250(6)	115.0	D16@250(8)	90.0
2	1	Top Slab	1900.0	450.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	1900.0	450.0	D16@250(6)	115.0	D16@250(8)	90.0
3	1	Top Slab	1900.0	450.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	1900.0	450.0	D16@250(6)	115.0	D16@250(8)	90.0
	2	Top Slab	2000.0	500.0	D25@250(6)	90.0	D25@250(8)	90.0
		Bottom Slab	2000.0	500.0	D25@250(6)	115.0	D25@250(8)	90.0

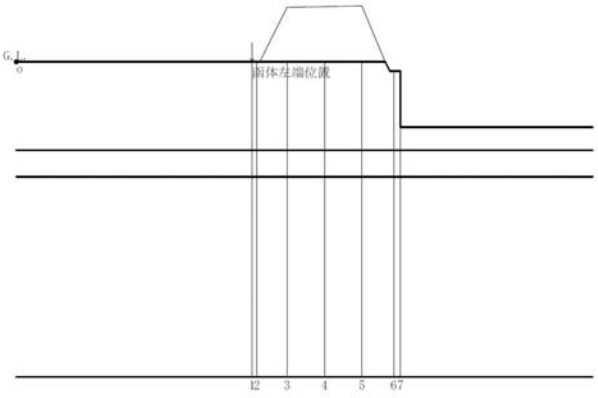
2 Settlement and Lateral Displacement

2.1 Immediate Settlement

2.1.1 Settlemet Calculation Points

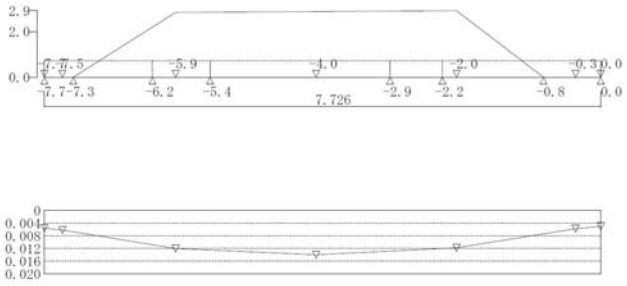
Settlemet Calculation Points

No	Calculation Point (m)	Name
1	-7.726	Box end (land side)
2	-7.476	Breast wall (land side)
3	-5.903	Levee end (land side)
4	-3.953	Levee center
5	-2.003	Levee end (river side)
6	-0.350	Breast wall (river side)
7	0.000	Box end (river side)



2.1.2 Summery of Immediate Settlement

No	Calculation Point (m)	Name	Immediate Settlement (mm)
1	-7.726	Box end (land side)	5.6
2	-7.476	Breast wall (land side)	6.2
3	-5.903	Levee end (land side)	12.0
4	-3.953	Levee center	14.0
5	-2.003	Levee end (river side)	11.8
6	-0.350	Breast wall (river side)	5.8
7	0.000	Box end (river side)	5.0

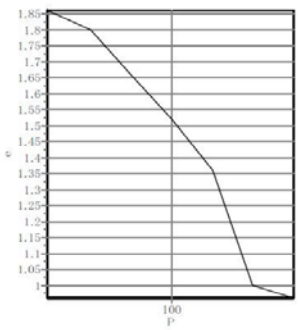


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

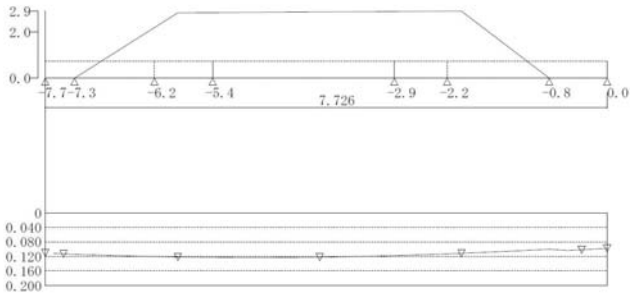
No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/ m³)	Unit Weight (Saturated) (kN/ m³)	Pre-Consolidation Stress q0 (kN/m²)	Elastic Modulus Es (kN/m²)
1	Adobe BL	Sand	4.622	17.500	18.500	0.0	6900.0
2	As	Sand	6.019	17.500	18.500	0.0	6900.0
3	Dc1	Clay	16.449	17.500	18.500	0.0	15700.0

No	Concolidation Pressure P(kN/m²)	Void Ratio e
1	12.0000	1.8600
2	25.0000	1.8000
3	50.0000	1.6600
4	100.0000	1.5200
5	200.0000	1.3600
6	400.0000	1.0000
7	800.0000	0.9600



2.2.2 Summery of Consolidation Settlement

No	Calculation Point (m)	Name	Consolidation Settlement (mm)
1	-7.726	Box end (land side)	110.1
2	-7.476	Breast wall (land side)	112.6
3	-5.903	Levee end (land side)	121.3
4	-3.953	Levee center	121.8
5	-2.003	Levee end (river side)	111.1
6	-0.350	Breast wall (river side)	101.5
7	0.000	Box end (river side)	97.5

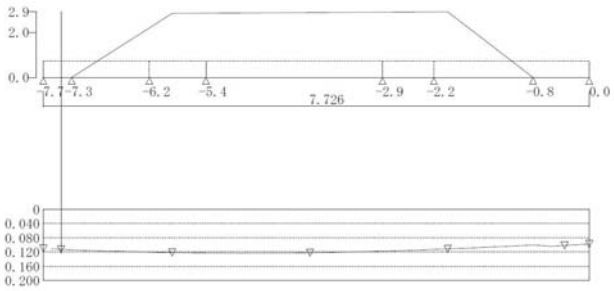


2.3 Residual Settlement

2.3.1 Sumarry of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vaue	Judge
1	-7.726	Box end (land side)	5.6	110.1	0.0	115.7	300.000	OK
2	-7.476	Breast wall (land side)	6.2	112.6	0.0	118.8	300.000	OK
3	-5.903	Levee end (land side)	12.0	121.3	0.0	133.3	300.000	OK
4	-3.953	Levee center	14.0	121.8	0.0	135.8	300.000	OK
5	-2.003	Levee end (river side)	11.8	111.1	0.0	122.9	300.000	OK
6	-0.350	Breast wall (river side)	5.8	101.5	0.0	107.3	300.000	OK
7	0.000	Box end (river side)	5.0	97.5	0.0	102.5	300.000	OK

The maximum of residual settlement is above 50.0(mm), herence the foundation is taken as flexible



▽ : Immediate Settlement
○ : Residual Settlement

3 Calculation of Box Culvert regarding Longitudal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B}\cdot\frac{d^4w}{dx^4}+k_v(w-w_g)=q \text{ (Swag)}$$

$$\frac{EA}{U}\cdot\frac{d^2u}{dx^2}+k_s(u-u_g)=p \text{ (Displacement in axial direction of Box Culvert)}$$

Thus,

w : Displacement of Box Culvert (Swag : cm {m})
w_g : Displacement of the Ground (Residual Settlement: cm {m})
k_v : Modulus of Sub grade Reaction in Vertical Direction (kgf/cm^3) {kN/m^3}
B : Width of Box Culvert (cm) {m}
EI : Rigidity of Box Culvert (kgf･cm^2) {kN･m^2}
q : Vertical External Force (kgf/cm^2) {kN/m^2}
u : Displacement on axial direction of Box Culvert (cm) {m}
u_g : Displacement of Ground (Lateral Displacement ; cm {m})
k_s : Modulus of Lateral Shear Sub grade Reaction (kgf/cm^3) {kN/m^3}
U : Circumference of Box Culvert (cm) {m}
EA : Rigidity of Box Culvert in axial direction (kgf) {kN}
p : Axial External Force (kgf/cm^2){kN/m^2}

3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{om}=\frac{\log\frac{(B+2h_n\cdot\tan\theta)\cdot L}{(L+2h_n\cdot\tan\theta)\cdot B}}{\Sigma\frac{1}{E_i}\log\frac{(B+2h_i\cdot\tan\theta)(L+2h_{i-1}\cdot\tan\theta)}{(L+2h_i\cdot\tan\theta)(B+2h_{i-1}\cdot\tan\theta)}}$$

In case of B=L

$$E_{om}=\frac{-\frac{1}{B+2h_n\cdot\tan\theta}+\frac{1}{B}}{\Sigma\frac{1}{E_i}\left(-\frac{1}{B+2h_i\cdot\tan\theta}+\frac{1}{B+2h_{i-1}\cdot\tan\theta}\right)}$$

Thus

Eom ; Converted Modulus of Deformation
B ; Loading Width = Width of Culvert
L ; Loading Length = Length of a span
hn ; Depth for Calculation
hn ; Depth from the ground to the bottom Elevation of Each Layer （m）
Ei ; Converted Modulus of Deformation of Each Layer（kN/m^2）
θ ; Angle of Load Dispersion （θ=30°）

Span1-Block1 Land Side

B			4.000 (m)
L			2.300 (m)
hn			12.000 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	1.297	1.297	27600.0
2	10.703	12.000	62800.0
Total	12.000		
Eom	41422.5 (kN/m^2)		

※Layer Thickness and Depths are the values based on subgrade Surface.

Span1-Block2 Land Side

B			1.900 (m)
L			2.300 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	1.297	1.297	27600.0
2	4.403	5.700	62800.0
Total	5.700		
Eom	36905.7 (kN/m^2)		

※Layer Thickness and Depths are values Calculated from the subgrade

Span2-Block1 Center

B			1.900 (m)
L			2.500 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	1.297	1.297	27600.0
2	4.403	5.700	62800.0
Total	5.700		
Eom	37116.8 (kN/m^2)		

※Layer and Depth is the values from the subgrade

Span3-Block1 River Side

B			1.900 (m)
L			2.926 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	1.297	1.297	27600.0
2	4.403	5.700	62800.0
Total	5.700		
Eom	37509.5 (kN/m^2)		

※Layer and Depth is the values from the subgrade

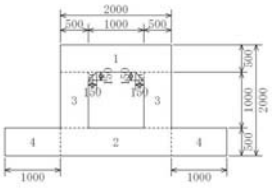
Span3-Block2　River Side

B	4.000 (m)		
L	2.926 (m)		
hn	12.000 (m)		
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	1.297	1.297	27600.0
2	10.703	12.000	62800.0
Total	12.000		
Eom	42290.6 kN/m²		

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

Span1-Block1　Land Side

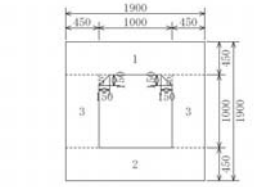


Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.023	1.450	0.0326	0.0473	0.00003
Total	4.023		3.2826	4.2348	0.14586

Yg = Σ(Ai・Yi)/ΣAi = 3.2826 / 4.023 = 0.8161 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 4.2348 + 0.14586 - 0.6660・4.023= 1.70183 (m⁴)

Span1-Block2　Land Side

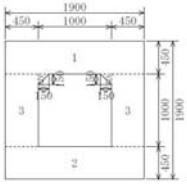


Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.633 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.633= 1.00722 (m⁴)

Span2-Block1　Center

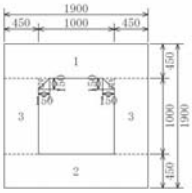


Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.633 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.633= 1.00722 (m⁴)

Span3-Block1　River Side

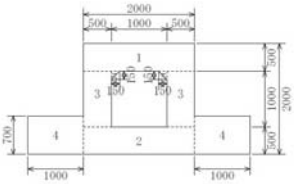


Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.633 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg²・ΣAi = 3.2984 + 0.10388 - 0.9098・2.633 = 1.00722 (m⁴)

Span3-Block2　River Side



Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.400	0.350	0.4900	0.1715	0.05717
5	0.023	1.450	0.0326	0.0473	0.00003
Total	4.423		3.5226	4.3438	0.18219

Yg = Σ(Ai・Yi)/ΣAi = 3.5226 / 4.423 = 0.7965 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg²・ΣAi = 4.3438 + 0.18219 - 0.6344・4.423 = 1.72015 (m⁴)

3.2.3 Table of Modulus of Subgarade Reaction

Coefficient of Lateral Shear Reaction of Soil

$k_s = \lambda \cdot k_v$

Thus、

ks : Coefficient of Lateral Shear Reaction of Soil (kN/m2)

λ ; Ratio between the coefficient of Lateral Shear Reaction of Soil and Vertical Sub grade Reaction (=0.333)

kv : Coefficient of Vertical Sub grade Reaction

3.2.4 List of Modulus of Subgrade Reaction

Calculated Value

Normal Condition

Span Block	Position (m)	B (m)	k_v (kN/m³)	k_s (kN/m²)	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
1-1	-7.726～ -6.226	4.000	24352.1	8109.2	97408.3	32437.0
1-2	-6.226～ -5.426	1.900	28683.5	9551.6	54498.7	18148.1
2-1	-5.426～ -2.926	1.900	27959.5	9310.5	53123.1	17690.0
3-1	-2.926～ -2.200	1.900	26636.4	8869.9	50609.1	16852.8
3-2	-2.200～ 0.000	4.000	22716.3	7564.5	90865.3	30258.1

Seismic Condition

Span Block	Position (m)	B (m)	k_v (kN/m³)	k_s (kN/m²)	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
1-1	-7.726～ -6.226	4.000	48704.1	16218.5	194816.5	64873.9
1-2	-6.226～ -5.426	1.900	57367.0	19103.2	108997.3	36296.1
2-1	-5.426～ -2.926	1.900	55919.1	18621.0	106246.2	35380.0
3-1	-2.926～ -2.200	1.900	53272.8	17739.8	101218.3	33705.7
3-2	-2.200～ 0.000	4.000	45432.6	15129.1	181730.6	60516.3

Used Value

Normal Condition

Span Block	Position (m)	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
1-1	-7.726～ -6.226	97408.3	32437.0
1-2	-6.226～ -5.426	54498.7	18148.1
2-1	-5.426～ -2.926	53123.1	17690.0
3-1	-2.926～ -2.200	50609.1	16852.8
3-2	-2.200～ 0.000	90865.3	30258.1

Seismic Condition

Span Block	Position (m)	Reduction Ratio DE	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
1-1	-7.726～ -6.226	1.000	194816.5	64873.9
1-2	-6.226～ -5.426	1.000	108997.3	36296.1
2-1	-5.426～ -2.926	1.000	106246.2	35380.0
3-1	-2.926～ -2.200	1.000	101218.3	33705.7
3-2	-2.200～ 0.000	1.000	181730.6	60516.3

3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

W = (A1 + A2 + A3) ・γc (kN/m)

A1: Cross Sectional Area (Excluding Hunch) (m^2)

A2: Area of Upper Side Hunch (m^2)

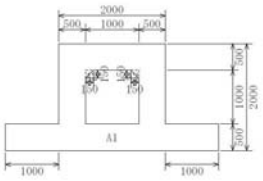
A3: Area of Lower Side Hunch (m^2)

γc: Unit Weight (Concrete) (kN/m^3)

Span No. 1-1 Land Side

W = (4.000 + 0.023 + 0.000) ・ 24.000

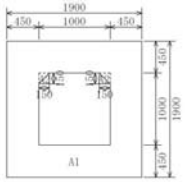
= 96.540 (kN/m)



Span No. 1-2 Land Side

W = (2.610 + 0.023 + 0.000) ・ 24.000

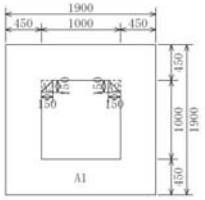
= 63.180 (kN/m)



Span No. 2-1 Center

W = (2.610 + 0.023 + 0.000) ・ 24.000

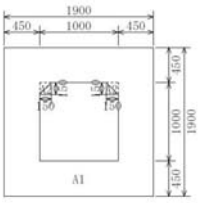
= 63.180 (kN/m)



Span No. 3-1 River Side

W = (2.610 + 0.023 + 0.000) ・ 24.000

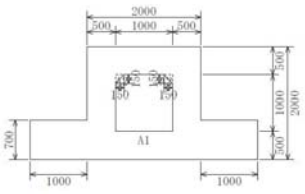
= 63.180 (kN/m)



Span No. 3-2 River Side

W = (4.400 + 0.023 + 0.000) ・ 24.000

= 106.140 (kN/m)



2) Seepage Cutoff Wall Body Weight

A1 = X1・L2

A2 = L1・Y1・2

W = (A1 + A2) ・B・γc (kN)

X1: Top Slab Width (m)

Y1: Side Wall Height (m)

L1: Side Wall Width (m)

L2: Top Slab Height (m)

A1: Top Slab Area (m^2)

A2: Side Wall Area (m^2)

B: Thickness (m)

γc: Unit Weight (Concrete) (kN/m^3)

SpanNo.2-SpanDistance from Base Point (1.250)

A1 = 3.900・ 1.000

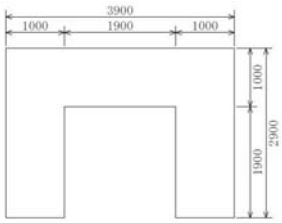
= 3.900 (m^2)

A2 = 1.000・ 1.900 ・2

= 3.800 (m^2)

W = (3.900 + 3.800)・ 0.500・ 24.00

= 92.400 (kN)



3.3.2 Ground Displacement Load (Settlement、Lateral Displacement)

1) Equivalent Load for Ground Settlement

【Normal Condition】

Span1 Name of Span: [Land Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-7.726～ -7.476	4.000	97408.3	115.7	118.8	-11273.979	-11571.182
1-(2)	-7.476～ -7.226	4.000	97408.3	118.8	121.6	-11571.182	-11840.403
1-(3)	-7.226～ -6.726	4.000	97408.3	121.6	126.4	-11840.403	-12308.472
1-(4)	-6.726～ -6.226	4.000	97408.3	126.4	131.2	-12308.472	-12781.055
2-(5)	-6.226～ -5.726	1.900	54498.7	131.2	134.2	-7150.835	-7314.104
2-(6)	-5.726～ -5.426	1.900	54498.7	134.2	135.4	-7314.104	-7380.741

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(7)	-5.426～ -4.926	1.900	53123.1	135.4	136.6	-7194.451	-7256.227
1-(8)	-4.926～ -4.426	1.900	53123.1	136.6	136.7	-7256.227	-7261.882
1-(9)	-4.426～ -3.926	1.900	53123.1	136.7	135.8	-7261.882	-7212.673
1-(10)	-3.926～ -3.426	1.900	53123.1	135.8	133.8	-7212.673	-7109.800
1-(11)	-3.426～ -2.926	1.900	53123.1	133.8	130.9	-7109.800	-6954.482

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(12)	-2.926～ -2.426	1.900	50609.1	130.9	127.0	-6625.370	-6428.104
1-(13)	-2.426～ -2.200	1.900	50609.1	127.0	124.9	-6428.104	-6322.552
1-(14)	-2.200～ -1.926	4.000	90865.3	124.9	122.1	-11351.718	-11095.944
1-(15)	-1.926～ -1.426	4.000	90865.3	122.1	115.9	-11095.944	-10530.039
1-(16)	-1.426～ -0.926	4.000	90865.3	115.9	108.8	-10530.039	-9885.656
1-(17)	-0.926～ -0.426	4.000	90865.3	108.8	108.3	-9885.656	-9840.862
1-(18)	-0.426～ -0.350	4.000	90865.3	108.3	107.3	-9840.862	-9747.126
1-(19)	-0.350～ 0.000	4.000	90865.3	107.3	102.5	-9747.126	-9316.269



2) Equivalent Load for Ground Settlement

【Seismic Condition】

Span1 Name of Span: [Land Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-7.726～ -7.476	4.000	194816.5	115.7	118.8	-22547.959	-23142.363
1-(2)	-7.476～ -7.226	4.000	194816.5	118.8	121.6	-23142.363	-23680.806
1-(3)	-7.226～ -6.726	4.000	194816.5	121.6	126.4	-23680.806	-24616.944
1-(4)	-6.726～ -6.226	4.000	194816.5	126.4	131.2	-24616.944	-25562.111
2-(5)	-6.226～ -5.726	1.900	108997.3	131.2	134.2	-14301.669	-14628.208
2-(6)	-5.726～ -5.426	1.900	108997.3	134.2	135.4	-14628.208	-14761.482

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(7)	-5.426～ -4.926	1.900	106246.2	135.4	136.6	-14388.902	-14512.453
1-(8)	-4.926～ -4.426	1.900	106246.2	136.6	136.7	-14512.453	-14523.765
1-(9)	-4.426～ -3.926	1.900	106246.2	136.7	135.8	-14523.765	-14425.346
1-(18)	-3.926～ -3.426	1.900	106246.2	135.8	133.8	-14425.346	-14219.601
1-(11)	-3.426～ -2.926	1.900	106246.2	133.8	130.9	-14219.601	-13908.964

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(12)	-2.926～ -2.426	1.900	101218.3	130.9	127.0	-13250.740	-12856.208
1-(13)	-2.426～ -2.200	1.900	101218.3	127.0	124.9	-12856.208	-12645.104
2-(14)	-2.200～ -1.926	4.000	181730.6	124.9	122.1	-22703.435	-22191.889
2-(15)	-1.926～ -1.426	4.000	181730.6	122.1	115.9	-22191.889	-21060.078
2-(16)	-1.426～ -0.926	4.000	181730.6	115.9	108.8	-21060.078	-19771.312
2-(17)	-0.926～ -0.426	4.000	181730.6	108.8	108.3	-19771.312	-19681.724
2-(18)	-0.426～ -0.350	4.000	181730.6	108.3	107.3	-19681.724	-19494.251
2-(19)	-0.350～ 0.000	4.000	181730.6	107.3	102.5	-19494.251	-18632.538



3.3.3 Point Load from Breast Walls

1) Normal Condition (Case Number: 1)

Case of Normal Condition 1

Name of Normal Load: [Gate Piers and Breast Walls (Normal) 1]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	5.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-40.40	93.20	-47.97
3	Right Breast Wall	7.376	622.05	385.92	-759.30



2) Seismic Condition (Total Number: 2)

Case of Seismic Conditon 1 [Land Side →River Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	5.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-5.53	9.09	-20.15
3	Right Breast Wall	7.376	567.24	126.37	-770.04



Case of Seimic Condition 2 [River Side→Land Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	5.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-62.33	9.09	-6.90
3	Right Breast Wall	7.376	376.02	126.37	-420.91



3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
2	Fixed Load Data 2	Water Weight (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Engaging Load (Normal)1	Gate Structure ･Breast Wall (Normal)1	1.0000
6	Arbitrary Load (Normal)1	Surcharge in Normal Condition	1.0000

2) Seismic Condition

1) Case 1 [Seismic Condition: Land Side→River Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Dead Load)1	Gate Structure ･Breast Wall (Dead Load)1	1.0000
6	Ingaging Load (Seismic)1	Seismic Load :Land Side →River Side	1.0000

2) Case 2 [Seismic Condition: River Side→Land Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Dead Load)2	Seismic Load	1.0000
6	Ingaging Load (Dead Load)2	Gate Structure ･Breast Wall (Dead Load)2	1.0000

3.4 Displacement between Sluiceway and Adjoining Levee

3.4.1 Normal Condition

1) Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-6.8	-6.0	119.6	115.7	3.9	40.0	○	377.088
2	0.250	-6.8	-6.1	121.7	118.8	2.9	40.0	○	285.468
3	0.500	-6.8	-6.1	123.8	121.6	2.3	40.0	○	221.829
4	1.000	-6.8	-6.1	128.1	126.4	1.7	40.0	○	164.924
5	1.500	-6.8	-5.2	132.3	131.2	1.1	19.0	○	103.504
6	2.000	-6.8	-4.1	136.5	134.2	2.3	19.0	○	124.681
7	2.300	-6.8	-3.4	139.0	135.4	3.6	19.0	○	196.068

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground Spring (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-0.5	-3.4	139.6	135.4	4.1	19.0	○	219.288
2	0.500	-0.5	-2.2	138.6	136.6	2.1	19.0	○	109.109
3	1.000	-0.5	-1.0	137.7	136.7	1.0	19.0	○	55.049
4	1.500	-0.5	0.1	136.8	135.8	1.1	19.0	○	55.854
5	2.000	-0.5	1.3	135.9	133.8	2.1	19.0	○	110.323
6	2.500	-0.5	2.5	135.0	130.9	4.1	19.0	○	217.237

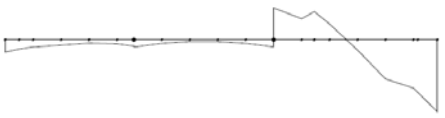
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	21.2	2.5	111.5	130.9	-19.4	-50.0	○	-981.809
2	0.500	21.2	3.7	114.1	127.0	-12.9	-50.0	○	-651.306
3	0.726	21.2	4.2	115.3	124.9	-9.6	-50.0	○	-871.737
4	1.000	21.2	4.9	116.8	122.1	-5.3	-50.0	○	-484.871
5	1.500	21.2	6.0	119.4	115.9	3.5	40.0	○	320.257
6	2.000	21.2	6.1	122.0	108.8	13.2	40.0	○	1203.867
7	2.500	21.2	6.1	124.7	108.3	16.4	40.0	○	1487.896
8	2.576	21.2	6.0	125.1	107.3	17.8	40.0	○	1617.996
9	2.926	21.2	6.0	126.9	102.5	24.4	40.0	○	2216.321

Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-5.6	-6.0	118.6	115.7	2.9	40.0	○	278.274
2	0.250	-5.6	-6.1	120.8	118.8	2.0	40.0	○	195.736
3	0.500	-5.6	-6.1	123.0	121.6	1.4	40.0	○	141.179
4	1.000	-5.6	-6.1	127.4	126.4	1.1	40.0	○	102.437
5	1.500	-5.6	-5.2	131.8	131.2	0.6	19.0	○	59.181
6	2.000	-5.6	-4.1	136.2	134.2	2.0	19.0	○	110.045
7	2.300	-5.6	-3.4	138.9	135.4	3.4	19.0	○	187.529

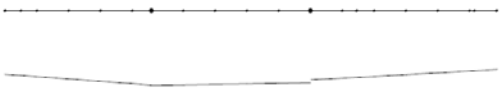
Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-0.5	-3.4	139.4	135.4	3.9	19.0	○	209.709
2	0.500	-0.5	-2.2	138.5	136.6	1.9	19.0	○	99.529
3	1.000	-0.5	-1.0	137.6	136.7	0.9	19.0	○	45.470
4	1.500	-0.5	0.1	136.6	135.8	0.9	19.0	○	46.275
5	2.000	-0.5	1.3	135.7	133.8	1.9	19.0	○	100.743
6	2.500	-0.5	2.5	134.8	130.9	3.9	19.0	○	207.657

Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	9.0	2.5	129.1	130.9	-1.8	-50.0	○	-89.271
2	0.500	9.0	3.7	125.8	127.0	-1.2	-50.0	○	-59.027
3	0.726	9.0	4.2	124.4	124.9	-0.6	-50.0	○	-52.011
4	1.000	9.0	4.9	122.5	122.1	0.4	40.0	○	39.431
5	1.500	9.0	6.0	119.2	115.9	3.4	40.0	○	305.462
6	2.000	9.0	6.1	115.9	108.8	7.2	40.0	○	649.973
7	2.500	9.0	6.1	112.6	108.3	4.3	40.0	○	394.897
8	2.576	9.0	6.0	112.1	107.3	4.9	40.0	○	443.053
9	2.926	9.0	6.0	109.8	102.5	7.3	40.0	○	664.002

Displacement Diagram



Reaction Force of Ground



Reaction Force



2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-6.1	-6.0	119.8	115.7	4.1	40.0	○	397.272
2	0.250	-6.1	-6.1	121.9	118.8	3.1	40.0	○	306.731
3	0.500	-6.1	-6.1	124.1	121.6	2.5	40.0	○	244.170
4	1.000	-6.1	-6.1	128.3	126.4	1.9	40.0	○	189.422
5	1.500	-6.1	-5.2	132.5	131.2	1.3	19.0	○	130.159
6	2.000	-6.1	-4.1	136.8	134.2	2.6	19.0	○	140.800
7	2.300	-6.1	-3.4	139.3	135.4	3.9	19.0	○	212.912

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-0.5	-3.4	139.4	135.4	3.9	19.0	○	209.709
2	0.500	-0.5	-2.2	138.5	136.6	1.9	19.0	○	99.529
3	1.000	-0.5	-1.0	137.6	136.7	0.9	19.0	○	45.470
4	1.500	-0.5	0.1	136.6	135.8	0.9	19.0	○	46.275
5	2.000	-0.5	1.3	135.7	133.8	1.9	19.0	○	100.743
6	2.500	-0.5	2.5	134.8	130.9	3.9	19.0	○	207.657

Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	7.8	2.5	131.7	130.9	0.8	19.0	○	42.137
2	0.500	7.8	3.7	127.8	127.0	0.7	19.0	○	37.405
3	0.726	7.8	4.2	125.9	124.9	1.0	19.0	○	92.741
4	1.000	7.8	4.9	123.8	122.1	1.6	40.0	○	149.769
5	1.500	7.8	6.0	119.8	115.9	3.9	40.0	○	353.001
6	2.000	7.8	6.1	115.8	108.8	7.0	40.0	○	634.712
7	2.500	7.8	6.1	111.8	108.3	3.5	40.0	○	316.834
8	2.576	7.8	6.0	111.2	107.3	3.9	40.0	○	355.444
9	2.926	7.8	6.0	108.4	102.5	5.9	40.0	○	532.430

Displacement Diagram



Reaction Force of Ground



Reaction Force



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.002	0.000	0.000
2	0.250	-6.446	56.290	7.513
3	0.250	74.350	-130.110	103.453
4	0.500	68.068	-93.228	75.867
5	1.000	55.986	-49.599	41.341
6	1.500	36.985	-35.552	21.328
7	2.000	17.031	-26.284	4.478
8	2.300	0.001	0.000	0.000

Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	2.300	0.000	0.000	0.000
2	2.800	20.655	45.720	13.725
3	3.300	31.038	50.379	38.876
4	3.800	31.142	-50.675	38.786
5	4.300	20.838	-45.510	13.605
6	4.800	0.000	0.000	0.000

Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	4.800	0.001	0.000	0.000
2	5.300	152.197	-444.658	-118.049
3	5.526	217.697	-589.565	-235.619
4	5.800	355.354	-807.127	-429.386
5	6.300	592.859	-906.141	-874.472
6	6.800	821.130	-582.970	-1265.152
7	7.300	1049.256	32.111	-1408.784
8	7.376	1083.984	141.337	-1402.156
9	7.376	-160.112	-630.504	116.444
10	7.726	-0.002	0.000	0.000

Bending Moment



Axial Force



Shear Force



3.5.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side →River Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.002	0.000	0.000
2	0.250	3.216	33.771	4.639
3	0.250	8.742	-58.519	65.889
4	0.500	12.122	-41.343	53.679
5	1.000	19.364	-28.688	36.884
6	1.500	19.687	-34.364	21.927
7	2.000	10.544	-27.727	4.751
8	2.300	0.001	0.000	0.000

Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	2.300	0.000	0.000	0.000
2	2.800	20.655	45.720	13.725
3	3.300	31.038	50.379	38.876
4	3.800	31.142	-50.675	38.786
5	4.300	20.838	-45.510	13.605
6	4.800	0.000	0.000	0.000

Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	4.800	0.001	0.000	0.000
2	5.300	79.820	-164.474	-43.331
3	5.526	112.606	-219.525	-86.997
4	5.800	179.052	-298.737	-159.039
5	6.300	286.610	-301.080	-317.375
6	6.800	384.933	-82.527	-423.293
7	7.300	483.111	226.648	-384.793
8	7.376	498.087	271.755	-365.863
9	7.376	-69.149	-275.186	51.387
10	7.726	-0.002	0.000	0.000

Bending Moment



Axial Force



Shear Force



Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.002	0.000	0.000
2	0.250	-4.075	64.456	8.528
3	0.250	58.251	-196.354	167.588
4	0.500	54.340	-151.038	124.489
5	1.000	47.000	-89.739	65.431
6	1.500	32.741	-56.951	29.989
7	2.000	15.439	-34.489	5.714
8	2.300	0.001	0.000	0.000

Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	2.300	0.000	0.000	0.000
2	2.800	20.655	45.720	13.725
3	3.300	31.038	50.379	38.876
4	3.800	31.142	-50.675	38.786
5	4.300	20.838	-45.510	13.605
6	4.800	0.000	0.000	0.000

Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	4.800	0.001	0.000	0.000
2	5.300	59.373	-67.438	-17.725
3	5.526	82.917	-89.243	-35.579
4	5.800	129.245	-111.996	-63.791
5	6.300	200.092	-56.260	-111.817
6	6.800	261.703	162.300	-92.903
7	7.300	323.170	413.409	55.914
8	7.376	332.566	444.605	88.515
9	7.376	-43.451	-193.806	36.315
10	7.726	-0.002	0.000	0.000

Bending Moment



Axial Force



Shear Force



3.6 Design of Flexible Joint

Opening

Opening = (Lateral Displacement of Span in Right Side) - (Lateral Displacement of Span in Left Side)

Bending Angle

$\theta = |\theta 1 - \theta 2|$ - Initial Bending Angle

Thus、

θ1: Angle of Displacement (Left Side) (rad)

θ2: Angle of Displacement (Right Side) (rad)

θ: Average Angle of Displacement (rad)

Unevenness

Unevenness = (Vertical Displacement of Span in Right Side) - (Vertical Displacement of Span in Left Side)

3.6.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Check of Opening Allowable Opening: 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-6.8	
Span (2- 1)	-0.5- (-6.8)	6.4 OK
Span (3- 2)	21.2- (-0.5)	21.6 OK
EP	21.2	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.48369 -0.00844	0.10441 0.00182	0.58811 0.01026
Span (3- 2)	0.00000 0.00000	0.10441 0.00182	-0.30168 -0.00527	0.40610 0.00709

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-119.6	
Span (2- 1)	-139.6-(-139.0)	0.5 OK
Span (3- 2)	-111.5-(-135.0)	23.5 OK
EP	-126.9	

3.6.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-5.6	
Span (2- 1)	-0.5-(-5.6)	5.2 OK
Span (3- 2)	9.0-(-0.5)	9.4 OK
EP	9.0	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)間	0.00000 0.00000	-0.50506 -0.00882	0.10441 0.00182	0.60947 0.01064
Span (3- 2)間	0.00000 0.00000	0.10441 0.00182	0.37818 0.00660	0.27376 0.00478

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-118.6	
Span (2- 1)	-139.4-(-138.9)	0.5 OK
Span (3- 2)	-129.1-(-134.8)	5.7 OK
EP	-109.8	

Calculation Case2 - Load: [Seismic Condition Land Side →River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-6.1	
Span (2- 1)	-0.5-(-6.1)	5.6 OK
Span (3- 2)	7.8-(-0.5)	8.2 OK
EP	7.8	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.48623 -0.00849	0.10441 0.00182	0.59064 0.01031
Span (3- 2)	0.00000 0.00000	0.10441 0.00182	0.45737 0.00798	0.35296 0.00616

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-119.8	
Span (2- 1)	-139.4-(-139.3)	0.0 OK
Span (3- 2)	-131.7-(-134.8)	3.1 OK
EP	-108.4	

3.7 Stress Intensity Analysis

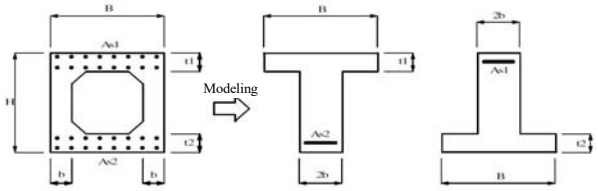
3.7.1 Calculation Condition

It is considered that double reinforced section which bending moment is acting on.
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.
Position of Neutral Axis

$$x=\frac{n\cdot(As\cdot d+As'\cdot d')+B\cdot t^2/2}{n\cdot(As+As')+B\cdot t}$$

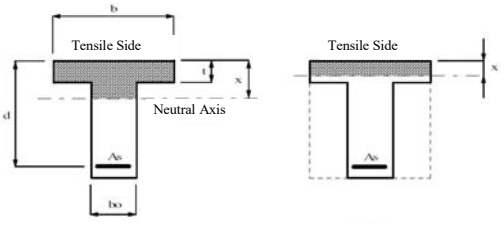
Thus,

- x : Position of Neutral Axis (mm)
- n : Ratio of Young modulus = 9.0
- As : Area of Re-bar in tensile side (mm^2)
- As' : Area of Re-bar in compressive side (mm^2)
- d : Effective Height of Beam (mm)
- d' : Distance from the compressive edge of concrete to the centric of Re-bar (mm)
- B : Width of Flange (mm)
- t : Thickness of Flange (mm)



The stress calculation is conducted as follows based on the position of neutral axis

1) In case the neutral axis is in web, the section is considered as T-shape.
2) In case the neutral axis is in top slab or Bottom slab, the section is considered as rectangle.



T-shaped Section Rectanglar Section

Calculation Condition (In Case Bottom Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b (m)	Thickness t (m)	Neutral Axis x (m)	Calculation Section
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.265	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.265	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.265	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.334	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side As(mm^2)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side As' (mm^2)
1- 1	2.000	2.000	1.716	2780.4	0.273	2780.4
1- 2	1.900	1.900	1.645	2780.4	0.244	2780.4
2- 1	1.900	1.900	1.645	2780.4	0.244	2780.4
3- 1	1.900	1.900	1.645	2780.4	0.244	2780.4
3- 2	2.000	2.000	1.716	7093.8	0.273	7093.8

Calculation Condition (In Case Top Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b (m)	Thickness t (m)	Neutral Axis x (m)	Calculation
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.265	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.265	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.265	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.334	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side	Position of Re-bar in Compressive	Area of Re-bar in Tensile Side
1- 1	2.000	2.000	1.727	2780.4	0.284	2780.4
1- 2	1.900	1.900	1.656	2780.4	0.255	2780.4
2- 1	1.900	1.900	1.656	2780.4	0.255	2780.4
3- 1	1.900	1.900	1.656	2780.4	0.255	2780.4
3- 2	2.000	2.000	1.727	7093.8	0.284	7093.8

3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	103.453	0.000	103.453	7.513
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	200.4		200.4	14.2
	Top Slab Inside	Aq2	mm^2	267.2		267.2	19.0
	Bottom Slab Inside	Aq3	mm^2	267.2		267.2	19.0
	Bottom Slab Outside	Aq4	mm^2	200.4		200.4	14.2
Neutral Axis		X	m	0.199	----	0.199	0.199
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.32	----	0.32	0.02
		σs	N/mm^2	24.46	----	24.46	1.78
		σs'	N/mm^2	-1.59	----	-1.59	-0.12
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		
		req	mm^2	623.6	----	623.6	44.3
		inp	mm^2	2780.4	----	2780.4	2780.4

Calculation Case1: Normal Condition

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	21.328	0.000	21.328	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	42.2		42.2	
	Top Slab Inside	Aq2	mm^2	56.3		56.3	
	Bottom Slab Inside	Aq3	mm^2	56.3		56.3	
	Bottom Slab Outside	Aq4	mm^2	42.2		42.2	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.07	----	0.07	----
		σs	N/mm^2	5.23	----	5.23	----
		σs'	N/mm^2	-0.36	----	-0.36	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	131.4	----	131.4	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Normal Condition

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	38.876	0.000	38.786	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	77.4		77.2	
	Top Slab Inside	Aq2	mm^2	103.1		102.9	
	Bottom Slab Inside	Aq3	mm^2	103.1		102.9	
	Bottom Slab Outside	Aq4	mm^2	77.4		77.2	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.13	----	0.13	----
		σs	N/mm^2	9.54	----	9.52	----
		σs'	N/mm^2	-0.65	----	-0.65	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	240.7	----	240.1	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Normal Condition

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-235.619	-235.619	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		481.4	481.4	
	Top Slab Inside	Aq2	mm^2		641.9	641.9	
	Bottom Slab Inside	Aq3	mm^2		641.9	641.9	
	Bottom Slab Outside	Aq4	mm^2		481.4	481.4	
Neutral Axis		X	m	----	0.199	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	0.80	0.80	----
		σs	N/mm^2	----	57.90	57.90	----
		σs'	N/mm^2	----	-3.04	-3.04	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	1497.8	1497.8	----
		inp	mm^2	----	2780.4	2780.4	----

Calculation Case1: Normal Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	116.444	-1408.784	-1402.156	116.444
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D25- 6	90.0 D25- 6	90.0 D25- 6	90.0 D25- 6
	Inside of Top Slab	d2 As2	mm	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D25- 6	115.0 D25- 6	115.0 D25- 6	115.0 D25- 6
Total Area of Rebar		As	mm^2	14187.6	14187.6	14187.6	14187.6
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	226.0	2930.6	2916.5	226.0
	Top Slab Inside	Aq2	mm^2	301.3	3907.4	3888.6	301.3
	Bottom Slab Inside	Aq3	mm^2	301.3	3907.4	3888.6	301.3
	Bottom Slab Outside	Aq4	mm^2	226.0	2930.6	2916.5	226.0
Neutral Axis		X	m	0.298	0.300	0.300	0.298
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.23	2.80	2.79	0.23
		σs	N/mm^2	11.15	135.17	134.54	11.15
		σs'	N/mm^2	-1.46	-15.54	-15.46	-1.46
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		5181.4	5181.4	
		req	mm^2	703.1	9117.4	9073.4	703.1
		inp	mm^2	7093.8	7093.8	7093.8	7093.8

3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	65.889	0.000	21.927	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	95.2		31.4	
	Top Slab Inside	Aq2	mm^2	127.0		41.9	
	Bottom Slab Inside	Aq3	mm^2	127.0		41.9	
	Bottom Slab Outside	Aq4	mm^2	95.2		31.4	
Neutral Axis		X	m	0.199	----	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.20	----	0.07	----
		σs	N/mm^2	15.58	----	5.18	----
		σs'	N/mm^2	-1.01	----	-0.34	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	296.3	----	97.8	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	21.927	0.000	21.927	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	32.6		32.6	
	Top Slab Inside	Aq2	mm^2	43.5		43.5	
	Bottom Slab Inside	Aq3	mm^2	43.5		43.5	
	Bottom Slab Outside	Aq4	mm^2	32.6		32.6	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.07	----	0.07	----
		σs	N/mm^2	5.38	----	5.38	----
		σs'	N/mm^2	-0.37	----	-0.37	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	101.5	----	101.5	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	38.876	0.000	38.786	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	58.1		57.9	
	Top Slab Inside	Aq2	mm^2	77.4		77.3	
	Bottom Slab Inside	Aq3	mm^2	77.4		77.3	
	Bottom Slab Outside	Aq4	mm^2	58.1		57.9	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.13	----	0.13	----
		σs	N/mm^2	9.54	----	9.52	----
		σs'	N/mm^2	-0.65	----	-0.65	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	180.7	----	180.3	----
		inp	mm^2	2780.4	----	2780.4	----

Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-86.997	-86.997	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		131.0	131.0	
	Top Slab Inside	Aq2	mm^2		174.7	174.7	
	Bottom Slab Inside	Aq3	mm^2		174.7	174.7	
	Bottom Slab Outside	Aq4	mm^2		131.0	131.0	
Neutral Axis		X	m	----	0.199	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	0.29	0.29	----
		σs	N/mm^2	----	21.38	21.38	----
		σs'	N/mm^2	----	-1.12	-1.12	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	407.6	407.6	----
		inp	mm^2	----	2780.4	2780.4	----

Calculation Case1: Seismic Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	51.387	-423.293	-365.863	51.387
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D25- 6	90.0 D25- 6	90.0 D25- 6	90.0 D25- 6
	Inside of Top Slab	d2 As2	mm	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D25- 6	115.0 D25- 6	115.0 D25- 6	115.0 D25- 6
Total Area of Rebar		As	mm^2	14187.6	14187.6	14187.6	14187.6
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	74.1	630.6	543.1	74.1
	Top Slab Inside	Aq2	mm^2	98.8	840.7	724.2	98.8
	Bottom Slab Inside	Aq3	mm^2	98.8	840.7	724.2	98.8
	Bottom Slab Outside	Aq4	mm^2	74.1	630.6	543.1	74.1
Neutral Axis		X	m	0.298	0.300	0.300	0.298
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.10	0.84	0.73	0.10
		σs	N/mm^2	4.92	40.61	35.10	4.92
		σs'	N/mm^2	-0.65	-4.67	-4.03	-0.65
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	230.5	1961.7	1689.8	230.5
		inp	mm^2	7093.8	7093.8	7093.8	7093.8

2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	167.588	0.000	167.588	8.528
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	245.1		245.1	12.2
	Top Slab Inside	Aq2	mm^2	326.8		326.8	16.2
	Bottom Slab Inside	Aq3	mm^2	326.8		326.8	16.2
	Bottom Slab Outside	Aq4	mm^2	245.1		245.1	12.2
Neutral Axis		X	m	0.199	----	0.199	0.199
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.52	----	0.52	0.03
		σs	N/mm^2	39.62	----	39.62	2.02
		σs'	N/mm^2	-2.57	----	-2.57	-0.13
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		
		req	mm^2	762.6	----	762.6	37.9
		inp	mm^2	2780.4	----	2780.4	2780.4

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	29.989	0.000	29.989	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	44.7		44.7	
	Top Slab Inside	Aq2	mm^2	59.6		59.6	
	Bottom Slab Inside	Aq3	mm^2	59.6		59.6	
	Bottom Slab Outside	Aq4	mm^2	44.7		44.7	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.10	----	0.10	----
		σs	N/mm^2	7.36	----	7.36	----
		σs'	N/mm^2	-0.50	----	-0.50	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	139.1	----	139.1	----
		inp	mm^2	2780.4	----	2780.4	----

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	38.876	0.000	38.786	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	58.1		57.9	
	Top Slab Inside	Aq2	mm^2	77.4		77.3	
	Bottom Slab Inside	Aq3	mm^2	77.4		77.3	
	Bottom Slab Outside	Aq4	mm^2	58.1		57.9	
Neutral Axis		X	m	0.198	----	0.198	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.13	----	0.13	----
		σs	N/mm^2	9.54	----	9.52	----
		σs'	N/mm^2	-0.65	----	-0.65	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	180.7	----	180.3	----
		inp	mm^2	2780.4	----	2780.4	----

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-35.579	-35.579	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		53.1	53.1	
	Top Slab Inside	Aq2	mm^2		70.8	70.8	
	Bottom Slab Inside	Aq3	mm^2		70.8	70.8	
	Bottom Slab Outside	Aq4	mm^2		53.1	53.1	
Neutral Axis		X	m	----	0.199	0.199	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	0.12	0.12	----
		σs	N/mm^2	----	8.74	8.74	----
		σs'	N/mm^2	----	-0.46	-0.46	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	165.2	165.2	----
		inp	mm^2	----	2780.4	2780.4	----

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	88.515	-111.817	88.515	36.315
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D25- 6	90.0 D25- 6	90.0 D25- 6	90.0 D25- 6
	Inside of Top Slab	d2 As2	mm	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8	90.0 D25- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D25- 6	115.0 D25- 6	115.0 D25- 6	115.0 D25- 6
Total Area of Rebar		As	mm^2	14187.6	14187.6	14187.6	14187.6
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	128.4	162.6	128.4	52.2
	Top Slab Inside	Aq2	mm^2	171.1	216.8	171.1	69.6
	Bottom Slab Inside	Aq3	mm^2	171.1	216.8	171.1	69.6
	Bottom Slab Outside	Aq4	mm^2	128.4	162.6	128.4	52.2
Neutral Axis		X	m	0.298	0.300	0.298	0.298
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.18	0.22	0.18	0.07
		σs	N/mm^2	8.48	10.73	8.48	3.48
		σs'	N/mm^2	-1.11	-1.23	-1.11	-0.46
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	399.3	505.8	399.3	162.5
		inp	mm^2	7093.8	7093.8	7093.8	7093.8

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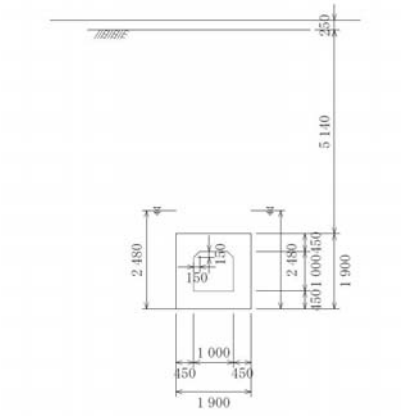
2.2.2.4 SLUICEWAY TYPE F

(2) BOX - TRANSVERSE

1 Calculation of Box Culvert in Transverse Direction

1.1 Design Condition

1.1.1 Dimension



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil(Wet)	γt	kN/m³	19.00
Soil(Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
	—	——			—	——	
Right Corner	D16	247	804.0	Right Corner	D16	250	794.4

Outside of Sidewall	Diameter	Pitch	Area (mm^2)	Inside of Sidewall	Diameter	Pitch	Area (mm^2)
Left Sidewall	D16	250	794.4	Left Sidewall	D13	250	506.8
	—	——			—	——	
Right Sidewall	D16	250	794.4	Right Sidewall	D13	250	506.8
	—	——			—	——	

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
	—	——			—	——	
Right Corner	D16	250	794.4	Right Corner	D16	250	794.4

■Cover

Location		Cover(mm)	Location		Cover(mm)
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Midwall		———	———		——

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Top Slab	100	0.0
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Load

■Surcharge

	(kN/m^2)
Surcharge	0.000
Snow Load	0.000

■Dead Load (Water Level)

Case	External Water Level(m)	Internal Water Level(m)
1	2.480	0.000

External Water Level: Height from Bottom Surface of Bottom Slab
Internal Water Level: Height from Top Surface of Bottom Slab

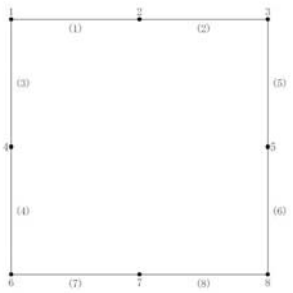
■Live Load

Intensity of Distribution Load Qw(kN/m^2)	10.000

1.2 Cross-section Calculation

1.2.1 Model

1) Frame Dimension



2) Coordinate

No	X(m)	Y(m)
1	0.000	1.450
2	0.725	1.450
3	1.450	1.450
4	0.000	0.725
5	1.450	0.725
6	0.000	0.000
7	0.725	0.000
8	1.450	0.000

3) Member Material and Sectional Characteristics

Member	Number	Point Number i Edge	Point Number j Edge	Area (m^2)	Geometric Moment of Inertia (m^4)	Young Modules (kN/m^2)
Left Side of Top Slab	1	1	2	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Top Slab	2	2	3	4.500000E-001	7.593750E-003	2.310000E+007
Upper Side of Left Side Wall	3	1	4	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Left Side Wall	4	4	6	4.500000E-001	7.593750E-003	2.310000E+007
Upper side of Right Wall	5	3	5	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Right Wall	6	5	8	4.500000E-001	7.593750E-003	2.310000E+007
Left Side of Bottom Slap	7	6	7	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slap	8	7	8	4.500000E-001	7.593750E-003	2.310000E+007

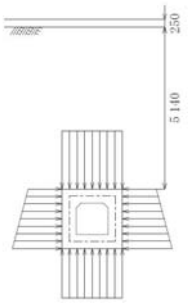
4) Supporting Point

Point	Horizontal (kN/m)	Vertical (kN/m)	Rotate (kN.m/rad)
9	-1	-1	0
13	0	-1	0

Note) -1 : Fixed, 0 : Free

1.2.2 Load

1) Dead Load (case-1) [RWL]



Weight of Box Culvert
(1) Top Slab
w = 0.450 × 24.00 = 10.80 (kN/m²)
(2) Left Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)
(3) Right Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

Surcharge Load
(1) Pavement and Embankment

Pavement (Above Water Level) = 1.000 × 0.250 × 22.60 = 5.65 (kN/m²)
Embankment (Above Water Level) =1.000 × 4.560 × 18.00 = 82.08 (kN/m²)
Embankment (Below Water Level) =1.000 × 0.580 × 9.20 = 5.34 (kN/m²)
Water Pressure = 0.580 × 9.80 = 5.68 (kN/m²)

Σwd = 98.75 (kN/m²)

(2) Surcharge Load at Road
Surcharge = 0.000 (kN/m²)
Snow Load= 0.00 (kN/m²)

Σqd = 0.000 (kN/m²)

(3) Load Acting on Top Slab
Uniformly Distributed Load
w =98.75 + 0.00 = 98.75 (kN/m²)

Water and Earth Pressure
Intensity of Earth Pressure and Water Pressure
pi = Ko×(qd + Yo×γa + Zu×γ + (Zo - Zu)×γ') + (Zo - Zu)×γw
Ko: Coefficient of Earth Pressure at Rest = 0.500
Zo:Depth of Calculation Point from Embankment Top(m)

(1)Left Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	5.140	52.22
p_2	Center of Top Slab	5.365	55.46
p_3	Center of Bottom Slab	6.815	76.34
p_4	Bottom Surface of Bottom Slab	7.040	79.58

(2)Right Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	5.140	52.22
p_2	Center of Top Slab	5.365	55.46
P_3	Center of Bottom Slab	6.815	76.34
p_4	Bottom Surface of Bottom Slab	7.040	79.58

Uplift and Buoyancy
This Act on Bottom Slab Upward

$$U = 2.480 \times 1.900 \times 9.80 = 46.18 \ (kN/m)$$
$$w = \frac{-46.18}{1.900} = -24.30 \ (kN/m^2)$$

Summary of Acting Forces

Item			V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/
Weight of Body		Top Slab	21.06		0.950		20.01
		Left Side Wall	10.80		0.225		2.43
		Right Side Wall	10.80		1.675		18.09
Surcharge		Distribution Load	187.63		0.950		178.24
Earth Pressure and Water Pressure	Left Side Wall			125.20		0.884	110.71
	Right Side Wall			-125.20		0.884	-110.71
Uplift/Buoyancy			-46.18		0.950		-43.87
Total			184.11				174.90

Subgrade Reaction Force
(1) Force Acting Position and Eccentric Distance

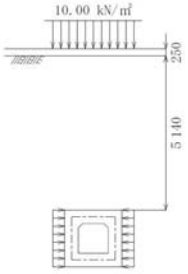
$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$
$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity
Me = ΣV × e = 0.00 (kN.m/m)

$$Me = \Sigma V \times e = 0.00 \ (kN.m/m)$$
$$q1 = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 96.90 \ (kN/m^2)$$
$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 96.90 \ (kN/m^2)$$
$$q1' = q1 + \frac{qr - q1}{B} \times \frac{T}{2} = 96.90 \ (kN/m^2)$$
$$qr' = qr + \frac{q1 - qr}{B} \times \frac{T}{2} = 96.90 \ (kN/m^2)$$

Thus, T : Thickness of Side Wall
q1 : Subgrade Reaction Intensity on Left Edge
qr : Subgrade Reaction Intensity on Right Edge
q1': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface qL= 10.000 (kN/m²)

Load
(1)Vertical Load Effecting Top Slab
wl = qL= 10.00 (kN/m²)
(2)Horizontal Load Acting on Left Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

(3)Horizontal Load Effecting on Right Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

Summary of Acting Force

		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Top Slab	Distribution	19.00		0.950		18.05
Left Side Wall	Distribution		9.50		0.950	9.03
Right Side Wall	Distribution		-9.50		0.950	-9.03
Total		19.00				18.05

Subgrade Reaction Force
(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$
$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$ql = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$ql' = ql + \frac{qr - ql}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

$$qr' = qr + \frac{ql - qr}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

Thus、T : Thickness of Side Wall

ql : Subgrade Reaction Intensity on Left Edge

qr : Subgrade Reaction Intensity on Right Edge

ql': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

Dead Load + Live Load

Load Number	Beginning Member Number	End Member Number	Load Intensity at i Edge	Distance from i Edge (m)	Distance from j Edge (m)	Load Width (m)
14	1	2	-10.80	-10.80	0.000	0.000
14	3	4	-10.80	-10.80	0.225	0.225
14	5	6	-10.80	-10.80	0.225	0.225
14	1	2	-98.75	-98.75	0.000	0.000
13	3	4	55.46	76.34	0.000	0.000
13	5	6	-55.46	-76.34	0.000	0.000
14	7	8	24.30	24.30	0.000	0.000
14	1	2	-10.00	-10.00	0.000	0.000
13	3	4	5.00	5.00	0.000	0.000
13	5	6	-5.00	-5.00	0.000	0.000
14	7	8	106.90	106.90	0.000	0.000

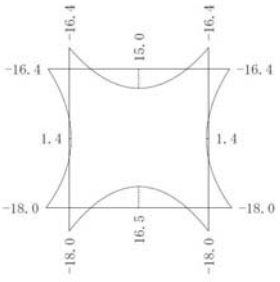
Load Number

13:MemberDistribution Load(X Direction)

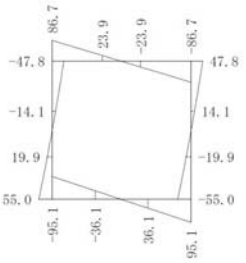
14:MemberDistribution Load(Y Direction)

1.2.4 Calculation Results of Frame Analysis

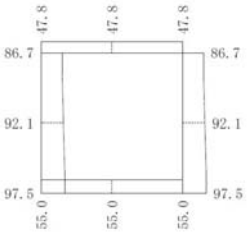
Bending Moment



Shear Force



Axial Force



1.2.5 Stress Intensity Calculation

■Bending Stress Intensity

Top Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-16.400	15.019	-16.400
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	339.2	0.0	339.2
	Internal	mm^2	0.0	310.1	0.0
Re-Bar	External	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 247 D— @— 804.0
	Internal	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
Neutral Axis	X	m	0.065	0.065	0.065
Stress Intensity	σc	N/mm^2	1.49	1.37	1.49
	σs	N/mm^2	61.02	55.88	60.31
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	452.2	413.4	452.2
	inp	mm^2	794.4	794.4	804.0
Case	——	——	Dead-1+Live-1	Dead-1+Liva-1	Dead-1+Liev-1

※Axial force is not considered.

Left Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-16.400	1.438	-17.988
Axial Force	N	kN	86.674	92.074	97.474
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar Arrangement	External	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
	Internal	mm^2	D13 @ 250 D— @— 506.8	D13 @ 250 D— @— 506.8	D13 @ 250 D— @— 506.8
Neutral Axis	X	m	0.182	1.221	0.188
Stress Intensity	σc	N/mm^2	1.03	0.25	1.11
	σs	N/mm^2	9.07	0.00	9.17
	σs'	N/mm^2	0.00	-1.58	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	794.4	506.8	794.4
Case	——	———	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Right Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-16.400	1.438	-17.988
Axial Force	N	kN	86.674	92.074	97.474
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar	External	mm^2	D16 @ 247 D— @— 804.0	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
	Internal	mm^2	D13 @ 250 D— @— 506.8	D13 @ 250 D— @— 506.8	D13 @ 250 D— @— 506.8
Neutral Axis	X	m	0.182	1.221	0.188
Stress Intensity	σc	N/mm^2	1.03	0.25	1.11
	σs	N/mm^2	9.02	0.00	9.17
	σs'	N/mm^2	0.00	-1.58	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	804.0	506.8	794.4
Case	——	———	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Bottom Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-17.988	16.493	-17.988
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	115.0	115.0	115.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	401.8	0.0	401.8
	Internal	mm^2	0.0	341.2	0.0
Re-Bar	External	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
	Internal	mm^2	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4	D16 @ 250 D— @— 794.4
Neutral Axis	X	m	0.062	0.065	0.062
Stress Intensity	σc	N/mm^2	1.83	1.50	1.83
	σs	N/mm^2	72.08	61.37	72.08
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	535.7	454.9	535.7
	inp	mm^2	794.4	794.4	794.4
Case	——	———	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

■Shear Stress Intensity

$$\tau m = \frac{S}{b \times d} \leqq \tau a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm2)	τa (N/mm2)	Cases	L (m)
Top Slap	Left τ Point	23.910	360.0	0.066	0.457	Dead-1+Live-1	0.525
	Right τ Point	-23.910	360.0	0.066	0.457	Dead-1+Live-1	0.525
Left Side Wall	Upper τ Point	-14.058	360.0	0.039	0.457	Dead-1+Live-1	0.525
	Lower τ Point	19.875	360.0	0.055	0.495	Dead-1+Live-1	0.450
Right Side Wall	Upper τ Point	14.058	360.0	0.039	0.457	Dead-1+Live-1	0.525
	Lower τ Point	-19.875	360.0	0.055	0.495	Dead-1+Live-1	0.450
Bottom Slab	Left τ Point	-36.081	360.0	0.100	0.478	Dead-1+Live-1	0.450
	Right τ Point	36.081	360.0	0.100	0.478	Dead-1+Live-1	0.450

Note) τ Point: Check point for shear stress intensity
L: Distance from grid point of corner

2.2.2.4 SLUICEWAY TYPE F

(3) BREAST WALL - LAND SIDE

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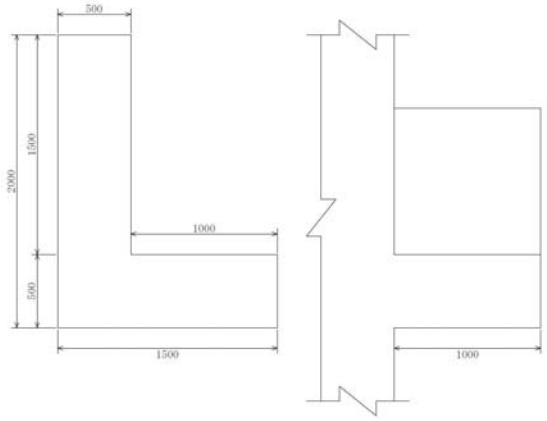
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1 Calculation of Land Side Breast Wall

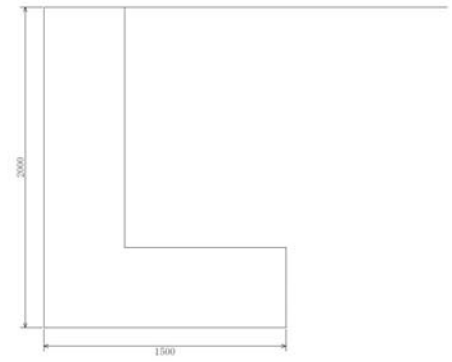
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/℃	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φres	°	30
Peak Angle of Internal Friction	φpeak	°	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm^2/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D22	250	1548.4
	Bottom Face	115.0	D22	250	1548.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

1.1.4 Loads

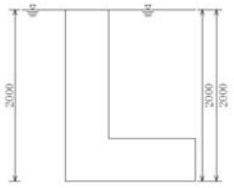
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

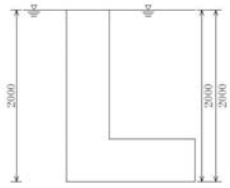
	(m)
Toe	2.000
Heel	2.000



1-2) Seismic Condition Number of Cases [1]

<Case 1>

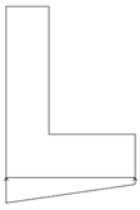
	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front



2) Subgrade Reaction

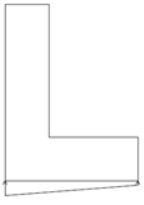
2-1) Normal <Case 1>

	(kN/m^2), (m)
Toe	94.27
Heel	25.88
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m^2), (m)
Toe	52.07
Heel	14.74
Load Width	0.000



3) Surcharge Load

Normal	kN/m^2	10.00
Seismic	kN/m^2	5.00

4) Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W = 0.000 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load $q0' = (W+q0 \cdot wq0)/B$

$= (0.000+ 10.00\times 1.500)/ 1.500$

$= 10.000\ (kN/m^2)$

Earth Pressure at the Top

$p1 = q0' \cdot Ko = 10.000 \times 0.500 = 5.000\ (kN/m^2)$

Earth Pressure at Water Level

$p2 = Ko \cdot \gamma_t \cdot h1+p1$

$= 0.500\times 19.00\times 0.000+ 5.000$

$= 5.000\ (kN/m^2)$

Earth Pressure at Junction

$p3 = Ko \cdot (\gamma_{sat}-\gamma_w) \cdot h2+p2$

$= 0.500\times(20.00- 9.80)\times 1.500+ 5.000$

$= 12.650\ (kN/m^2)$

Design Earth Pressure

$P = p3$

$= 12.650\ (kN/m^2)$

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.5

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

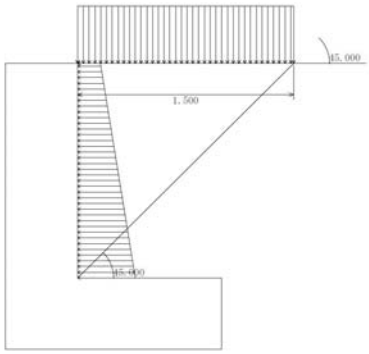
q_0 : Surcharge (kN/m^2)

w_{qo} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 1.500× 9.80 = 14.700 (kN/m^2)

Thus,

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

(2) **Seismic Condition-1**

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.500× 24.00× 0.20 = 2.400

Thus,

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_c : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	0.000	(m)
Embankment Height under the water level surface	h2	=	1.500	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_t	=	19.00	(kN/m^3)
Unit Weight of Soil (Saturated)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	1.863	(m)
Width of Converted Load	B	=	1.863	(m)
Internal Friction Angle of Soil	ϕ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh	=	0.345	(degree)
Compound Angle in Seismic Condition	θ_0= tan^{-1} (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	θ_0= tan^{-1} (kh')	=	19.026	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ + 0.00^\circ + 11.310^\circ\ )\times\sin(\ 30.00^\circ + 0.00^\circ\ )}{\cos(\ 0.00^\circ - 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}}$$

$$\cot(\xi_{EA}-\alpha) = 0.85094$$

Thus,

$$\cot(\xi_{EA}-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604(^\circ\ )$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ + 0.00^\circ + 19.026^\circ\ )\times\sin(\ 30.00^\circ + 0.00^\circ\ )}{\cos(\ 0.00^\circ - 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 19.026^\circ\ )}}$$

$$\cot(\xi_{EA}'-\alpha) = 1.24217$$

Thus,

$$\cot(\xi_{EA}'-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA}')} = 1.24217$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{1.24217}\right) = 38.836(^\circ\ )$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ - 11.310^\circ - 0.00^\circ\ )}{\cos(\ 11.310^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )}$$
$$\times\frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ + 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}{\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )\times\cos(\ 0.00^\circ - 0.00^\circ\ )}}\right]^2}$$

= 0.4733

In case φ-α-θ_o< 0, sin(φ-α-θ_o) = 0.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ - 19.026^\circ - 0.00^\circ\ )}{\cos(\ 19.026^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ + 19.026^\circ + 0.00^\circ\ )}$$
$$\times\frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ + 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 19.026^\circ\ )}{\cos(\ 0.00^\circ + 19.026^\circ + 0.00^\circ\ )\times\cos(\ 0.00^\circ - 0.00^\circ\ )}}\right]^2}$$

= 0.6214

In case φ-α-θ'$_o$< 0, sin(φ-α-θ'$_o$) = 0.

Weight of Embankment W = 0.000 (kN/m)

Converted Load q0' = (W + q0・wq0) / B

= (0.000+ 5.00× 1.863) / 1.863

= 5.000 (kN/m^2)

Earth Pressure at the Top

P1 = q0'・K_{EA} = 5.000× 0.4733 = 2.366 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 0.000+ 2.366

= 2.366 (kN/m^2)

Earth Pressure at Junction

P3 = K_{EA}・(γ_{sat}-γ_w)・h2 + p2

= 0.6214×(20.00- 9.80)× 1.500+ 2.366

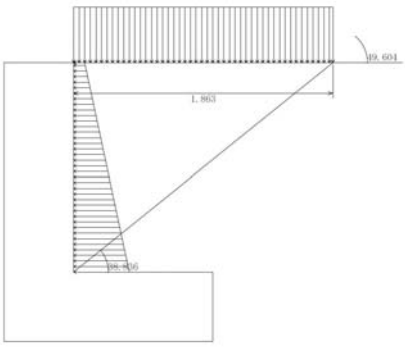
= 11.874 (kN/m^2)

Design Earth Pressure

P_{HE} = P3 ・cosδ= 11.874×cos(0.00°)

= 11.874 (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

Ph = hh・γ_w= 1.500× 9.80 = 14.700 (kN/m^2)

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

1.2.2 **Summary of Cross-sectional Internal Forces**

1) Normal Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Water Pressure	14.70	1.000	7.35
Earth Pressure	12.65	1.000	6.32
Σ	27.35	----	13.68
Bending Moment M (kN.m/m) Σ(P・l2/2) = 13.68			
Shear Force S (kN/m) Σ(P・l) = 27.35			

2) Seismic Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Inertia force	2.40	1.000	1.20
Water Pressure	14.70	1.000	7.35
Earth Pressure	11.87	1.000	5.94
Σ	28.97	----	14.49
Bending Moment M (kN.m/m) Σ(P・l2/2) = 14.49			
Shear Force S (kN/m) Σ(P・l) = 28.97			

1.2.3 **Stress Calculation**

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Front	mm²	D16 - 4.00 =794.4
	Back	mm²	D16 - 4.00 =794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	13.68
Re-bar	d1 As1	mm mm²	410.0 794.4
Required Area of Re-bar	Back	mm²	246.4
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm²	1.01
	σs	N/mm²	44.51
Allowable Value	σca	N/mm²	8.20
	σsa	N/mm²	140.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	328.5
	inp	mm²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	14.49
Re-bar	d1 As1	mm mm²	410.0 794.4
Required Area of Re-bar	Back	mm²	195.7
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm²	1.07
	σs	N/mm²	47.15
Allowable Value	σca	N/mm²	12.30
	σsa	N/mm²	186.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	261.0
	inp	mm²	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	27.35
Re-bar	d1 As1	mm mm²	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.067
Allowable Value	τa	N/mm²	0.360
	τa2	N/mm²	1.600

■Seismic Condition-1

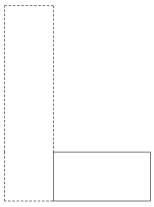
	Symbol	Unit	Junction
Shear Force	S	kN	28.97
Re-bar	d1 As1	mm mm²	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.071
Allowable Value	τa	N/mm²	0.540
	τa2	N/mm²	2.400

1.3 **Calculation of Heel Slab**

1.3.1 **Load**

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γc= 0.500 × 24.00 = 12.000

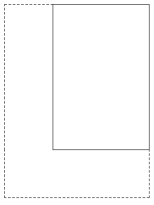
Thus,

Sw : Weight of Body (kN/m2)

h : Height of Bottom Slab (m)

γc : Unit Weight of Concrete (kN/m³)

1-2) Weight of the Embankment



Pw1 = (h1・γt+ h2・γsat) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Pw2 = (h1・γt+ h2・γsat) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Thus、

Pw1 : Wight of Embankment at basis (kN/m²)

Pw2 : Weight of Embankment at edge (kN/m²)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γt : Wet Unit Weight of Soil (kN/m³)

γsat : Unit Weight of Soil underwater (kN/m³)

1-3) Subgrade Reaction Force

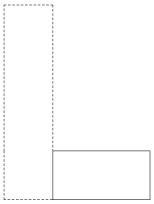
	Intensity of subgrade reaction (kN/m²)
Base	71.47
Edge	25.88

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

(2) **) Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

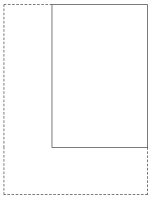
Thus、

Sw : Weight of Wall (kN/m2)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	39.63
Edge	14.74

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

1.3.2 Summary of Cross-sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	71.47	1.000	35.74
Surcharge	-10.00	1.000	-5.00
Σ	39.07	----	19.54
Bending Moment M (kN.m/m) Σ(P・l2/2) = 19.54			
Shear Force S (kN/m) Σ(P・l) = 39.07			

1-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	25.88	1.000	12.94
Surcharge	-10.00	1.000	-5.00
Σ	-6.52	----	-3.26
Bending Moment M (kN.m/m) Σ(P・l2/2) = -3.26			
Shear Force S (kN/m) Σ(P・l) = -6.52			

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	39.63	1.000	19.81
Surcharge	-5.00	1.000	-2.50
Σ	12.23	----	6.11
Bending Moment M (kN.m/m) Σ(P・l2/2) = 6.11			
Shear Force S (kN/m) Σ (P・l) = 12.23			

2-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	14.74	1.000	7.37
Surcharge	-5.00	1.000	-2.50
Σ	-12.66	----	-6.33
Bending Moment M (kN.m/m) Σ(P・l^2/2) = -6.33			
Shear Force S (kN/m) Σ(P・l) = -12.66			

1.3.3 Stress Intensity Calculation

(1) Flexural Stress Intensity

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Upper	mm^2	D22 - 4.00 =1548.4
	Lower	mm^2	D22 - 4.00 =1548.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	19.54	-3.26
Re-bar	d1 As1	mm mm^2	385.0 1548.4	90.0 1548.4
Required Area of Re-bar	Upper	mm^2		57.7
	Lower	mm^2	378.1	
Neutral Axis	X	m	0.091	0.094
Stress Intensity	σc	N/mm^2	1.22	0.18
	σs	N/mm^2	35.56	5.56
Allowable Value	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	504.2	77.0
	inp	mm^2	1548.4	1548.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	6.11	-6.33
Re-bar	d1 As1	mm mm^2	385.0 1548.4	90.0 1548.4
Required Area of Re-bar	Upper	mm^2		84.7
	Lower	mm^2	87.2	
Neutral Axis	X	m	0.091	0.094
Stress Intensity	σc	N/mm^2	0.38	0.36
	σs	N/mm^2	11.13	10.79
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	116.2	112.9
	inp	mm^2	1548.4	1548.4

(2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	39.07	-6.52
Re-bar	d1 As1	mm mm^2	385.0 1548.4	90.0 1548.4
Effective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.101	0.016
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	12.23	-12.66
Re-bar	d1 As1	mm mm^2	385.0 1548.4	90.0 1548.4
Effective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.032	0.031
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400

2.2.2.4 SLUICEWAY TYPE F

(4) BREAST WALL - RIVER SIDE

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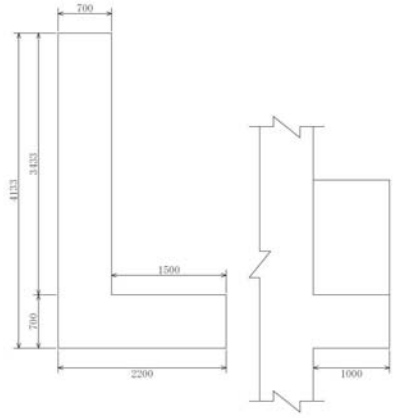
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1 Calculation of River Side Breast Wall

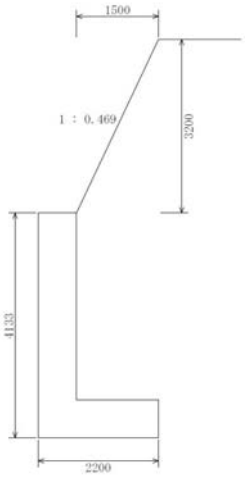
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/℃	9.00	9.00

■Steel Reinforcement

Material				
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φres	○	30
Peak Angle of Internal Friction	φpeak	○	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm²/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D22	250	1548.4
Bottom Slab	Top Face	90.0	D22	250	1548.4
	Bottom Face	115.0	D22	250	1548.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Side Wall	100.0	0.0
Bottom Slab	100.0	0.0

1.1.4 Loads

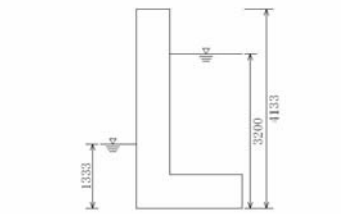
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

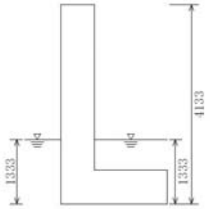
	(m)
Toe	1.333
Heel	3.200



1-2) Seismic Condition Number of Cases [1]

<Case 1>

	(m)
Toe	1.333
Heel	1.333
Direction	Back → Front



2) Subgrade Reaction

2-1) Normal <Case 1>

	(kN/m²), (m)
Toe	354.08
Heel	0.00
Load Width	2.200



2-2) Seismic <Case 1>

	(kN/m²), (m)
Toe	171.95
Heel	0.00
Load Width	2.200



3) Surcharge Load

Normal	kN/m²	10.00
Seismic	kN/m²	5.00

4) Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W = 260.406 (kN/m)

※ξ_{EA}(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (260.406+ 10.00× 5.133)/ 3.433

= 90.806 (kN/m^2)

Earth Pressure at the Top

p1 = q0'・Ko = 90.806× 0.500 = 45.403 (kN/m^2)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.933+ 45.403

= 54.266 (kN/m^2)

Earth Pressure at Junction

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500×(20.00- 9.80)× 2.500+ 54.266

= 67.016 (kN/m^2)

Design Earth Pressure

P = p3

= 67.016 (kN/m^2)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

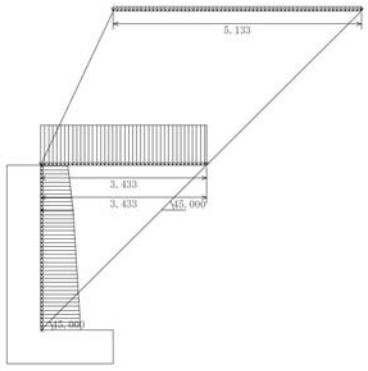
q_0 : Surcharge (kN/m^2)

w_{q0} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 2.500× 9.80 = 24.500 (kN/m^2)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

(2) Seismic Condition-1

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.700× 24.00× 0.20 = 3.360

Thus、

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	2.800	(m)
Embankment Height under the water level surface	h2	=	0.633	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γt	=	19.00	(kN/m^3)
Unit Weight of Soil (Saturated)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	4.168	(m)
Width of Converted Load	B	=	2.945	(m)
Internal Friction Angle of Soil	φ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh	=	0.219	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}$ (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}$ (kh')	=	12.363	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_0)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_0)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times\sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$\cot(\xi_{EA}-\alpha) = 0.85094$

Thus,

$$\cot(\xi_{EA}-0.00^\circ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604(^\circ)$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_0')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_0')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times\sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 12.363^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 12.363^\circ)}}$$

$\cot(\xi_{EA}'-\alpha) = 0.88870$

Thus,

$$\cot(\xi_{EA}'-0.00^\circ) = \frac{1}{\tan(\xi_{EA}')} = 0.88870$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{0.88870}\right) = 48.372(^\circ)$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_0-\theta)}{\cos\theta_0\cdot\cos^2\theta\cdot\cos(\theta+\theta_0+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_0)}{\cos(\theta+\theta_0+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$= 0.4733$

In case φ-α-θ_0< 0, sin(φ-α-θ_0) = 0.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_0'-\theta)}{\cos\theta_0'\cdot\cos^2\theta\cdot\cos(\theta+\theta_0'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_0')}{\cos(\theta+\theta_0'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 12.363^\circ - 0.00^\circ)}{\cos(12.363^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 12.363^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 12.363^\circ)}{\cos(0.00^\circ + 12.363^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$= 0.4900$

In case φ-α-θ'$_0$< 0, sin(φ-α-θ'$_0$) = 0.

Weight of Embankment W W = 216.247 (kN/m)

Converted Load q0' q0' = (W + q0・wq0) / B

= (216.247+ 5.00× 4.168) / 2.945

= 80.500 (kN/m^2)

Earth Pressure at the Top

P1 = q0'・K_{EA} = 80.500× 0.4733 = 38.098 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 2.900+ 38.098

= 63.276 (kN/m^2)

Earth Pressure at Junction

P3 = K_{EA}・(γ_{sat} -- γ_w)・h2 + p2

= 0.4900×(20.00- 9.80)× 0.633+ 63.276

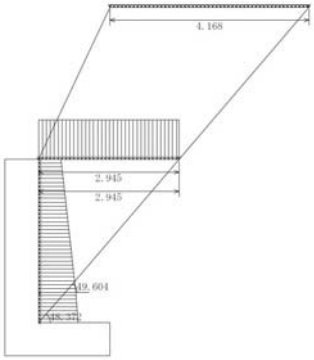
= 66.439 (kN/m^2)

Design Earth Pressure

$P_{HE} = P3 \cdot \cos\delta = 66.439 \times \cos(0.00°)$

$= 66.439\ (kN/m^2)$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$Ph = hh \cdot \gamma_w = 0.633 \times 9.80 = 6.203\ (kN/m^2)$

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m^2)	L (m)	$P \cdot l^2/2$ (kN.m/m)
Water Pressure	24.50	1.000	12.25
Earth Pressure	67.02	1.000	33.51
Σ	91.52	----	45.76
Bending Moment M (kN.m/m)	$\Sigma(P \cdot l^2/2) = 45.76$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 91.52$		

2) Seismic Condition-1

	P (kN/m^2)	L (m)	$P \cdot l^2/2$ (kN.m/m)
Inertia force	3.36	1.000	1.68
Water Pressure	6.20	1.000	3.10
Earth Pressure	66.44	1.000	33.22
Σ	76.00	----	38.00
Bending Moment M (kN.m/m)	$\Sigma(P \cdot l^2/2) = 38.00$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 76.00$		

1.2.3 Stress Calculation

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Front	mm^2	D16 - 4.00 =794.4
	Back	mm^2	D22 - 4.00 =1548.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	45.76
Re-bar	d1 As1	mm mm^2	610.0 1548.4
Required Area of Re-bar	Back	mm^2	558.2
Neutral Axis	X	m	0.117
Stress Intensity	σc	N/mm^2	1.37
	σs	N/mm^2	51.76
Allowable Value	σca	N/mm^2	8.20
	σsa	N/mm^2	140.00
Minimum Area of Re-Bar	min	mm^2	1220.0
	inp	mm^2	1548.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	38.00
Re-bar	d1 As1	mm mm^2	610.0 1548.4
Required Area of Re-bar	Back	mm^2	346.0
Neutral Axis	X	m	0.117
Stress Intensity	σc	N/mm^2	1.14
	σs	N/mm^2	42.98
Allowable Value	σca	N/mm^2	12.30
	σsa	N/mm^2	186.00
Minimum Area of Re-Bar	min	mm^2	1220.0
	inp	mm^2	1548.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	91.52
Re-bar	d1 As1	mm mm^2	610.0 1548.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.150
Allowable Value	τa	N/mm^2	0.360
	τa2	N/mm^2	1.600

■Seismic Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	76.00
Re-bar	d1 As1	mm mm^2	610.0 1548.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.125
Allowable Value	τa	N/mm^2	0.540
	τa2	N/mm^2	2.400

1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

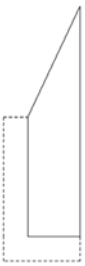
Thus,

Sw : Weight of Body (kN/m^2)

h : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

1-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.933× 19.00 + 2.500× 20.00 = 67.727

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 4.133× 19.00 + 2.500× 20.00 = 128.527

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

1-3) Subgrade Reaction Force

	Intensity of subgrade reaction (kN/m^2)
Base	241.42
Edge	0.00

1-4) Uplift Force

	Calculating Formula Height of Water Level× Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	1.927× 9.80	18.885
Edge	3.200× 9.80	31.360

(2)) Seismic Condition-1

2-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

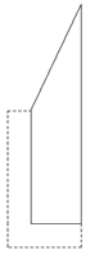
Thus、

Sw : Weight of Wall (kN/m^2)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 2.800× 19.00 + 0.633× 20.00 = 65.860

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 6.000× 19.00 + 0.633× 20.00 = 126.660

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	117.24
Edge	0.00

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	1.333× 9.80	13.063
Edge	1.333× 9.80	13.063

1.3.2 Summary of Cross-Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-67.73	1.000	-33.86
Uplift Force	18.89	1.000	9.44
Intensity of Subgrade Reaction	241.42	1.000	120.71
Σ	175.78	----	87.89
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 87.89		
Shear Force	S (kN/m) Σ(P・l) = 175.78		

1-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-128.53	1.000	-64.26
Uplift Force	31.36	1.000	15.68
Intensity of Subgrade Reaction	0.00	1.000	0.00
Σ	-113.97	----	-56.98
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = -56.98		
Shear Force	S (kN/m) Σ(P・l) = -113.97		

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-65.86	1.000	-32.93
Uplift Force	13.06	1.000	6.53
Intensity of Subgrade Reaction	117.24	1.000	58.62
Σ	47.64	----	23.82
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 23.82		
Shear Force	S (kN/m) Σ(P・l) = 47.64		

2-2) Edge

	P (kN/m^2)	L (m)	P･l^2/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-126.66	1.000	-63.33
Uplift Force	13.06	1.000	6.53
Intensity of Subgrade Reaction	0.00	1.000	0.00
Σ	-130.40	----	-65.20
Bending Moment M (kN.m/m) Σ (P･l^2/2) = -65.20			
Shear Force S (kN/m) Σ (P･l) = -130.40			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Upper	mm^2	D22 - 4.00 =1548.4
	Lower	mm^2	D22 - 4.00 =1548.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	87.89	-56.98
Re-bar	d1 As1	mm mm^2	585.0 1548.4	90.0 1548.4
Required Area of Re-bar	Upper	mm^2		698.3
	Lower	mm^2	1137.7	
Neutral Axis	X	m	0.115	0.117
Stress Intensity	σc	N/mm^2	2.81	1.70
	σs	N/mm^2	103.80	64.45
Allowable Value	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
Minimum of Re-bar Area	min	mm^2	1170.0	1220.0
	inp	mm^2	1548.4	1548.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	23.82	-65.20
Re-bar	d1 As1	mm mm^2	585.0 1548.4	90.0 1548.4
Required Area of Re-bar	Upper	mm^2		599.5
	Lower	mm^2	224.9	
Neutral Axis	X	m	0.115	0.117
Stress Intensity	σc	N/mm^2	0.76	1.95
	σs	N/mm^2	28.13	73.74
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2	1170.0	1220.0
	inp	mm^2	1548.4	1548.4

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	175.78	-113.97
Re-bar	d1 As1	mm mm^2	585.0 1548.4	90.0 1548.4
Effective Height	d	mm	585.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.300	0.187
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	47.64	-130.40
Re-bar	d1 As1	mm mm^2	585.0 1548.4	90.0 1548.4
Effective Height	d	mm	585.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.081	0.214
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400

2.2.2.5 SLUICEWAY TYPE H

(1) BOX - LONGITUDINAL

Structural Calculation of Sluiceway Type-H

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1 Design Condition

1.1 Design Condition

1.1.1 Basic Condition

1) Culvert Shape:Rectanglar

2) Culvert Type: Double Holes

3) Allowable Displacement

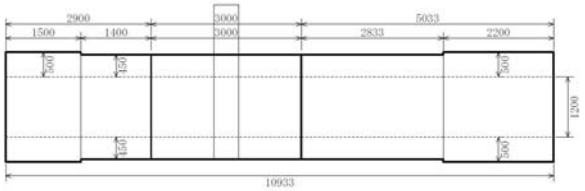
Residual Settlement		: 300.0 (mm)
Residual Settlement for Rigid Support		: 50.0 (mm)
Relative Displacement	Base Width	: 1.0 (%)
		± : 50.0 (mm)

4) Type of Joint : Flexible Joint

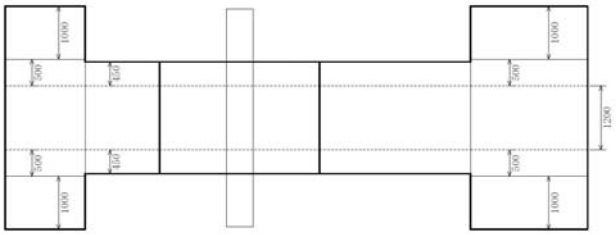
5) Allowable Opening : 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

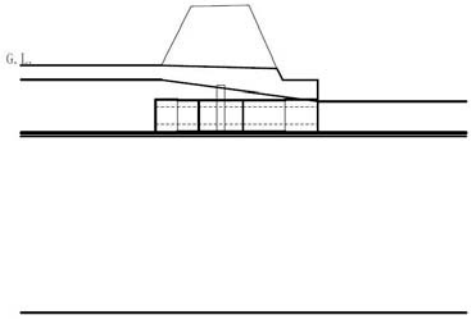
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Leeve Cross-section



1.2 Shape of Culvert Body

1.2.1 Span and Block

1) Spans

Number of Spans : 3
Total Length of Spans : 10.933 (m)

Span No	Name of Span	Length of Span (m)	Number of Blocks
1	Land Side	2.900	2
2	Center	3.000	1
3	River Side	5.033	2

2) Blocks

Span/ Block	Length of Block (m)	Depth for Subgrade Reaction(m)
1- 1	1.500	12.600
1- 2	1.400	6.300
2- 1	3.000	6.300
3- 1	2.833	6.300
3- 2	2.200	12.600

1.2.2 Sectional Dimension

1) Dimension (Block)

Span/ Block	Left Inside Width X2 (m)	Inside Height Y2 (m)
1- 1	1.200	1.200
1- 2	1.200	1.200
2- 1	1.200	1.200
3- 1	1.200	1.200
3- 2	1.200	1.200

Span/ Block	Thickness of Left Side Wall X1(m)	Thickness of Top Slab Y1(m)	Thickness of Bottom Slab Y3(m)	Height of Overhang Y4(m)	Length of Left Overhang B1(m)
1- 1	0.500	0.500	0.500	0.500	1.000
1- 2	0.450	0.450	0.450	0.000	0.000
2- 1	0.450	0.450	0.450	0.000	0.000
3- 1	0.450	0.450	0.450	0.000	0.000
3- 2	0.500	0.500	0.500	0.700	1.000

1.3 Reinforcement

Main Re-bar

Span No	Block No	Flange			Reinforcing Bar			
		Portion	b (mm)	t (mm)	Outside		Inside	
					Diameter@Pitch (Number)	Cover (mm)	Diameter@Pitch (Number)	Cover (mm)
1	1	Top Slab	2200.0	500.0	D16@250(7)	90.0	D16@250(9)	90.0
		Bottom Slab	2200.0	500.0	D16@250(7)	115.0	D16@250(9)	90.0
	2	Top Slab	2100.0	450.0	D16@250(7)	90.0	D16@250(9)	90.0
		Bottom Slab	2100.0	450.0	D16@250(7)	115.0	D16@250(9)	90.0
2	1	Top Slab	2100.0	450.0	D16@250(7)	90.0	D16@250(9)	90.0
		Bottom Slab	2100.0	450.0	D16@250(7)	115.0	D16@250(9)	90.0
3	1	Top Slab	2100.0	450.0	D16@250(7)	90.0	D16@250(9)	90.0
		Bottom Slab	2100.0	450.0	D16@250(7)	115.0	D16@250(9)	90.0
	2	Top Slab	2200.0	500.0	D19@250(7)	90.0	D19@250(9)	90.0
		Bottom Slab	2200.0	500.0	D19@250(7)	115.0	D19@250(9)	90.0

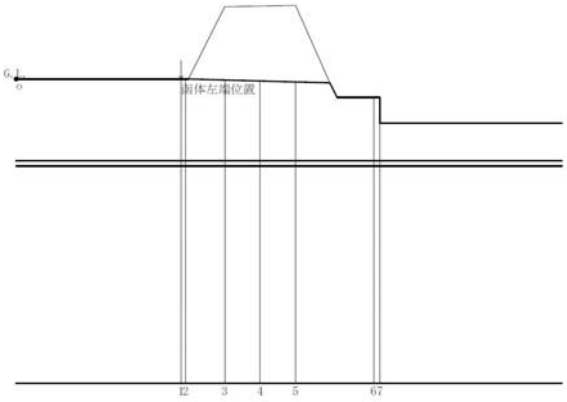
2 Settlement and Lateral Displacement

2.1 Immediate Settlement

2.1.1 Settlemet Calculation Points

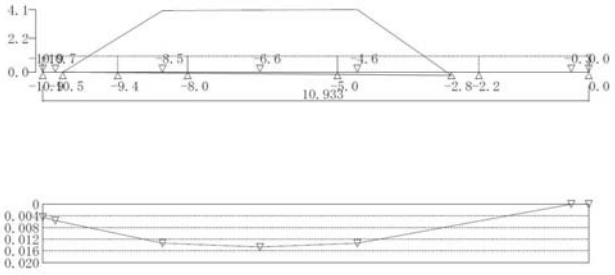
Settlemet Calculation Points

No	Calculation Point (m)	Name
1	-10.933	Box end (land side)
2	-10.683	Breast wall (land side)
3	-8.536	Levee end (land side)
4	-6.586	Levee center
5	-4.636	Levee end (river side)
6	-0.350	Breast wall (river side)
7	0.000	Box end (river side)



2.1.2 Summery of Immediate Settlement

No	Calculation Point (m)	Name	Immediate Settlement (mm)
1	-10.933	Box end (land side)	4.5
2	-10.683	Breast wall (land side)	5.6
3	-8.536	Levee end (land side)	13.3
4	-6.586	Levee center	14.7
5	-4.636	Levee end (river side)	13.4
6	-0.350	Breast wall (river side)	0.0
7	0.000	Box end (river side)	0.0

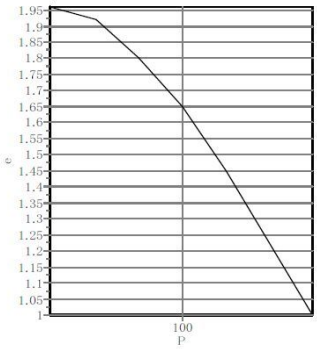


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

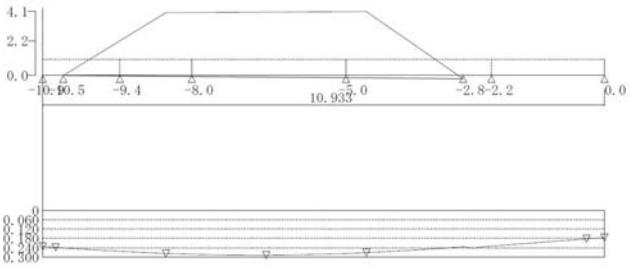
No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/ m³)	Unit Weight (Saturated) (kN/ m³)	Pre-Consolidation Stress q0 (kN/m²)	Elastic Modulus Es (kN/m²)
1	Adobe BL	Sand	4.512	17.500	18.500	0.0	6900.0
2	As	Sand	4.812	17.500	18.500	0.0	6900.0
3	Dc1	Clay	16.762	17.500	18.500	0.0	15700.0

No	Concolidation Pressure P(kN/m²)	Void Ratio e
1	12.0000	1.9600
2	25.0000	1.9200
3	50.0000	1.8000
4	100.0000	1.6500
5	200.0000	1.4500
6	800.0000	1.0000



2.2.2 Summery of Consolidation Settlement

No	Calculation Point (m)	Name	Consolidation Settlement (mm)
1	-10.933	Box end (land side)	231.1
2	-10.683	Breast wall (land side)	237.1
3	-8.536	Levee end (land side)	276.3
4	-6.586	Levee center	287.5
5	-4.636	Levee end (river side)	271.1
6	-0.350	Breast wall (river side)	182.7
7	0.000	Box end (river side)	174.1

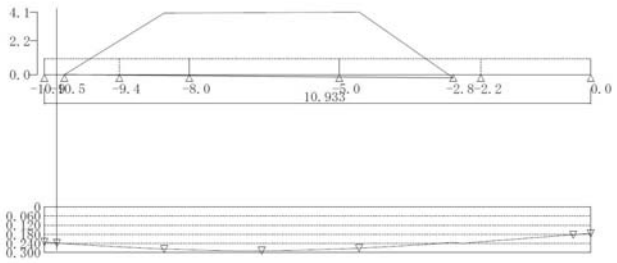


2.3 Residual Settlement

2.3.1 Sumarry of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vaue	Judge
1	-10.933	Box end (land side)	4.5	231.1	0.0	235.6	300.000	OK
2	-10.683	Breast wall (land side)	5.6	237.1	4.3	238.4	300.000	OK
3	-8.536	Levee end (land side)	13.3	276.3	41.3	248.3	300.000	OK
4	-6.586	Levee center	14.7	287.5	50.0	252.2	300.000	OK
5	-4.636	Levee end (river side)	13.4	271.1	46.1	238.4	300.000	OK
6	-0.350	Breast wall (river side)	0.0	182.7	3.5	179.2	300.000	OK
7	0.000	Box end (river side)	0.0	174.1	0.0	174.1	300.000	OK

The maximum of residual settlement is above 50.0(mm), herence the foundation is taken as flexible



▽ : Immediate Settlement
○ : Residual Settlement

3 Calculation of Box Culvert regarding Longitudal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B}\cdot\frac{d^4w}{dx^4}+k_v(w-w_g)=q \text{ (Swag)}$$

$$\frac{EA}{U}\cdot\frac{d^2u}{dx^2}+k_s(u-u_g)=p \quad \text{(Displacement in axial direction of Box Culvert)}$$

Thus,

w : Displacement of Box Culvert (Swag : cm {m})
w_g : Displacement of the Ground (Residual Settlement : cm {m})
k_v : Modulus of Sub grade Reaction in Vertical Direction (kgf/cm^3) {kN/m^3}
B : Width of Box Culvert (cm) {m}
EI : Rigidity of Box Culvert (kgf･cm^2) {kN･m^2}
q : Vertical External Force (kgf/cm^2) {kN/m^2}
u : Displacement on axial direction of Box Culvert (cm) {m}
u_g : Displacement of Ground (Lateral Displacement ; cm {m})
k_s : Modulus of Lateral Shear Sub grade Reaction (kgf/cm^3) {kN/m^3}
U : Circumference of Box Culvert (cm) {m}
EA : Rigidity of Box Culvert in axial direction (kgf) {kN}
p : Axial External Force (kgf/cm^2){kN/m^2}

3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{om}=\frac{\log\frac{(B+2h_n\cdot\tan\theta)\cdot L}{(L+2h_n\cdot\tan\theta)\cdot B}}{\Sigma\frac{1}{E_i}\log\frac{(B+2h_i\cdot\tan\theta)(L+2h_{i-1}\cdot\tan\theta)}{(L+2h_i\cdot\tan\theta)(B+2h_{i-1}\cdot\tan\theta)}}$$

In case of B=L

$$E_{om}=\frac{-\frac{1}{B+2h_n\cdot\tan\theta}+\frac{1}{B}}{\Sigma\frac{1}{E_i}\left(-\frac{1}{B+2h\cdot\tan\theta}+\frac{1}{B+2h_{i-1}\cdot\tan\theta}\right)}$$

Thus

Eom ; Converted Modulus of Deformation
B ; Loading Width = Width of Culvert
L ; Loading Length = Length of a span
hn ; Depth for Calculation
hn ; Depth from the ground to the bottom Elevation of Each Layer（m）
Ei ; Converted Modulus of Deformation of Each Layer(kN/m^2)
θ ; Angle of Load Dispersion（θ=30°）

Span1-Block1 Land Side

B			4.200 (m)
L			2.900 (m)
hn			12.600 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	0.200	0.200	27600.0
2	12.400	12.600	62800.0
Total	12.600		
Eom	57160.0 (kN/m^2)		

※Layer Thickness and Depths are the values based on subgrade Surface.

Span1-Block2 Land Side

B			2.100 (m)
L			2.900 (m)
hn			6.300 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	0.200	0.200	27600.0
2	6.100	6.300	62800.0
Total	6.300		
Eom	54764.9 (kN/m2)		

※Layer Thickness and Depths are values Calculated from the subgrade

Span2-Block1 Center

B			2.100 (m)
L			3.000 (m)
hn			6.300 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	0.200	0.200	27600.0
2	6.100	6.300	62800.0
Total	6.300		
Eom	54837.0 (kN/m2)		

※Layer and Depth is the values from the subgrade

Span3-Block1 River Side

B			2.100 (m)
L			5.033 (m)
hn			6.300 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	0.200	0.200	27600.0
2	6.100	6.300	62800.0
Total	6.300		
Eom	55771.7 (kN/m2)		

※Layer and Depth is the values from the subgrade

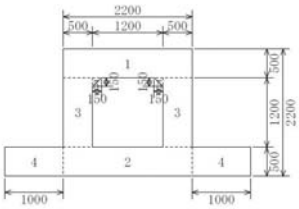
Span3-Block2　River Side

B			4.200 (m)
L			5.033 (m)
hn			12.600 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	0.200	0.200	27600.0
2	12.400	12.600	62800.0
Total	12.600		
Eom			58127.6 (kN/m2)

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

Span1-Block1　Land Side

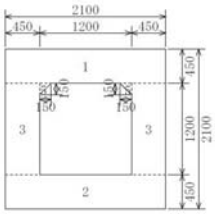


Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	1.100	1.950	2.1450	4.1828	0.02292
2	1.100	0.250	0.2750	0.0688	0.02292
3	1.200	1.100	1.3200	1.4520	0.14400
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.023	1.650	0.0371	0.0613	0.00003
Total	4.423		4.0271	5.8273	0.21069

Yg = Σ(Ai・Yi)/ΣAi = 4.0271 / 4.423 = 0.9106 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 5.8273 + 0.21069 - 0.8292・4.423= 2.37085 (m⁴)

Span1-Block2　Land Side

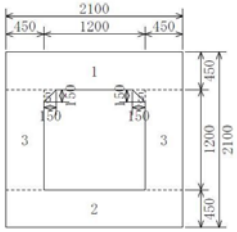


Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	0.945	1.875	1.7719	3.3223	0.01595
2	0.945	0.225	0.2126	0.0478	0.01595
3	1.080	1.050	1.1340	1.1907	0.12960
5	0.023	1.600	0.0360	0.0576	0.00003
Total	2.993		3.1545	4.6184	0.16152

Yg = Σ(Ai・Yi)/ΣAi = 3.1545 / 2.993 = 1.0541 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 4.6184 + 0.16152 - 1.1112・2.993= 1.45466 (m4)

Span2-Block1　Center

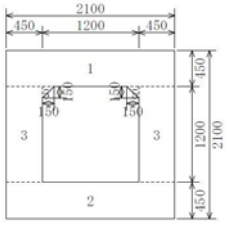


Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	0.945	1.875	1.7719	3.3223	0.01595
2	0.945	0.225	0.2126	0.0478	0.01595
3	1.080	1.050	1.1340	1.1907	0.12960
5	0.023	1.600	0.0360	0.0576	0.00003
Total	2.993		3.1545	4.6184	0.16152

Yg = Σ(Ai・Yi)/ΣAi =3.1545 / 2.993 = 1.0541 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 4.6184 + 0.16152 - 1.1112・2.993= 1.45466 (m⁴)

Span3-Block1　River Side

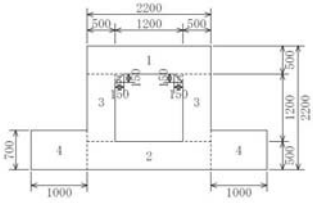


Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	0.945	1.875	1.7719	3.3223	0.01595
2	0.945	0.225	0.2126	0.0478	0.01595
3	1.080	1.050	1.1340	1.1907	0.12960
5	0.023	1.600	0.0360	0.0576	0.00003
Total	2.993		3.1545	4.6184	0.16152

Yg = Σ(Ai・Yi)/ΣAi = 3.1545 / 2.993 = 1.0541 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg²・ΣAi = 4.6184 + 0.16152 - 1.1112・2.993= 1.45466 (m⁴)

Span3-Block2　River Side



Position	Ai (m²)	Yi (m)	Ai・Yi (m³)	Ai・Yi² (m³)	Ioi (m⁴)
1	1.100	1.950	2.1450	4.1828	0.02292
2	1.100	0.250	0.2750	0.0688	0.02292
3	1.200	1.100	1.3200	1.4520	0.14400
4	1.400	0.350	0.4900	0.1715	0.05717
5	0.023	1.650	0.0371	0.0613	0.00003
Total	4.823		4.2671	5.9363	0.24703

Yg = Σ(Ai・Yi)/ΣAi = 4.2671 / 4.823 = 0.8848 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg²・ΣAi = 5.9363 + 0.24703 - 0.7829・4.823= 2.40758 (m⁴)

3.2.3 Table of Modulus of Subgarade Reaction

Coefficient of Lateral Shear Reaction of Soil

$k_s = \lambda \cdot k_v$

Thus、

ks : Coefficient of Lateral Shear Reaction of Soil (kN/m2)

λ ; Ratio between the coefficient of Lateral Shear Reaction of Soil and Vertical Sub grade Reaction (=0.333)

kv : Coefficient of Vertical Sub grade Reaction

3.2.4 List of Modulus of Subgrade Reaction

Calculated Value

Normal Condition

Span Block	Position (m)	B (m)	k_v (kN/m³)	k_s (kN/m²)	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
1-1	-10.933～ -9.433	4.200	30247.8	10072.5	127040.8	42304.6
1-2	-9.433～ -8.033	2.100	37582.9	12515.1	78924.1	26281.7
2-1	-8.033～ -5.033	2.100	37157.0	12373.3	78029.6	25983.9
3-1	-5.033～ -2.200	2.100	31125.5	10364.8	65363.5	21766.1
3-2	-2.200～ 0.000	4.200	25014.9	8330.0	105062.6	34985.8

Seismic Condition

Span Block	Position (m)	B (m)	k_v (kN/m³)	k_s (kN/m²)	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
1-1	--10.933～ -9.433	4.200	60495.6	20145.0	254081.6	84609.2
1-2	-9.433～ -8.033	2.100	75165.8	25030.2	157848.1	52563.4
2-1	-8.033～ -5.033	2.100	74313.9	24746.5	156059.3	51967.7
3-1	-5.033～ -2.200	2.100	62251.0	20729.6	130727.1	43532.1
3-2	-2.200～ 0.000	4.200	50029.8	16659.9	210125.2	69971.7

Used Value

Normal Condition

Span Block	Position (m)	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
1-1	-10.933～ -9.433	125587.5	41820.6
1-2	-9.433～ -8.033	78029.6	25983.9
2-1	-8.033～ -5.033	78029.6	25983.9
3-1	-5.033～ -2.200	65820.9	21918.4
3-2	-2.200～ 0.000	105802.0	35232.1

Seismic Condition

Span Block	Position (m)	Reduction Ratio DE	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
1-1	-10.933～ -9.433	1.000	251175.0	83641.3
1-2	-9.433～ -8.033	1.000	156059.3	51967.7
2-1	-8.033～ -5.033	1.000	156059.3	51967.7
3-1	-5.033～ -2.200	1.000	131641.8	43836.7
3-2	-2.200～ 0.000	1.000	211604.0	70464.1

3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

W = (A1 + A2 + A3)･γc (kN/m)

A1: Cross Sectional Area (Excluding Hunch) (m²)

A2: Area of Upper Side Hunch (m²)

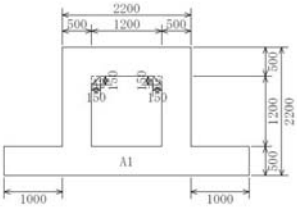
A3: Area of Lower Side Hunch (m²)

γc: Unit Weight(Concrete) (kN/m³)

Span No. 1-1 Land Side

W = (4.400 + 0.023 + 0.000)・ 24.000

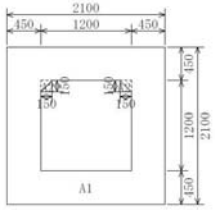
= 106.140 (kN/m)



Span No. 1-2 Land Side

W = (2.970 + 0.023 + 0.000)・ 24.000

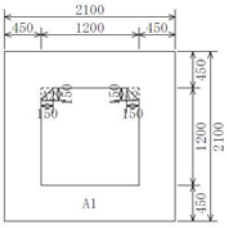
= 71.820 (kN/m)



Span No. 2-1 Center

W = (2.970 + 0.023 + 0.000)・ 24.00

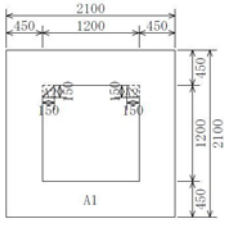
= 71.820 (kN/m)



Span No. 3-1 River Side

W = (2.970 + 0.023 + 0.000)・ 24.00

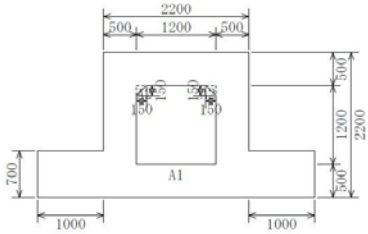
= 71.820 (kN/m)



Span No. 3-2 River Side

W = (4.800 + 0.023 + 0.000)・ 24.00

= 115.740 (kN/m)



2) Seepage Cutoff Wall Body Weight

A1 = X1･L2

A2 = L1･Y1･2

W = (A1 + A2)･B･γc (kN)

X1: Top Slab Width (m)

Y1: Side Wall Height (m)

L1: Side Wall Width (m)

L2: Top Slab Height (m)

A1: Top Slab Area (m²)

A2: Side Wall Area (m²)

B : Thickness (m)

γc: Unit Weight (Concrete) (kN/m³)

SpanNo.2-SpanDistance from Base Point (1.450)

A1 = 4.100･ 1.000

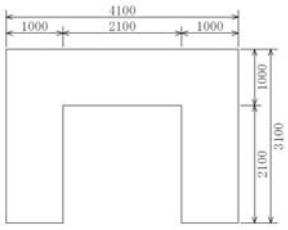
= 4.100 (m²)

A2 = 1.000･ 2.100･2

= 4.200 (m²)

W = (4.100 + 4.200)･ 0.500･ 24.00

= 99.600 (kN)



3.3.2 Ground Displacement Load (Settlement、Lateral Displacement)

1) Equivalent Load for Ground Settlement

【Normal Condition】

Span1 Name of Span: [Land Side]

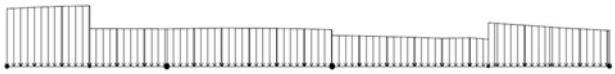
Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-10.933～-10.683	4.200	125587.5	235.6	238.4	-29583.702	-29942.725
1-(2)	-10.683～-10.433	4.200	125587.5	238.4	241.5	-29942.725	-30332.255
1-(3)	-10.433～ -9.933	4.200	125587.5	241.5	245.5	-30332.255	-30828.006
1-(4)	-9.933～ -9.433	4.200	125587.5	245.5	247.8	-30828.006	-31117.477
2-(5)	-9.433～ -8.933	2.100	78029.6	247.8	248.6	-19333.818	-19397.983
2-(6)	-8.933～ -8.433	2.100	78029.6	248.6	248.1	-19397.983	-19362.123
2-(7)	-8.433～ -8.033	2.100	78029.6	248.1	246.2	-19362.123	-19213.317

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(8)	-8.033～ -7.533	2.100	78029.6	246.2	250.4	-19213.317	-19540.638
1-(9)	-7.533～ -7.033	2.100	78029.6	250.4	252.4	-19540.638	-19695.480
1-(10)	-7.033～ -6.533	2.100	78029.6	252.4	252.1	-19695.480	-19673.320
1-(11)	-6.533～ -6.033	2.100	78029.6	252.1	250.6	-19673.320	-19550.921
1-(12)	-6.033～ -5.533	2.100	78029.6	250.6	246.8	-19550.921	-19254.496
1-(13)	-5.533～ -5.033	2.100	78029.6	246.8	240.8	-19254.496	-18789.540

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(14)	-5.033～ -4.533	2.100	65820.9	240.8	237.5	-15849.679	-15633.356
1-(15)	-4.533～ -4.033	2.100	65820.9	237.5	232.7	-15633.356	-15315.666
1-(16)	-4.033～ -3.533	2.100	65820.9	232.7	226.4	-15315.666	-14903.457
1-(17)	-3.533～ -3.033	2.100	65820.9	226.4	218.6	-14903.457	-14391.319
1-(18)	-3.033～ -2.533	2.100	65820.9	218.6	222.6	-14391.319	-14648.551
1-(19)	-2.533～ -2.200	2.100	65820.9	222.6	211.5	-14648.551	-13924.151
2-(20)	-2.200～ -2.033	4.200	105802.0	211.5	208.5	-22381.994	-22057.706
2-(21)	-2.033～ -1.533	4.200	105802.0	208.5	199.4	-22057.706	-21091.774
2-(22)	-1.533～ -1.083	4.200	105802.0	199.4	191.0	-21091.774	-20206.641
2-(23)	-1.083～ -1.033	4.200	105802.0	191.0	189.7	-20206.641	-20066.325
2-(24)	-1.033～ -0.533	4.200	105802.0	189.7	182.0	-20066.325	-19253.963
2-(25)	-0.533～ -0.033	4.200	105802.0	182.0	174.6	-19253.963	-18469.649
2-(26)	-0.033～ 0.000	4.200	105802.0	174.6	174.1	-18469.649	-18419.351



2) Equivalent Load for Ground Settlement

【Seismic Condition】

Span1 Name of Span: [Land Side]

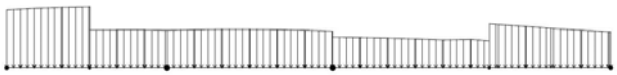
Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-10.933～-10.683	4.200	251175.0	235.6	238.4	-59167.404	-59885.450
1-(2)	-10.683～-10.433	4.200	251175.0	238.4	241.5	-59885.450	-60664.509
1-(3)	-10.433～ -9.933	4.200	251175.0	241.5	245.5	-60664.509	-61656.012
1-(4)	-9.933～ -9.433	4.200	251175.0	245.5	247.8	-61656.012	-62234.954
2-(5)	-9.433～ -8.933	2.100	156059.3	247.8	248.6	-38667.635	-38795.966
2-(6)	-8.933～ -8.433	2.100	156059.3	248.6	248.1	-38795.966	-38724.246
2-(7)	-8.433～ -8.033	2.100	156059.3	248.1	246.2	-38724.246	-38426.634

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(8)	-8.033～ -7.533	2.100	156059.3	246.2	250.4	-38426.634	-39081.275
1-(9)	-7.533～ -7.033	2.100	156059.3	250.4	252.4	-39081.275	-39390.959
1-(10)	-7.033～ -6.533	2.100	156059.3	252.4	252.1	-39390.959	-39346.639
1-(11)	-6.533～ -6.033	2.100	156059.3	252.1	250.6	-39346.639	-39101.841
1-(12)	-6.033～ -5.533	2.100	156059.3	250.6	246.8	-39101.841	-38508.991
1-(13)	-5.533～ -5.033	2.100	156059.3	246.8	240.8	-38508.991	-37579.081

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(14)	-5.033～ -4.533	2.100	131641.8	240.8	237.5	-31699.358	-31266.712
1-(15)	-4.533～ -4.033	2.100	131641.8	237.5	232.7	-31266.712	-30631.332
1-(16)	-4.033～ -3.533	2.100	131641.8	232.7	226.4	-30631.332	-29806.913
1-(17)	-3.533～ -3.033	2.100	131641.8	226.4	218.6	-29806.913	-28782.638
1-(18)	-3.033～ -2.533	2.100	131641.8	218.6	222.6	-28782.638	-29297.102
1-(19)	-2.533～ -2.200	2.100	131641.8	222.6	211.5	-29297.102	-27848.303
2-(20)	-2.200～ -2.033	4.200	211604.0	211.5	208.5	-44763.987	-44115.412
2-(21)	-2.033～ -1.533	4.200	211604.0	208.5	199.4	-44115.412	-42183.548
2-(22)	-1.533～ -1.083	4.200	211604.0	199.4	191.0	-42183.548	-40413.283
2-(23)	-1.083～ -1.033	4.200	211604.0	191.0	189.7	-40413.283	-40132.650
2-(24)	-1.033～ -0.533	4.200	211604.0	189.7	182.0	-40132.650	-38507.927
2-(25)	-0.533～ -0.033	4.200	211604.0	182.0	174.6	-38507.927	-36939.297
2-(26)	-0.033～ 0.000	4.200	211604.0	174.6	174.1	-36939.297	-36838.702



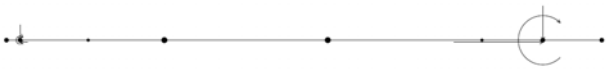
3.3.3 Point Load from Breast Walls

1) Normal Condition (Case Number: 1)

Case of Normal Condition 1

Name of Normal Load: [Gate Piers and Breast Walls (Normal) 1]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-46.68	100.12	-51.87
3	Right Breast Wall	9.850	583.80	224.32	-321.16



2) Seismic Condition (Total Number: 2)

Case of Seismic Conditon 1 [Land Side →River Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-9.35	10.80	-24.51
3	Right Breast Wall	9.850	514.59	119.62	-196.58



Case of Seimic Condition 2 [River Side→Land Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-71.27	10.80	-9.74
3	Right Breast Wall	9.850	378.24	119.62	-78.57



3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
2	Fixed Load Data 2	Water Weight (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Engaging Load (Normal)1	Gate Structure ・Breast Wall (Normal)1	1.0000
6	Arbitrary Load (Normal)1	Surcharge in Normal Condition	1.0000

2) Seismic Condition

1) Case 1 [Seismic Condition: Land Side→River Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Arbitrary Load (Seismic)1	Surcharge in Seismic Condition	1.0000
6	Ingaging Load (Dead Load)1	Gate Structure ・Breast Wall (Dead Load)1	1.0000
7	Ingaging Load (Seismic)1	Seismic Load :Land Side →River Side	1.0000

2) Case 2 [Seismic Condition: River Side→Land Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Dead Load)2	Seismic Load	1.0000
6	Ingaging Load (Dead Load)2	Gate Structure ・Breast Wall (Dead Load)2	1.0000
7	Arbitrary Load (Seismic)1	Surcharge in Seismic Condition	1.0000

3.4 Displacement between Sluiceway and Adjoining Levee

3.4.1 Normal Condition

1) Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-7.4	-7.6	241.9	235.6	6.4	42.0	○	801.132
2	0.250	-7.4	-7.6	242.8	238.4	4.4	42.0	○	551.751
3	0.500	-7.4	-7.5	243.7	241.5	2.2	42.0	○	271.863
4	1.000	-7.4	-6.9	245.4	245.5	0.0	-50.0	○	-4.606
5	1.500	-7.4	-6.3	247.2	247.8	-0.6	-50.0	○	-74.794
6	2.000	-7.4	-5.6	248.9	248.6	0.3	21.0	○	25.607
7	2.500	-7.4	-4.9	250.7	248.1	2.5	21.0	○	197.709
8	2.900	-7.4	-3.8	252.1	246.2	5.8	21.0	○	455.510

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground Spring (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	0.2	-3.8	253.6	246.2	7.3	21.0	○	571.955
2	0.500	0.2	-2.5	252.6	250.4	2.2	21.0	○	173.420
3	1.000	0.2	-1.2	251.7	252.4	-0.7	-50.0	○	-52.638
4	1.500	0.2	0.2	250.8	252.1	-1.3	-50.0	○	-101.693
5	2.000	0.2	1.5	249.9	250.6	-0.6	-50.0	○	-50.511
6	2.500	0.2	2.8	249.0	246.8	2.2	21.0	○	174.697
7	3.000	0.2	4.1	248.1	240.8	7.3	21.0	○	568.434

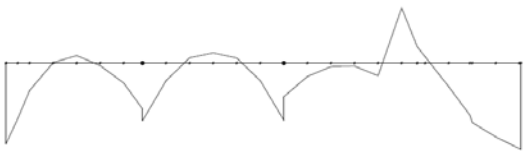
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	15.4	4.1	245.9	240.8	5.1	21.0	○	333.387
2	0.500	15.4	5.3	239.5	237.5	2.0	21.0	○	133.222
3	1.000	15.4	6.0	233.2	232.7	0.5	21.0	○	34.424
4	1.500	15.4	6.6	226.9	226.4	0.5	21.0	○	30.145
5	2.000	15.4	7.3	220.6	218.6	1.9	21.0	○	125.794
6	2.500	15.4	7.6	214.2	222.6	-8.3	-50.0	○	-547.927
7	2.833	15.4	7.6	210.0	211.5	-1.5	-50.0	○	-162.204
8	3.000	15.4	7.6	207.9	208.5	-0.6	-50.0	○	-61.521
9	3.500	15.4	7.5	201.6	199.4	2.2	42.0	○	234.936
10	3.950	15.4	7.5	195.9	191.0	4.9	42.0	○	517.541
11	4.000	15.4	7.5	195.2	189.7	5.6	42.0	○	590.910
12	4.500	15.4	7.4	188.9	182.0	6.9	42.0	○	733.797
13	5.000	15.4	7.4	182.6	174.6	8.0	42.0	○	848.637
14	5.033	15.4	7.4	182.2	174.1	8.1	42.0	○	854.749

Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-6.5	-7.6	241.1	235.6	5.5	42.0	○	696.139
2	0.250	-6.5	-7.6	242.0	238.4	3.6	42.0	○	455.298
3	0.500	-6.5	-7.5	243.0	241.5	1.5	42.0	○	183.952
4	1.000	-6.5	-6.9	244.9	245.5	-0.6	-50.0	○	-75.435
5	1.500	-6.5	-6.3	246.8	247.8	-1.0	-50.0	○	-128.542
6	2.000	-6.5	-5.6	248.6	248.6	0.0	21.0	○	2.826
7	2.500	-6.5	-4.9	250.5	248.1	2.4	21.0	○	185.542
8	2.900	-6.5	-3.8	252.0	246.2	5.8	21.0	○	451.833

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	0.2	-3.8	253.4	246.2	7.2	21.0	○	558.064
2	0.500	0.2	-2.5	252.5	250.4	2.0	21.0	○	159.528
3	1.000	0.2	-1.2	251.6	252.4	-0.9	-50.0	○	-66.529
4	1.500	0.2	0.2	250.6	252.1	-1.5	-50.0	○	-115.585
5	2.000	0.2	1.5	249.7	250.6	-0.8	-50.0	○	-64.402
6	2.500	0.2	2.8	248.8	246.8	2.1	21.0	○	160.805
7	3.000	0.2	4.1	247.9	240.8	7.1	21.0	○	554.543

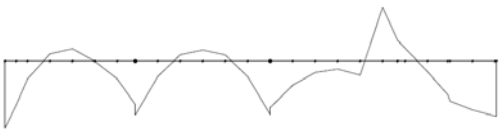
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	8.8	4.1	248.1	240.8	7.3	21.0	○	481.697
2	0.500	8.8	5.3	241.3	237.5	3.8	21.0	○	249.363
3	1.000	8.8	6.0	234.5	232.7	1.8	21.0	○	118.396
4	1.500	8.8	6.6	227.7	226.4	1.2	21.0	○	81.949
5	2.000	8.8	7.3	220.9	218.6	2.2	21.0	○	145.428
6	2.500	8.8	7.6	214.0	222.6	-8.5	-50.0	○	-560.463
7	2.833	8.8	7.6	209.5	211.5	-2.0	-50.0	○	-216.797
8	3.000	8.8	7.6	207.2	208.5	-1.3	-50.0	○	-133.387
9	3.500	8.8	7.5	200.4	199.4	1.1	42.0	○	111.354
10	3.950	8.8	7.5	194.3	191.0	3.3	42.0	○	347.414
11	4.000	8.8	7.5	193.6	189.7	3.9	42.0	○	415.611
12	4.500	8.8	7.4	186.8	182.0	4.8	42.0	○	506.779
13	5.000	8.8	7.4	180.0	174.6	5.4	42.0	○	569.900
14	5.033	8.8	7.4	179.5	174.1	5.4	42.0	○	572.599

Displacement Diagram



Reaction Force of Ground



Reaction Force



2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-6.8	-7.6	241.2	235.6	5.6	42.0	○	709.306
2	0.250	-6.8	-7.6	242.1	238.4	3.7	42.0	○	466.579
3	0.500	-6.8	-7.5	243.1	241.5	1.5	42.0	○	193.345
4	1.000	-6.8	-6.9	244.9	245.5	-0.6	-50.0	○	-69.815
5	1.500	-6.8	-6.3	246.8	247.8	-1.0	-50.0	○	-126.696
6	2.000	-6.8	-5.6	248.6	248.6	0.0	21.0	○	1.628
7	2.500	-6.8	-4.9	250.5	248.1	2.3	21.0	○	182.000
8	2.900	-6.8	-3.8	252.0	246.2	5.7	21.0	○	446.415

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	0.2	-3.8	253.4	246.2	7.2	21.0	○	558.064
2	0.500	0.2	-2.5	252.5	250.4	2.0	21.0	○	159.528
3	1.000	0.2	-1.2	251.6	252.4	-0.9	-50.0	○	-66.529
4	1.500	0.2	0.2	250.6	252.1	-1.5	-50.0	○	-115.585
5	2.000	0.2	1.5	249.7	250.6	-0.8	-50.0	○	-64.402
6	2.500	0.2	2.8	248.8	246.8	2.1	21.0	○	160.805
7	3.000	0.2	4.1	247.9	240.8	7.1	21.0	○	554.543

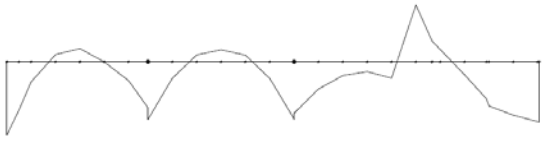
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	8.3	4.1	248.4	240.8	7.6	21.0	○	498.328
2	0.500	8.3	5.3	241.5	237.5	4.0	21.0	○	264.880
3	1.000	8.3	6.0	234.7	232.7	2.0	21.0	○	132.797
4	1.500	8.3	6.6	227.9	226.4	1.4	21.0	○	95.234
5	2.000	8.3	7.3	221.0	218.6	2.4	21.0	○	157.598
6	2.500	8.3	7.6	214.2	222.6	-8.3	-50.0	○	-549.409
7	2.833	8.3	7.6	209.7	211.5	-1.9	-50.0	○	-200.223
8	3.000	8.3	7.6	207.4	208.5	-1.1	-50.0	○	-117.412
9	3.500	8.3	7.5	200.5	199.4	1.2	42.0	○	125.534
10	3.950	8.3	7.5	194.4	191.0	3.4	42.0	○	359.978
11	4.000	8.3	7.5	193.7	189.7	4.0	42.0	○	427.996
12	4.500	8.3	7.4	186.9	182.0	4.9	42.0	○	517.368
13	5.000	8.3	7.4	180.0	174.6	5.5	42.0	○	578.694
14	5.033	8.3	7.4	179.6	174.1	5.5	42.0	○	581.274

Displacement Diagram



Reaction Force of Ground



Reaction Force



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	2.444	139.103	18.685
3	0.250	95.798	-61.137	122.425
4	0.500	97.806	11.806	117.714
5	1.000	94.151	18.605	131.072
6	1.500	77.465	-61.261	121.868
7	2.000	59.000	-109.333	77.719
8	2.500	31.502	-96.359	22.710
9	2.900	0.001	0.000	0.000

Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	2.900	-0.001	0.000	0.000
2	3.400	43.078	143.488	44.177
3	3.900	68.923	130.828	117.467
4	4.400	77.538	49.389	163.543
5	4.400	77.538	-50.211	163.543
6	4.900	68.923	-131.118	117.144
7	5.400	43.076	-142.927	43.938
8	5.900	-0.001	0.000	0.000

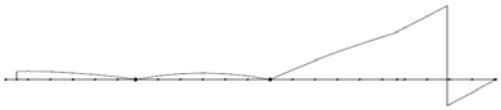
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	5.900	0.001	0.000	0.000
2	6.400	116.434	73.797	22.620
3	6.900	222.791	72.852	61.342
4	7.400	321.999	46.139	91.180
5	7.900	414.059	42.268	111.291
6	8.400	500.658	-106.121	109.363
7	8.733	557.200	-242.694	47.155
8	8.900	602.929	-283.023	3.024
9	9.400	740.440	-304.485	-150.025
10	9.850	864.962	-193.512	-266.839
11	9.850	-302.633	-642.151	375.480
12	9.900	-288.758	-620.865	344.221
13	10.400	-149.465	-354.498	97.409
14	10.900	-9.286	-23.705	0.470
15	10.933	-0.003	-0.020	0.000

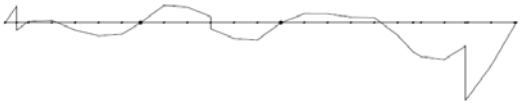
Bending Moment



Axial Force



Shear Force



3.5.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition　Land Side →River Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	11.306	116.742	15.840
3	0.250	20.650	15.822	84.510
4	0.500	31.521	68.804	96.494
5	1.000	45.591	42.878	129.770
6	1.500	46.629	-60.115	126.521
7	2.000	39.177	-113.963	81.251
8	2.500	22.692	-100.802	23.726
9	2.900	0.001	0.000	0.000

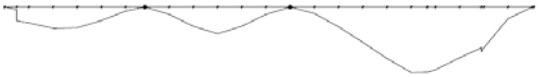
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	2.900	-0.001	0.000	0.000
2	3.400	43.078	143.488	44.177
3	3.900	68.923	130.828	117.467
4	4.400	77.538	49.389	163.543
5	4.400	77.538	-50.211	163.543
6	4.900	68.923	-131.118	117.144
7	5.400	43.076	-142.927	43.938
8	5.900	-0.001	0.000	0.000

Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	5.900	0.001	0.000	0.000
2	6.400	65.172	135.506	38.587
3	6.900	120.267	183.315	120.892
4	7.400	168.213	192.400	215.451
5	7.900	209.011	211.372	314.943
6	8.400	244.348	72.870	400.578
7	8.733	266.750	-64.307	398.033
8	8.900	284.957	-110.009	383.276
9	9.400	340.068	-161.452	310.107
10	9.850	390.430	-95.269	248.212
11	9.850	-124.155	-465.198	270.812
12	9.900	-118.520	-449.930	248.220
13	10.400	-61.627	-255.199	69.835
14	10.900	-3.847	-16.871	0.296
15	10.933	-0.003	-0.019	0.000

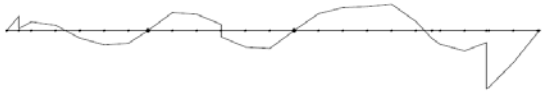
Bending Moment



Axial Force



Shear Force



Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.003	0.000	0.000
2	0.250	4.774	121.149	16.407
3	0.250	76.038	11.959	74.297
4	0.500	80.377	68.585	85.786
5	1.000	81.383	47.655	120.329
6	1.500	69.357	-53.396	120.081
7	2.000	53.787	-107.935	78.078
8	2.500	29.186	-97.364	22.998
9	2.900	0.001	0.000	0.000

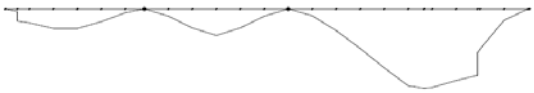
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	2.900	-0.001	0.000	0.000
2	3.400	43.078	143.488	44.177
3	3.900	68.923	130.828	117.467
4	4.400	77.538	49.389	163.543
5	4.400	77.538	-50.211	163.543
6	4.900	68.923	-131.118	117.144
7	5.400	43.076	-142.927	43.938
8	5.900	-0.001	0.000	0.000

Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	5.900	0.001	0.000	0.000
2	6.400	54.469	149.237	42.089
3	6.900	98.860	209.109	134.345
4	7.400	136.103	228.589	244.469
5	7.900	166.197	256.288	364.307
6	8.400	190.831	124.844	474.234
7	8.733	206.104	-8.557	489.646
8	8.900	218.565	-51.664	484.420
9	9.400	256.470	-97.125	442.031
10	9.850	291.347	-27.853	409.860
11	9.850	-86.887	-463.722	268.880
12	9.900	-82.973	-448.245	246.369
13	10.400	-43.286	-252.900	69.091
14	10.900	-2.712	-16.640	0.297
15	10.933	-0.003	-0.019	0.000

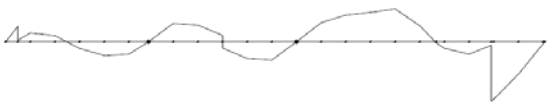
Bending Moment



Axial Force



Shear Force



3.6 Design of Flexible Joint

Opening

Opening = (Lateral Displacement of Span in Right Side) - (Lateral Displacement of Span in Left Side)

Bending Angle

θ = | θ1 - θ2 | - Initial Bending Angle

Thus、

θ1: Angle of Displacement (Left Side) (rad)

θ2: Angle of Displacement (Right Side) (rad)

θ: Average Angle of Displacement (rad)

Unevenness

Unevenness = (Vertical Displacement of Span in Right Side) - (Vertical Displacement of Span in Left Side)

3.6.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Check of Opening Allowable Opening : 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-7.4	
Span (2- 1)	0.2-(-7.4)	7.5 OK
Span (3- 2)	15.4-(0.2)	15.2 OK
EP	15.4	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.20008 -0.00349	0.10458 0.00183	0.30466 0.00532
Span (3- 2)	0.00000 0.00000	0.10459 0.00183	0.72509 0.01266	0.62050 0.01083

Check for Unevenness Allowable Unevenness 100.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-241.9	
Span (2- 1)	-253.6-(-252.1)	1.5 OK
Span (3- 2)	-245.9-(-248.1)	2.2 OK
EP	-182.2	

3.6.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-6.5	
Span (2- 1)間	0.2-(-6.5)	6.6 OK
Span (3- 2)間	8.8-(0.2)	8.7 OK
EP	8.8	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.21567 -0.00376	0.10458 0.00183	0.32025 0.00559
Span (3- 2)	0.00000 0.00000	0.10459 0.00183	0.78109 0.01363	0.67650 0.01181

Check for Unevenness Allowable Unevenness 100.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-241.1	
Span (2- 1)	-253.4-(-252.0)	1.4 OK
Span (3- 2)	-248.1-(-247.9)	0.2 OK
EP	-179.5	

Calculation Case2 - Load: [Seismic Condition Land Side →River Side]

Check for Opening Allowable Opening 100.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-6.8	
Span (2- 1)	0.2-(-6.8)	7.0 OK
Span (3- 2)	8.3-(0.2)	8.2 OK
EP	8.3	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.21222 -0.00370	0.10458 0.00183	0.31681 0.00553
Span (3- 2)	0.00000 0.00000	0.10459 0.00183	0.78303 0.01367	0.67845 0.01184

Check for Unevenness Allowable Unevenness 100.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-241.2	
Span (2- 1)	-253.4-(-252.0)	1.4 OK
Span (3- 2)	-248.4-(-247.9)	0.5 OK
EP	-179.6	

3.7 Stress Intensity Analysis

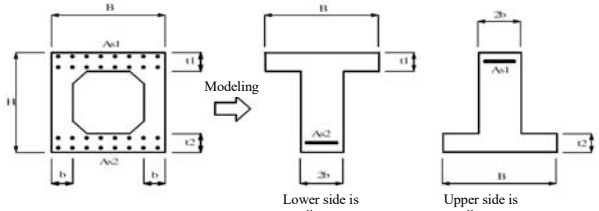
3.7.1 Calculation Condition

It is considered that double reinforced section which bending moment is acting on.
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.
Position of Neutral Axis

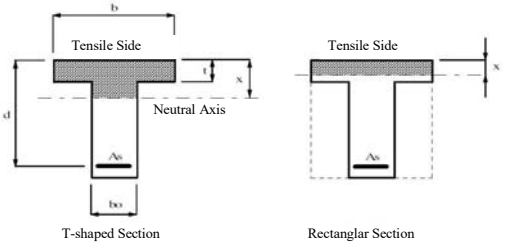
$$x=\frac{n\cdot(As\cdot d+As'\cdot d')+B\cdot t^2/2}{n\cdot(As+As')+B\cdot t}$$

Thus,

x : Position of Neutral Axis (mm)
n : Ratio of Young modulus = 9.0
As : Area of Re-bar in tensile side (mm^2)
As' : Area of Re-bar in compressive side (mm^2)
d : Effective Height of Beam (mm)
d' : Distance from the compressive edge of concrete to the centric of Re-bar (mm)
B : Width of Flange (mm)
t : Thickness of Flange (mm)



The stress calculation is conducted as follows based on the position of neutral axis
1) In case the neutral axis is in web, the section is considered as T-shape.
2) In case the neutral axis is in top slab or Bottom slab, the section is considered as rectangle.



Calculation Condition (In Case Bottom Slab is Tensile)
Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation Section
1- 1	2.200	2.200	1.000	0.500	0.292	Rectangle
1- 2	2.100	2.100	0.900	0.450	0.272	Rectangle
2- 1	2.100	2.100	0.900	0.450	0.272	Rectangle
3- 1	2.100	2.100	0.900	0.450	0.272	Rectangle
3- 2	2.200	2.200	1.000	0.500	0.292	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side As(mm^2)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side As' (mm^2)
1- 1	2.200	2.200	1.919	3177.6	0.270	3177.6
1- 2	2.100	2.100	1.847	3177.6	0.242	3177.6
2- 1	2.100	2.100	1.847	3177.6	0.242	3177.6
3- 1	2.100	2.100	1.847	3177.6	0.242	3177.6
3- 2	2.200	2.200	1.919	3177.6	0.270	3177.6

Calculation Condition (In Case Top Slab is Tensile)
Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation
1- 1	2.200	2.200	1.000	0.500	0.292	Rectangle
1- 2	2.100	2.100	0.900	0.450	0.272	Rectangle
2- 1	2.100	2.100	0.900	0.450	0.272	Rectangle
3- 1	2.100	2.100	0.900	0.450	0.272	Rectangle
3- 2	2.200	2.200	1.000	0.500	0.292	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side	Position of Re-bar in Compressive	Area of Re-bar in Tensile Side
1- 1	2.200	2.200	1.930	3177.6	0.281	3177.6
1- 2	2.100	2.100	1.858	3177.6	0.253	3177.6
2- 1	2.100	2.100	1.858	3177.6	0.253	3177.6
3- 1	2.100	2.100	1.858	3177.6	0.253	3177.6
3- 2	2.200	2.200	1.930	3177.6	0.281	3177.6

3.7.2 Normal Condition

1) Calculation Case1 : Normal Condition

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.200	2.200	2.200	2.200
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	131.072	0.000	117.714	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	230.7		206.9	
	Top Slab Inside	Aq2	mm^2	296.6		266.0	
	Bottom Slab Inside	Aq3	mm^2	296.6		266.0	
	Bottom Slab Outside	Aq4	mm^2	230.7		206.9	
Neutral Axis		X	m	0.214	----	0.214	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.31	----	0.27	----
		σs	N/mm^2	24.05	----	21.60	----
		σs'	N/mm^2	-1.59	----	-1.43	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	703.1	----	630.6	----
		inp	mm^2	3177.6	----	3177.6	----

Calculation Case1: Normal Condition

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.100	2.100	2.100	2.100
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	121.868	0.000	121.868	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	221.6		221.6	
	Top Slab Inside	Aq2	mm^2	284.9		284.9	
	Bottom Slab Inside	Aq3	mm^2	284.9		284.9	
	Bottom Slab Outside	Aq4	mm^2	221.6		221.6	
Neutral Axis		X	m	0.213	----	0.213	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.31	----	0.31	----
		σs	N/mm^2	23.11	----	23.11	----
		σs'	N/mm^2	-1.60	----	-1.60	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	675.3	----	675.3	----
		inp	mm^2	3177.6	----	3177.6	----

Calculation Case1: Normal Condition

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.100	2.100	2.100	2.100
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	163.543	0.000	163.543	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	298.5		298.5	
	Top Slab Inside	Aq2	mm^2	383.8		383.8	
	Bottom Slab Inside	Aq3	mm^2	383.8		383.8	
	Bottom Slab Outside	Aq4	mm^2	298.5		298.5	
Neutral Axis		X	m	0.213	----	0.213	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.41	----	0.41	----
		σs	N/mm^2	31.02	----	31.02	----
		σs'	N/mm^2	-2.15	----	-2.15	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	909.8	----	909.8	----
		inp	mm^2	3177.6	----	3177.6	----

Calculation Case1: Normal Condition

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.100	2.100	2.100	2.100
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	111.291	0.000	47.155	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	202.1		84.9	
	Top Slab Inside	Aq2	mm^2	259.9		109.2	
	Bottom Slab Inside	Aq3	mm^2	259.9		109.2	
	Bottom Slab Outside	Aq4	mm^2	202.1		84.9	
Neutral Axis		X	m	0.213	----	0.213	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.28	----	0.12	----
		σs	N/mm^2	21.11	----	8.94	----
		σs'	N/mm^2	-1.46	----	-0.62	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	616.0	----	258.7	----
		inp	mm^2	3177.6	----	3177.6	----

Calculation Case1: Normal Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.200	2.200	2.200	2.200
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	375.480	-266.839	-266.839	375.480
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	672.6	474.9	474.9	672.6
	Top Slab Inside	Aq2	mm^2	864.7	610.5	610.5	864.7
	Bottom Slab Inside	Aq3	mm^2	864.7	610.5	610.5	864.7
	Bottom Slab Outside	Aq4	mm^2	672.6	474.9	474.9	672.6
Neutral Axis		X	m	0.214	0.215	0.215	0.214
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.88	0.62	0.62	0.88
		σs	N/mm^2	68.91	49.01	49.01	68.91
		σs'	N/mm^2	-4.57	-2.59	-2.59	-4.57
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	2049.7	1447.2	1447.2	2049.7
		inp	mm^2	3177.6	3177.6	3177.6	3177.6

3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.200	2.200	2.200	2.200
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	129.770	0.000	126.521	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	171.3		167.0	
	Top Slab Inside	Aq2	mm^2	220.3		214.7	
	Bottom Slab Inside	Aq3	mm^2	220.3		214.7	
	Bottom Slab Outside	Aq4	mm^2	171.3		167.0	
Neutral Axis		X	m	0.214	----	0.214	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.30	----	0.30	----
		σs	N/mm^2	23.82	----	23.22	----
		σs'	N/mm^2	-1.58	----	-1.54	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	522.1	----	508.9	----
		inp	mm^2	3177.6	----	3177.6	----

Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.100	2.100	2.100	2.100
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	126.521	0.000	126.521	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	172.6		172.6	
	Top Slab Inside	Aq2	mm^2	221.9		221.9	
	Bottom Slab Inside	Aq3	mm^2	221.9		221.9	
	Bottom Slab Outside	Aq4	mm^2	172.6		172.6	
Neutral Axis		X	m	0.213	----	0.213	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.32	----	0.32	----
		σs	N/mm^2	24.00	----	24.00	----
		σs'	N/mm^2	-1.66	----	-1.66	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	526.1	----	526.1	----
		inp	mm^2	3177.6	----	3177.6	----

Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.100	2.100	2.100	2.100
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	163.543	0.000	163.543	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	223.8		223.8	
	Top Slab Inside	Aq2	mm^2	287.8		287.8	
	Bottom Slab Inside	Aq3	mm^2	287.8		287.8	
	Bottom Slab Outside	Aq4	mm^2	223.8		223.8	
Neutral Axis		X	m	0.213	----	0.213	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.41	----	0.41	----
		σs	N/mm^2	31.02	----	31.02	----
		σs'	N/mm^2	-2.15	----	-2.15	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	682.2	----	682.2	----
		inp	mm^2	3177.6	----	3177.6	----

Calculation Case1: Seismic Condition　　Land Side→River Side

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.100	2.100	2.100	2.100
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	400.578	0.000	398.033	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	556.1		552.5	
	Top Slab Inside	Aq2	mm^2	715.0		710.3	
	Bottom Slab Inside	Aq3	mm^2	715.0		710.3	
	Bottom Slab Outside	Aq4	mm^2	556.1		552.5	
Neutral Axis		X	m	0.213	----	0.213	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	1.01	----	1.01	----
		σs	N/mm^2	75.97	----	75.49	----
		σs'	N/mm^2	-5.26	----	-5.23	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	1694.8	----	1683.8	----
		inp	mm^2	3177.6	----	3177.6	----

Calculation Case1: Seismic Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.200	2.200	2.200	2.200
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	398.033	0.000	248.212	270.812
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	534.2		330.5	361.1
	Top Slab Inside	Aq2	mm^2	686.9		424.9	464.2
	Bottom Slab Inside	Aq3	mm^2	686.9		424.9	464.2
	Bottom Slab Outside	Aq4	mm^2	534.2		330.5	361.1
Neutral Axis		X	m	0.214	----	0.214	0.214
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.93	----	0.58	0.63
		σs	N/mm^2	73.05	----	45.55	49.70
		σs'	N/mm^2	-4.84	----	-3.02	-3.29
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		
		req	mm^2	1628.2	----	1007.2	1100.4
		inp	mm^2	3177.6	----	3177.6	3177.6

2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.200	2.200	2.200	2.200
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	120.329	0.000	120.329	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	158.7		158.7	
	Top Slab Inside	Aq2	mm^2	204.1		204.1	
	Bottom Slab Inside	Aq3	mm^2	204.1		204.1	
	Bottom Slab Outside	Aq4	mm^2	158.7		158.7	
Neutral Axis		X	m	0.214	----	0.214	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.28	----	0.28	----
		σs	N/mm^2	22.08	----	22.08	----
		σs'	N/mm^2	-1.46	----	-1.46	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	483.7	----	483.7	----
		inp	mm^2	3177.6	----	3177.6	----

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.100	2.100	2.100	2.100
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	120.081	0.000	120.081	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	163.7		163.7	
	Top Slab Inside	Aq2	mm^2	210.5		210.5	
	Bottom Slab Inside	Aq3	mm^2	210.5		210.5	
	Bottom Slab Outside	Aq4	mm^2	163.7		163.7	
Neutral Axis		X	m	0.213	----	0.213	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.30	----	0.30	----
		σs	N/mm^2	22.77	----	22.77	----
		σs'	N/mm^2	-1.58	----	-1.58	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	499.0	----	499.0	----
		inp	mm^2	3177.6	----	3177.6	----

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.100	2.100	2.100	2.100
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	163.543	0.000	163.543	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	223.8		223.8	
	Top Slab Inside	Aq2	mm^2	287.8		287.8	
	Bottom Slab Inside	Aq3	mm^2	287.8		287.8	
	Bottom Slab Outside	Aq4	mm^2	223.8		223.8	
Neutral Axis		X	m	0.213	----	0.213	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.41	----	0.41	----
		σs	N/mm^2	31.02	----	31.02	----
		σs'	N/mm^2	-2.15	----	-2.15	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	682.2	----	682.2	----
		inp	mm^2	3177.6	----	3177.6	----

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.100	2.100	2.100	2.100
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	489.646	0.000	489.646	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	682.5		682.5	
	Top Slab Inside	Aq2	mm^2	877.5		877.5	
	Bottom Slab Inside	Aq3	mm^2	877.5		877.5	
	Bottom Slab Outside	Aq4	mm^2	682.5		682.5	
Neutral Axis		X	m	0.213	----	0.213	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	1.24	----	1.24	----
		σs	N/mm^2	92.87	----	92.87	----
		σs'	N/mm^2	-6.43	----	-6.43	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	2079.9	----	2079.9	----
		inp	mm^2	3177.6	----	3177.6	----

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.200	2.200	2.200	2.200
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	489.646	0.000	409.860	268.880
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7	90.0 D16- 7
	Inside of Top Slab	d2 As2	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9	90.0 D16- 9
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7	115.0 D16- 7
Total Area of Rebar		As	mm^2	6355.2	6355.2	6355.2	6355.2
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	659.9		550.4	358.5
	Top Slab Inside	Aq2	mm^2	848.4		707.7	460.9
	Bottom Slab Inside	Aq3	mm^2	848.4		707.7	460.9
	Bottom Slab Outside	Aq4	mm^2	659.9		550.4	358.5
Neutral Axis		X	m	0.214	----	0.214	0.214
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	1.14	----	0.96	0.63
		σs	N/mm^2	89.86	----	75.22	49.35
		σs'	N/mm^2	-5.96	----	-4.99	-3.27
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		
		req	mm^2	2011.1	----	1677.5	1092.4
		inp	mm^2	3177.6	----	3177.6	3177.6

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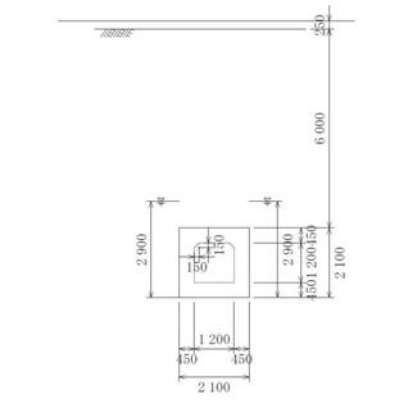
2.2.2.5 SLUICEWAY TYPE H

(2) BOX - TRANSVERSE

1 Calculation of Box Culvert in Transverse Direction

1.1 Design Condition

1.1.1 Dimension



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil(Wet)	γt	kN/m³	19.00
Soil(Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Outside of Top Slab	Diameter	Pitch	Area (mm²)	Inside of Top Slab	Diameter	Pitch	Area (mm²)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
	—	——			—	——	
Right Corner	D16	247	804.0	Right Corner	D16	250	794.4

Outside of Sidewall	Diameter	Pitch	Area (mm²)	Inside of Sidewall	Diameter	Pitch	Area (mm²)
Left Sidewall	D16	250	794.4	Left Sidewall	D13	250	506.8
	—	——			—	——	
Right Sidewall	D16	250	794.4	Right Sidewall	D13	250	506.8
	—	——			—	——	

Outside of Top Slab	Diameter	Pitch	Area (mm²)	Inside of Top Slab	Diameter	Pitch	Area (mm²)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
	—	——			—	——	
Right Corner	D16	250	794.4	Right Corner	D16	250	794.4

■Cover

Location		Cover(mm)	Location		Cover(mm)
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Midwall		90.0	———		——

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Top Slab	100	0.0
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Load

■Surcharge

	(kN/m²)
Surcharge	10.000
Snow Load	0.000

■Dead Load (Water Level)

Case	External Water Level(m)	Internal Water Level(m)
1	2.900	0.000

External Water Level: Height from Bottom Surface of Bottom Slab
Internal Water Level: Height from Top Surface of Bottom Slab

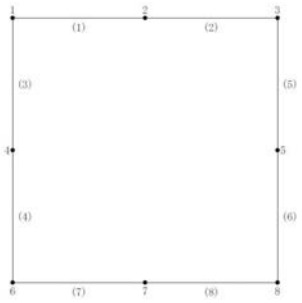
■Live Load

Intensity of Distribution Load Qw(kN/m²)	10.000

1.2 Cross-section Calculation

1.2.1 Model

1) Frame Dimension



2) Coordinate

No	X(m)	Y(m)
1	0.000	1.650
2	0.825	1.650
3	1.650	1.650
4	0.000	0.825
5	1.650	0.825
6	0.000	0.000
7	0.825	0.000
8	1.650	0.000

3) Member Material and Sectional Characteristics

Member	Number	Point Number		Area (m²)	Geometric Moment of Inertia (m⁴)	Young Modules (kN/m²)
		i Edge	j Edge			
Left Side of Top Slab	1	1	2	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Top Slab	2	2	3	4.500000E-001	7.593750E-003	2.310000E+007
Upper Side of Left Side Wall	3	1	4	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Left Side Wall	4	4	6	4.500000E-001	7.593750E-003	2.310000E+007
Upper side of Right Wall	5	3	5	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Right Wall	6	5	8	4.500000E-001	7.593750E-003	2.310000E+007
Left Side of Bottom Slap	7	6	7	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slap	8	7	8	4.500000E-001	7.593750E-003	2.310000E+007

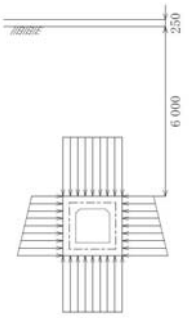
4) Supporting Point

Point	Horizontal (kN/m)	Vertical (kN/m)	Rotate (kN.m/rad)
9	-1	-1	0
13	0	-1	0

Note) -1 : Fixed, 0 : Free

1.2.2 Load

1) Dead Load (case-1) [RWL]



Weight of Box Culvert

(1) Top Slab
w = 0.450 × 24.00 = 10.80 (kN/m²)

(2) Left Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

(3) Right Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level) = 1.000 × 0.250 × 22.60 = 5.65 (kN/m²)
Embankment (Above Water Level) =1.000 × 5.200 × 18.00 = 93.60 (kN/m²)

Σwd = 114.45 (kN/m²)

(2) Surcharge Load at Road
Surcharge = 10.000 (kN/m²)
Snow Load= 0.00 (kN/m²)

Σqd = 10.000 (kN/m²)

(3) Load Acting on Top Slab
Uniformly Distributed Load
w = 114.45 + 10.00 = 124.45 (kN/m²)

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

pi = Ko×(qd + Yo×γa + Zu×γ + (Zo - Zu)×γ') + (Zo - Zu)×γw

Ko : Coefficient of Earth Pressure at Rest = 0.500
Zo:Depth of Calculation Point from Embankment Top(m)

(1)Left Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	6.000	66.15
p_2	Center of Top Slab	6.225	69.39
p_3	Center of Bottom Slab	7.875	93.15
p_4	Bottom Surface of Bottom Slab	8.100	96.39

(2)Right Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	6.000	66.15
p_2	Center of Top Slab	6.225	69.39
p_3	Center of Bottom Slab	7.875	93.15
p_4	Bottom Surface of Bottom Slab	8.100	96.39

Uplift and Buoyancy

This Act on Bottom Slab Upward

$$U = 2.900 \times 2.100 \times 9.80 = 59.68 \ (kN/m)$$

$$w = \frac{-59.68}{2.100} = -28.42 \ (kN/m^2)$$

Summary of Acting Forces

Item			V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/
Weight of Body		Top Slab	23.22		1.050		24.38
		Left Side Wall	12.96		0.225		2.92
		Right Side Wall	12.96		1.875		24.30
Surcharge		Distribution Load	261.35		1.050		274.41
Earth Pressure and Water Pressure	Left Side Wall	Distribution		170.66		0.985	168.08
	Right Side Wall	Distribution		-170.66		0.985	-168.08
Uplift/Buoyancy			-59.68		1.050		-62.67
Total			250.80				263.34

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 1.050 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$Me = \Sigma V \times e = 0.00 \ (kN \cdot m/m)$$

$$q1 = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 119.43 \ (kN/m^2)$$

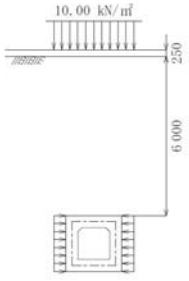
$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 119.43 \ (kN/m^2)$$

$$q1' = q1 + \frac{qr - q1}{B} \times \frac{T}{2} = 119.43 \ (kN/m^2)$$

$$qr' = qr + \frac{q1 - qr}{B} \times \frac{T}{2} = 119.43 \ (kN/m^2)$$

Thus, T : Thickness of Side Wall
q1 : Subgrade Reaction Intensity on Left Edge
qr : Subgrade Reaction Intensity on Right Edge
q1': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (Case-1)



Live Load Intensity on Road Surface qL= 10.000 (kN/m²)

Load

(1)Vertical Load Effecting Top Slab
wl = qL= 10.00 (kN/m²)

(2)Horizontal Load Acting on Left Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

(3)Horizontal Load Effecting on Right Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

Summary of Acting Force

		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Top Slab	Distribution	21.00		1.050		22.05
Left Side Wall	Distribution		10.50		1.050	11.03
Right Side Wall	Distribution		-10.50		1.050	-11.03
Total		21.00				22.05

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 1.050 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$ql = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$ql' = ql + \frac{qr - ql}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

$$qr' = qr + \frac{ql - qr}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

Thus、T : Thickness of Side Wall

ql : Subgrade Reaction Intensity on Left Edge

qr : Subgrade Reaction Intensity on Right Edge

ql': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

Dead Load + Live Load

Load Number	Beginning Member Number	End Member Number	Load Intensity at i Edge	Load Intensity at j Edge	Distance from i Edge (m)	Distance from j Edge (m)	Load Width (m)
14	1	2	-10.80	-10.80	0.000	0.000	1.650
14	3	4	-10.80	-10.80	0.225	0.225	1.200
14	5	6	-10.80	-10.80	0.225	0.225	1.200
14	1	2	-124.45	-124.45	0.000	0.000	1.650
13	3	4	69.39	93.15	0.000	0.000	1.650
13	5	6	-69.39	-93.15	0.000	0.000	1.650
14	7	8	28.42	28.42	0.000	0.000	1.650
14	1	2	-10.00	-10.00	0.000	0.000	1.650
13	3	4	5.00	5.00	0.000	0.000	1.650
13	5	6	-5.00	-5.00	0.000	0.000	1.650
14	7	8	129.43	129.43	0.000	0.000	1.650

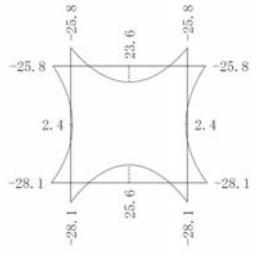
Load Number

13:MemberDistribution Load(X Direction)

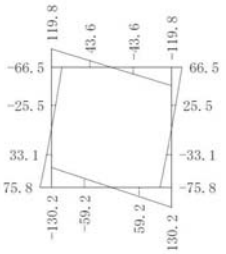
14:MemberDistribution Load(Y Direction)

1.2.4 Calculation Results of Frame Analysis

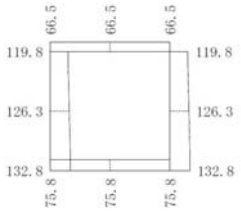
Bending Moment



Shear Force



Axial Force



1.2.5 Stress Intensity Calculation

■Bending Stress Intensity

Top Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-25.842	23.589	-25.842
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	540.0	0.0	540.0
	Internal	mm^2	0.0	491.8	0.0
Re-Bar	External	mm^2	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 247 D—@—— 804.0
	Internal	mm^2	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
Neutral Axis	X	m	0.065	0.065	0.065
Stress Intensity	σc	N/mm^2	2.35	2.15	2.34
	σs	N/mm^2	96.15	87.77	95.02
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	720.0	655.8	720.0
	inp	mm^2	794.4	794.4	804.0
Case	——	——	Dead-1+Live-1	Dead-1+Liva-1	Dead-1+Liev-1

※Axial force is not considered.

Left Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-25.842	2.380	-28.113
Axial Force	N	kN	119.831	126.311	132.791
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	34.1	0.0	29.5
	Internal	mm^2	0.0	0.0	0.0
Re-Bar Arrangement	External	mm^2	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
	Internal	mm^2	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8
Neutral Axis	X	m	0.155	1.062	0.159
Stress Intensity	σc	N/mm^2	1.75	0.35	1.89
	σs	N/mm^2	20.78	0.00	21.56
	σs'	N/mm^2	0.00	-2.10	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	45.5	0.0	39.4
	inp	mm^2	794.4	506.8	794.4
Case	——	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Right Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-25.842	2.380	-28.113
Axial Force	N	kN	119.831	126.311	132.791
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	34.1	0.0	29.5
	Internal	mm^2	0.0	0.0	0.0
Re-Bar	External	mm^2	D16 @ 247 D—@—— 804.0	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
	Internal	mm^2	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8
Neutral Axis	X	m	0.156	1.062	0.159
Stress Intensity	σc	N/mm^2	1.75	0.35	1.89
	σs	N/mm^2	20.62	0.00	21.56
	σs'	N/mm^2	0.00	-2.10	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	45.5	0.0	39.4
	inp	mm^2	804.0	506.8	794.4
Case	——	———	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Bottom Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-28.113	25.606	-28.113
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	115.0	115.0	115.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	635.1	0.0	635.1
	Internal	mm^2	0.0	534.9	0.0
Re-Bar	External	mm^2	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
	Internal	mm^2	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
Neutral Axis	X	m	0.062	0.065	0.062
Stress Intensity	σc	N/mm^2	2.87	2.33	2.87
	σs	N/mm^2	112.65	95.27	112.65
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2	670.0		670.0
	req	mm^2	846.8	713.2	846.8
	inp	mm^2	794.4	794.4	794.4
Case	——	———	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

■Shear Stress Intensity

$$\tau m = \frac{S}{b \times d} \leqq \tau a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm2)	τa (N/mm2)	Cases	L (m)
Top Slap	Left τ Point	43.575	360.0	0.121	0.457	Dead-1+Live-1	0.525
	Right τ Point	-43.575	360.0	0.121	0.457	Dead-1+Live-1	0.525
Left Side Wall	Upper τ Point	-25.489	360.0	0.071	0.457	Dead-1+Live-1	0.525
	Lower τ Point	33.105	360.0	0.092	0.495	Dead-1+Live-1	0.450
Right Side Wall	Upper τ Point	25.489	360.0	0.071	0.457	Dead-1+Live-1	0.525
	Lower τ Point	-33.105	360.0	0.092	0.495	Dead-1+Live-1	0.450
Bottom Slab	Left τ Point	-59.194	360.0	0.164	0.478	Dead-1+Live-1	0.450
	Right τ Point	59.194	360.0	0.164	0.478	Dead-1+Live-1	0.450

Note) τ Point: Check point for shear stress intensity
L: Distance from grid point of corner

2.2.2.5 SLUICEWAY TYPE H

(3) BREAST WALL - LAND SIDE

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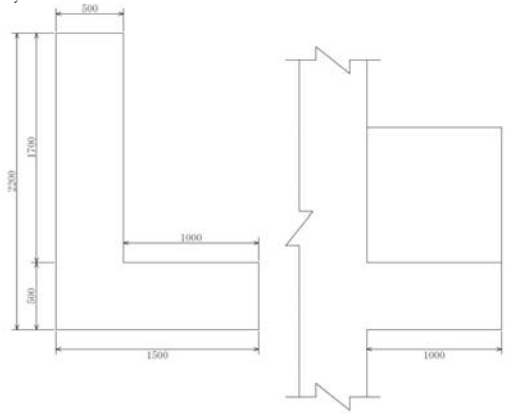
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1 Calculation of Land Side Breast Wall

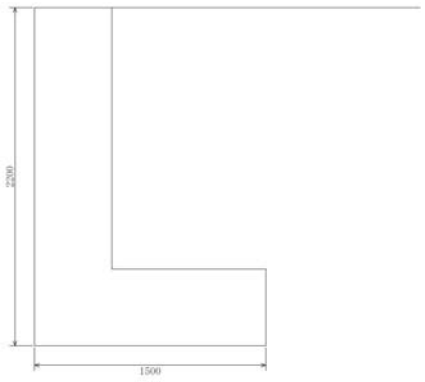
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil(Wet)	γt	kN/m³	19.00
Soil(Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material			SD295	
Normal			Sidewall	Harsh Environment
			Bottom Slab	Harsh Environment
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φres	°	30
Peak Angle of Internal Friction	φpeak	°	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm^2/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D19	250	1146.0
	Bottom Face	115.0	D19	250	1146.0

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

1.1.4 Loads

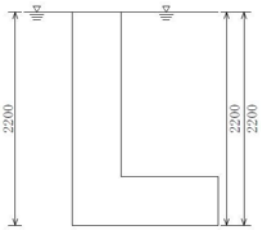
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

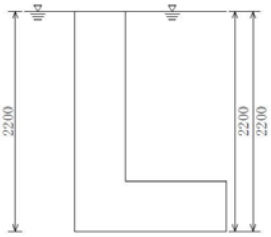
	(m)
Toe	2.200
Heel	2.200



1-2) Seismic Condition Number of Cases [1]

<Case 1>

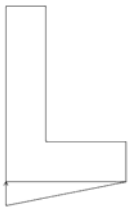
	(m)
Toe	2.200
Heel	2.200
Direction	Back → Front



2) Subgrade Reaction

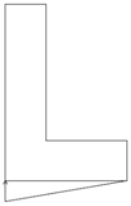
2-1) Normal <Case 1>

	(kN/m^2),(m)
Toe	190.75
Heel	0.00
Load Width	1.500



2-2) Seismic <Case 1>

	(kN/m^2),(m)
Toe	165.75
Heel	0.00
Load Width	1.500



3) Surcharge Load

Normal	kN/m^2	10.00
Seismic	kN/m^2	5.00

4) Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W = 0.000 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load $q0' = (W+q0 \cdot wq0)/B$

= (0.000+ 10.00× 1.700)/ 1.700

= 10.000 (kN/m^2)

Earth Pressure at the Top

$p1 = q0' \cdot Ko$ = 10.000 × 0.500 = 5.000 (kN/m^2)

Earth Pressure at Water Level

$p2 = Ko \cdot \gamma_t \cdot h1+p1$

= 0.500× 19.00× 0.000+ 5.000

= 5.000 (kN/m^2)

Earth Pressure at Junction

$p3 = Ko \cdot (\gamma_{sat}-\gamma_w) \cdot h2+p2$

= 0.500×(20.00- 9.80)× 1.700+ 5.000

= 13.670 (kN/m^2)

Design Earth Pressure

P = p3

=13.670 (kN/m^2)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

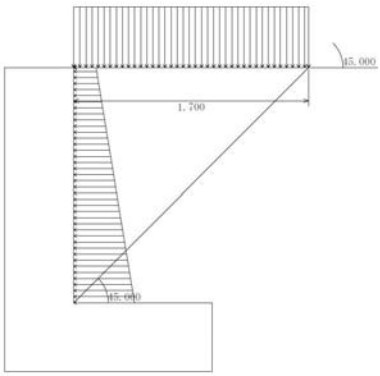
q_0 : Surcharge (kN/m^2)

w_{qo} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 1.700× 9.80 = 16.660 (kN/m^2)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

(2) **Seismic Condition-1**

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.500 × 24.00 × 0.20 = 2.400

Thus、

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	0.302	(m)
Embankment Height under the water level surface	h2	=	1.700	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_t	=	19.00	(kN/m^3)
Unit Weight of Soil (Dry)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	2.141	(m)
Width of Converted Load	B	=	2.141	(m)
Internal Friction Angle of Soil	ϕ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh	=	0.349	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}$ (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}$ (kh')	=	19.247	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(\ 30.00^\circ\ +\ 0.00^\circ\ +\ 0.00^\circ\ -\ 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ\ +\ 0.00^\circ\ +\ 0.00^\circ\ -\ 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ\ +\ 0.00^\circ\ +\ 11.310^\circ\ )\times\sin(\ 30.00^\circ\ +\ 0.00^\circ\ )}{\cos(\ 0.00^\circ\ -\ 0.00^\circ\ )\times\sin(\ 30.00^\circ\ -\ 0.00^\circ\ -\ 11.310^\circ\ )}}$$

$\cot(\xi_{EA}-\alpha)$ = 0.85094

Thus,

$$\cot(\xi_{EA}-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604(^\circ)$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(\ 30.00^\circ\ +\ 0.00^\circ\ +\ 0.00^\circ\ -\ 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ\ +\ 0.00^\circ\ +\ 0.00^\circ\ -\ 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ\ +\ 0.00^\circ\ +\ 19.247^\circ\ )\times\sin(\ 30.00^\circ\ +\ 0.00^\circ\ )}{\cos(\ 0.00^\circ\ -\ 0.00^\circ\ )\times\sin(\ 30.00^\circ\ -\ 0.00^\circ\ -\ 19.247^\circ\ )}}$$

$\cot(\xi_{EA}'-\alpha)$ = 1.25932

Thus,

$$\cot(\xi_{EA}'-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA}')} = 1.25932$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{1.25932}\right) = 38.452(^\circ)$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ\ -\ 11.310^\circ\ -\ 0.00^\circ\ )}{\cos(\ 11.310^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ\ +\ 11.310^\circ\ +\ 0.00^\circ\ )}$$
$$\times\frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ\ +\ 0.00^\circ\ )\times\sin(\ 30.00^\circ\ -\ 0.00^\circ\ -\ 11.310^\circ\ )}{\cos(\ 0.00^\circ\ +\ 11.310^\circ\ +\ 0.00^\circ\ )\times\cos(\ 0.00^\circ\ -\ 0.00^\circ\ )}}\right]^2}$$

= 0.4733

In case φ-α-θ_o< 0, sin(φ-α-θ_o) = 0.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ\ -\ 19.247^\circ\ -\ 0.00^\circ\ )}{\cos(\ 19.247^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ\ +\ 19.247^\circ\ +\ 0.00^\circ\ )}$$
$$\times\frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ\ +\ 0.00^\circ\ )\times\sin(\ 30.00^\circ\ -\ 0.00^\circ\ -\ 19.247^\circ\ )}{\cos(\ 0.00^\circ\ +\ 19.247^\circ\ +\ 0.00^\circ\ )\times\cos(\ 0.00^\circ\ -\ 0.00^\circ\ )}}\right]^2}$$

= 0.6268

In case φ-α-θ'$_o$< 0, sin(φ-α-θ'$_o$) = 0.

Weight of Embankment W W = 0.000 (kN/m)

Converted Load q0'

$$q0' = (W + q0\cdot wq0) / B$$
$$= (\ 0.000+\ 5.00\times\ 2.141) /\ 2.141$$
$$= 5.000\ (kN/m^2)$$

Earth Pressure at the Top

P1 = q0'・K_{EA} = 5.000× 0.4733 = 2.366 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 0.000+ 2.366

= 2.366 (kN/m^2)

Earth Pressure at Junction

P3 = K_{EA}・(γ_{sat}-γ_w)・h2 + p2

= 0.6268×(20.00- 9.80)× 1.700+ 2.366

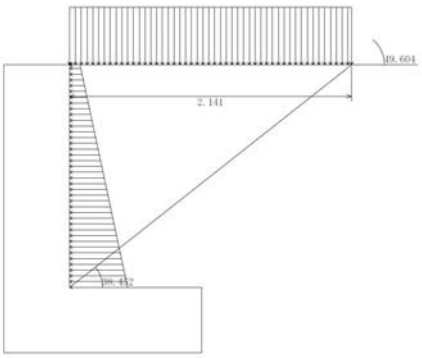
= 13.236 (kN/m^2)

Design Earth Pressure

P_{HE} = P3 ・cosδ= 13.236×cos(0.00°)

= 13.236 (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

Ph = hh・γ_w= 1.700× 9.80 = 16.660 (kN/m^2)

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

1.2.2 **Summary of Cross-sectional Internal Forces**

1) Normal Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Water Pressure	16.66	1.000	8.33
Earth Pressure	13.67	1.000	6.84
Σ	30.33	----	15.17
Bending Moment M (kN.m/m) Σ(P・l2/2) = 15.17			
Shear Force S (kN/m) Σ(P・l) = 30.33			

2) Seismic Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Inertia force	2.40	1.000	1.20
Water Pressure	16.66	1.000	8.33
Earth Pressure	13.24	1.000	6.62
Σ	32.30	----	16.15
Bending Moment M (kN.m/m) Σ(P・l2/2) = 16.15			
Shear Force S (kN/m) Σ(P・l) = 32.30			

1.2.3 **Stress Calculation**

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Front	mm²	D16 - 4.00 =794.4
	Back	mm²	D16 - 4.00 =794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	15.17
Re-bar	d1 As1	mm mm²	410.0 794.4
Required Area of Re-bar	Back	mm²	273.7
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm²	1.12
	σs	N/mm²	49.36
Allowable Value	σca	N/mm²	8.20
	σsa	N/mm²	140.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	364.9
	inp	mm²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	16.15
Re-bar	d1 As1	mm mm²	410.0 794.4
Required Area of Re-bar	Back	mm²	218.5
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm²	1.20
	σs	N/mm²	52.56
Allowable Value	σca	N/mm²	12.30
	σsa	N/mm²	186.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	291.4
	inp	mm²	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	30.33
Re-bar	d1 As1	mm mm²	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.074
Allowable Value	τa	N/mm²	0.360
	τa2	N/mm²	1.600

■Seismic Condition-1

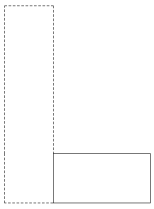
	Symbol	Unit	Junction
Shear Force	S	kN	32.30
Re-bar	d1 As1	mm mm²	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.079
Allowable Value	τa	N/mm²	0.540
	τa2	N/mm²	2.400

1.3 **Calculation of Heel Slab**

1.3.1 **Load**

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γc= 0.500 × 24.00 = 12.000

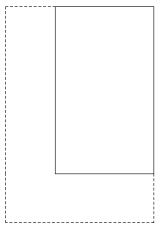
Thus,

Sw : Weight of Body (kN/m2)

h :Height of Bottom Slab (m)

γc : Unit Weight of Concrete (kN/m³)

1-2) Weight of the Embankment



Pw1 = (h1・γt+ h2・γsat) = 0.000× 19.00 + 1.700× 20.00 = 34.000

Pw2 = (h1・γt+ h2・γsat) = 0.000× 19.00 + 1.700× 20.00 = 34.000

Thus、

Pw1 :Wight of Embankment at basis (kN/m2)

Pw2 : Weight of Embankment at edge (kN/m2)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γt : Wet Unit Weight of Soil (kN/m³)

γsat : Unit Weight of Soil underwater (kN/m³)

1-3) Subgrade Reaction Force

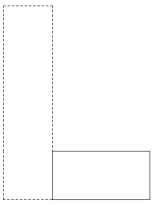
	Intensity of subgrade reaction (kN/m^2)
Base	127.17
Edge	0.00

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.200× 9.80	21.560
Edge	2.200× 9.80	21.560

(2)) Seismic Condition-1

2-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

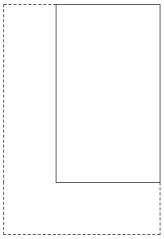
Thus、

Sw : Weight of Wall (kN/m2)

H :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.700× 20.00 = 34.000

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.700× 20.00 = 34.000

Thus、

Pw1 :Wight of Embankment at basis (kN/m2)

Pw2 : Weight of Embankment at edge (kN/m2)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	110.50
Edge	0.00

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.200× 9.80	21.560
Edge	2.200× 9.80	21.560

1.3.2 Summary of Cross-Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-34.00	1.000	-17.00
Uplift Force	21.56	1.000	10.78
Intensity of Subgrade Reaction	127.17	1.000	63.58
Surcharge	-10.00	1.000	-5.00
Σ	92.73	----	46.36
Bending Moment M(kN.m/m) Σ(P・l2/2) = 46.36			
Shear Force S(kN/m) Σ(P・l) = 92.73			

1-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-34.00	1.000	-17.00
Uplift Force	21.56	1.000	10.78
Intensity of Subgrade Reaction	0.00	1.000	0.00
Surcharge	-10.00	1.000	-5.00
Σ	-34.44	----	-17.22
Bending Moment M (kN.m/m) Σ(P・l2/2) = -17.22			
Shear Force S (kN/m) Σ(P・l) = -34.44			

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-34.00	1.000	-17.00
Uplift Force	21.56	1.000	10.78
Intensity of Subgrade Reaction	110.50	1.000	55.25
Surcharge	-5.00	1.000	-2.50
Σ	81.06	----	40.53
Bending Moment M (kN.m/m) Σ(P・l2/2) = 40.53			
Shear Force S (kN/m) Σ(P・l) = 81.06			

2-2) Edge

	P(kN/m^2)	l(m)	P・l^2/2(kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-34.00	1.000	-17.00
Uplift Force	21.56	1.000	10.78
Intensity of Subgrade Reaction	0.00	1.000	0.00
Surcharge	-5.00	1.000	-2.50
Σ	-29.44	----	-14.72
Bending Moment M(kN.m/m) Σ(P・l^2/2) = -14.72			
Shear Force S(kN/m) Σ(P・l) = -29.44			

1.3.3 Stress Intensity Calculation

(1) Flexural Stress Intensity

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Upper	mm^2	D19 - 4.00 =1146.0
	Lower	mm^2	D19 - 4.00 =1146.0

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	46.36	-17.22
Re-bar	d1 As1	mm mm^2	385.0 1146.0	90.0 1146.0
Required Area of Re-bar	Upper	mm^2		311.4
	Lower	mm^2	917.3	
Neutral Axis	X	m	0.079	0.082
Stress Intensity	σc	N/mm^2	3.26	1.09
	σs	N/mm^2	112.84	39.28
Allowable Value	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
Minimum of Re-bar Area	min	mm^2	770.0	
	req	mm^2	1223.0	415.3
	inp	mm^2	1146.0	1146.0

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	40.53	-14.72
Re-bar	d1 As1	mm mm^2	385.0 1146.0	90.0 1146.0
Required Area of Re-bar	Upper	mm^2		198.9
	Lower	mm^2	596.5	
Neutral Axis	X	m	0.079	0.082
Stress Intensity	σc	N/mm^2	2.85	0.94
	σs	N/mm^2	98.64	33.57
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	795.4	265.3
	inp	mm^2	1146.0	1146.0

(2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	92.73	-34.44
Re-bar	d1 As1	mm mm^2	385.0 1146.0	90.0 1146.0
Effective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.241	0.084
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	81.06	-29.44
Re-bar	d1 As1	mm mm^2	385.0 1146.0	90.0 1146.0
ffective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.211	0.072
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400

2.2.2.5 SLUICEWAY TYPE H

(4) BREAST WALL - RIVER SIDE

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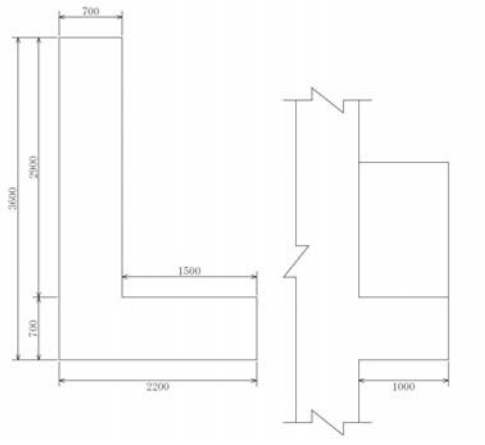
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1 Calculation of River Side Breast Wall

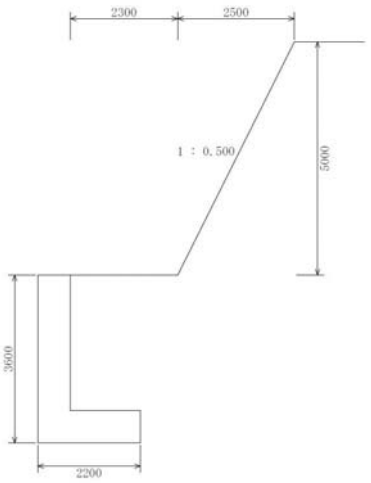
1.1 Design Condition

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 **Material and Design Parameters**

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil(Wet)	γt	kN/m³	19.00
Soil(Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/℃	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φres	°	30
Peak Angle of Internal Friction	φpeak	°	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 **Reinforcement Arrangement**

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm²/m)
all	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D19	250	1146.0
	Bottom Face	115.0	D19	250	1146.0

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 **Loads**

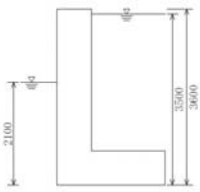
■Basic Load

1)Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

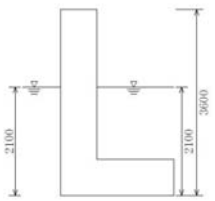
	(m)
Toe	2.100
Heel	3.500



1-2) Seismic Condition Number of Cases [1]

<Case 1>

	(m)
Toe	2.100
Heel	2.100
Direction	Back → Front



2)Subgrade Reaction

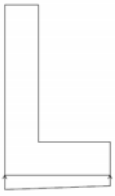
2-1) Normal <Case 1>

	(kN/m²),(m)
Toe	156.12
Heel	70.37
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m²),(m)
Toe	105.99
Heel	79.15
Load Width	0.000



3)Surcharge Load

Normal	kN/m²	10.00
Seismic	kN/m²	5.00

4)Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W =175.750 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (175.750+ 10.00× 3.100)/ 2.900

= 71.293 (kN/m^2)

Earth Pressure at the Top

p1 = q0'・Ko = 71.293× 0.500 = 35.647 (kN/m^2)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 1.100+ 35.647

= 36.597 (kN/m^2)

Earth Pressure at Bottom Surface of Base

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500×(20.00- 9.80)× 2.800+ 36.597

= 50.877 (kN/m^2)

Design Earth Pressure

P = p3

=50.877 (kN/m^2)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

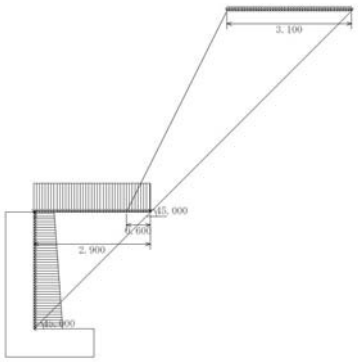
q_0 : Surcharge (kN/m^2)

w_{qo} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Loads Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 2.800× 9.80 = 27.440 (kN/m^2)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

(2) Seismic Condition-1

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.700 × 24.00 × 0.20 = 3.360

Thus、

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	1.500	(m)
Embankment Height under the water level surface	h2	=	1.400	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_t	=	19.00	(kN/m^3)
Unit Weight of Soil (Dry)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	2.095	(m)
Width of Converted Load	B	=	2.640	(m)
Internal Friction Angle of Soil	ϕ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh'	=	0.257	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}(kh)$	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}(kh')$	=	14.436	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$\cot(\xi_{EA}-\alpha) = 0.85094$

Thus,

$$\cot(\xi_{EA}-0.00^\circ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604(^\circ)$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 14.436^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 14.436^\circ)}}$$

$\cot(\xi_{EA}'-\alpha) = 0.97385$

Thus,

$$\cot(\xi_{EA}'-0.00^\circ) = \frac{1}{\tan(\xi_{EA}')} = 0.97385$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{0.97385}\right) = 45.759(^\circ)$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$= 0.4733$

In case $\varphi-\alpha-\theta_o < 0$, $\sin(\varphi-\alpha-\theta_o) = 0$.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 14.436^\circ - 0.00^\circ)}{\cos(14.436^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 14.436^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 14.436^\circ)}{\cos(0.00^\circ + 14.436^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$= 0.5255$

In case $\varphi-\alpha-\theta_o' < 0$, $\sin(\varphi-\alpha-\theta_o') = 0$.

Weight of Embankment	W	W = 115.630 (kN/m)
Converted Load	q0'	q0' = (W + q0・wq0) / B = (115.630+ 5.00× 2.095) / 2.640 = 47.770 (kN/m^2)

Earth Pressure at the Top

P1 = q0'・K_{EA} = 47.770× 0.4733 = 22.608 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 1.500+ 22.608

= 36.096 (kN/m^2)

Earth Pressure at Junction

P3 = K_{EA}・(γ_{sa} – γ_w)・h2 + p2

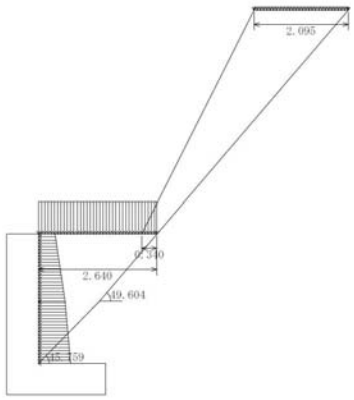
= 0.5255×(20.00- 9.80)× 1.400+ 36.096

= 43.600 (kN/m^2)

Design Earth Pressure

P_{HE} = P3 ・cosδ= 43.600×cos(0.00°)
= 43.600 (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

Ph = hh・γ_w= 1.400× 9.80 = 13.720 (kN/m^2)

Thus、

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P(kN/m^2)	l(m)	P・l^2/2(kN.m/m)
Water Pressure	27.44	1.000	13.72
Earth Pressure	50.88	1.000	25.44
Σ	78.32	----	39.16
Bending Moment M(kN.m/m) Σ(P・l^2/2) = 39.16			
Shear Force S(kN/m) Σ(P・l) = 78.32			

2) Seismic Condition-1

	P(kN/m^2)	l(m)	P・l^2/2(kN.m/m)
Inertia force	3.36	1.000	1.68
Water Pressure	13.72	1.000	6.86
Earth Pressure	43.60	1.000	21.80
Σ	60.68	----	30.34
Bending Moment M(kN.m/m) Σ(P・l^2/2) = 30.34			
Shear Force S(kN/m) Σ(P・l) = 60.68			

1.2.3 Stress Calculation

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Front	mm^2	D16 - 4.00 = 794.4
	Back	mm^2	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	39.16
Re-bar	dl As1	mm mm^2	610.0 794.4
Required Area of Re-bar	Back	mm^2	476.3
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm^2	1.56
	σs	N/mm^2	84.82
Allowable Value	σca	N/mm^2	8.20
	σsa	N/mm^2	140.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	635.0
	inp	mm^2	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	30.34
Re-bar	dl As1	mm mm^2	610.0 794.4
Required Area of Re-bar	Back	mm^2	275.3
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm^2	1.21
	σs	N/mm^2	65.72
Allowable Value	σca	N/mm^2	12.30
	σsa	N/mm^2	186.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	367.1
	inp	mm^2	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	78.32
Re-bar	dl As1	mm mm^2	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.128
Allowable Value	τa	N/mm^2	0.360
	τa2	N/mm^2	1.600

■Seismic Condition-1

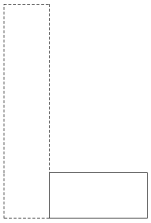
	Symbol	Unit	Junction
Shear Force	S	kN	60.68
Re-bar	dl As1	mm mm^2	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.099
Allowable Value	τa	N/mm^2	0.540
	τa2	N/mm^2	2.400

1.3 Calculation of Bottom Slab

1.3.1 Load

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

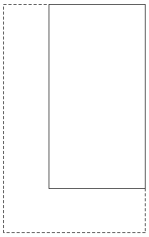
Thus,

Sw : Weight of Body (kN/m^2)

h :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

1-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.100× 19.00 + 2.800× 20.00 = 57.900

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.100× 19.00 + 2.800× 20.00 = 57.900

Thus、

Pw1 :Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

1-3) Subgrade Reaction Force

	Intensity of subgrade reaction (kN/m^2)
Base	128.84
Edge	70.37

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.545× 9.80	24.945
Edge	3.500× 9.80	34.300

(2) **Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

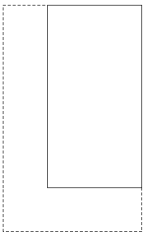
Thus、

Sw : Weight of Body (kN/m^2)

H :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 1.500× 19.00 + 1.400× 20.00 = 56.500

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 1.500× 19.00 + 1.400× 20.00 = 56.500

Thus、

Pw1 :Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	97.45
Edge	79.15

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.100× 9.80	20.580
Edge	2.100× 9.80	20.580

1.3.2 Summary of Cross Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-57.90	1.000	-28.95
Uplift Force	24.95	1.000	12.47
Intensity of Subgrade Reaction	128.84	1.000	64.42
Σ	79.08	----	39.54
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 39.54		
Shear Force S (kN/m)	Σ(P・l) = 79.08		

1-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-57.90	1.000	-28.95
Uplift Force	34.30	1.000	17.15
Intensity of Subgrade Reaction	70.37	1.000	35.19
Σ	29.97	----	14.99
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 14.99		
Shear Force S (kN/m)	Σ(P・l) = 29.97		

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-56.50	1.000	-28.25
Uplift Force	20.58	1.000	10.29
Intensity of Subgrade Reaction	97.45	1.000	48.73
Σ	44.73	----	22.37
Bending Moment M (kN.m/m)	Σ(P・l^2/2) = 22.37		
Shear Force S (kN/m)	Σ(P・l) = 44.73		

2-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-56.50	1.000	-28.25
Uplift Force	20.58	1.000	10.29
Intensity of Subgrade Reaction	79.15	1.000	39.58
Σ	26.43	----	13.22
Bending Moment M (kN.m/m) Σ (P・l²/2) = 13.22			
Shear Force S (kN/m) Σ (P・l) = 26.43			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Upper	mm²	D19 - 4.00 = 1146.0
	Lower	mm²	D19 - 4.00 = 1146.0

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	39.54	14.99
Re-bar	d1 As1	mm mm²	585.0 1146.0	585.0 1146.0
Required Area of Re-bar	Lower		502.3	187.5
Neutral Axis	X	m	0.100	0.100
Stress Intensity	σc	N/mm²	1.43	0.54
	σs	N/mm²	62.55	23.71
Allowable Value	σca	N/mm²	8.20	8.20
	σsa	N/mm²	140.00	140.00
Minimum of Re-bar Area	min	mm²		
	req	mm²	669.8	250.1
	inp	mm²	1146.0	1146.0

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	22.37	13.22
Re-bar	d1 As1	mm mm²	585.0 1146.0	585.0 1146.0
Required Area of Re-bar	Lower		211.0	123.9
Neutral Axis	X	m	0.100	0.100
Stress Intensity	σc	N/mm²	0.81	0.48
	σs	N/mm²	35.38	20.91
Allowable Value	σca	N/mm²	12.30	12.30
	σsa	N/mm²	186.00	186.00
Minimum of Re-bar Area	min	mm²		
	req	mm²	281.3	165.2
	inp	mm²	1146.0	1146.0

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	79.08	29.97
Re-bar	d1 As1	mm mm²	585.0 1146.0	585.0 1146.0
Effective Height	d	mm	585.0	585.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.135	0.051
Allowable Value	τa	N/mm²	0.360	0.360
	τa2	N/mm²	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	44.73	26.43
Re-bar	d1 As1	mm mm²	585.0 1146.0	585.0 1146.0
Effective Height	d	mm	585.0	585.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.076	0.045
Allowable Value	τa	N/mm²	0.540	0.540
	τa2	N/mm²	2.400	2.400

2.2.2.6 SLUICEWAY TYPE I

(1) BOX - LONGITUDINAL

Structural Calculation of Sluiceway Type-J

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1 Design Condition

1.1 Design Condition

1.1.1 Basic Condition

1) Culvert Shape:Rectanglar

2) Culvert Type: Double Holes

3) Allowable Displacement

Residual Settlement		: 300.0 (mm)
Residual Settlement for Rigid Support		: 50.0 (mm)
Relative Displacement	Base Width	: 1.0 (%)
		± : 50.0 (mm)

4) Type of Joint : Flexible Joint

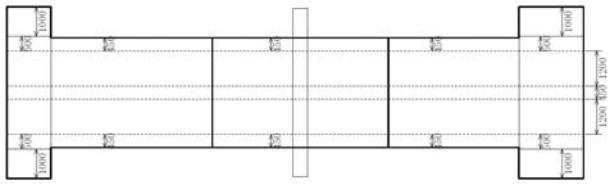
5) Allowable Opening : 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

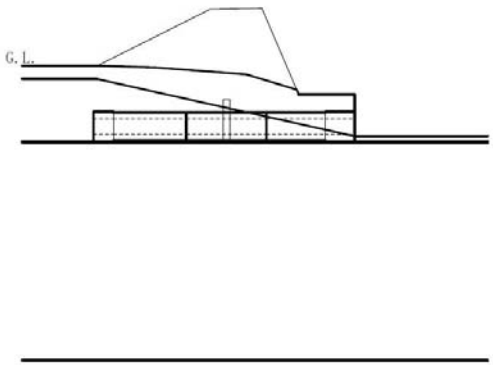
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Leeve Cross-section



1.2 Shape of Culvert Body

1.2.1 Span and Block

1) Spans

Number of Spans : 3
Total Length of Spans : 19.651 (m)

Span No	Name of Span	Length of Span (m)	Number of Blocks
1	Land Side	7.000	2
2	Center	6.000	1
3	River Side	6.651	2

2) Blocks

Span/ Block	Length of Block (m)	Depth for Subgrade Reaction(m)
1- 1	1.500	17.550
1- 2	5.500	12.600
2- 1	6.000	11.250
3- 1	4.451	11.250
3- 2	2.200	17.550

1.2.2 Sectional Dimension

1) Dimension (Block)

Span/ Block	Left Inside Width X2 (m)	Right Inside Width X4(m)	Inside Height Y2 (m)
1- 1	1.200	1.200	1.200
1- 2	1.200	1.200	1.200
2- 1	1.200	1.200	1.200
3- 1	1.200	1.200	1.200
3- 2	1.200	1.200	1.200

Span/ Block	Left side wall width X1(m)	中側壁幅 X3(m)	Right side wall width X5(m)	Thickness of Top Slab Y1(m)	Thickness of Bottom Slab Y3(m)	Height of Overhang Y4(m)	Left Overhang B1(m)	Right Overhang B3(m)
1- 1	0.500	0.450	0.500	0.500	0.500	0.500	1.000	1.000
1- 2	0.450	0.450	0.450	0.450	0.450	0.000	0.000	0.000
2- 1	0.450	0.450	0.450	0.450	0.450	0.000	0.000	0.000
3- 1	0.450	0.450	0.450	0.450	0.450	0.450	0.000	0.000
3- 2	0.500	0.450	0.500	0.500	0.500	0.700	1.000	1.000

Span/ Block	Left Side Wall Upper Haunch		Left Side Wall Lower Haunch		Right Side Wall Upper Haunch		Right Side Wall Lower Haunch	
	W1(m)	H1(m)	W2(m)	H2(m)	W3(m)	H3(m)	W4(m)	H4(m)
1- 1	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000
1- 2	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000
2- 1	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000
3- 1	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000
3- 2	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000

Span/ Block	Center Wall Left Upper Haunch		Center Wall Left Lower Haunch		Center Wall Right Lower Haunch		Center Wall Right Lower Haunch	
	W5(m)	H5(m)	W6(m)	H6(m)	W7(m)	H7(m)	W8(m)	H8(m)
1- 1	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000
1- 2	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000
2- 1	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000
3- 1	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000
3- 2	0.150	0.150	0.000	0.000	0.150	0.150	0.000	0.000

1.3 Reinforcement

Main Re-bar

Span No	Block No	Flange		Reinforcing Bar				
		Portion	b (mm)	t (mm)	Outside		Inside	
					Diameter@Pitch (Number)	Cover (mm)	Diameter@Pitch (Number)	Cover (mm)
1	1	Top Slab	3850.0	500.0	D16@250(15)	90.0	D16@250(17)	90.0
		Bottom Slab	3850.0	500.0	D16@250(15)	115.0	D16@250(17)	90.0
	2	Top Slab	3750.0	450.0	D16@250(15)	90.0	D16@250(17)	90.0
		Bottom Slab	3750.0	450.0	D16@250(15)	115.0	D16@250(17)	90.0
2	1	Top Slab	3750.0	450.0	D16@250(15)	90.0	D16@250(17)	90.0
		Bottom Slab	3750.0	450.0	D16@250(15)	115.0	D16@250(17)	90.0
3	1	Top Slab	3750.0	450.0	D16@250(15)	90.0	D16@250(17)	90.0
		Bottom Slab	3750.0	450.0	D16@250(15)	115.0	D16@250(17)	90.0
	2	Top Slab	3850.0	500.0	D16@250(15)	90.0	D16@250(17)	90.0
		Bottom Slab	3850.0	500.0	D16@250(15)	115.0	D16@250(17)	90.0

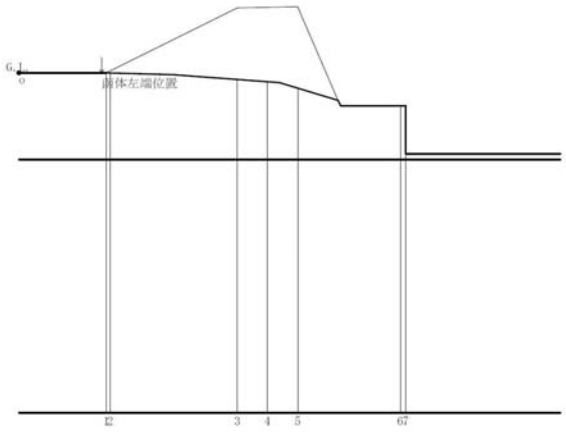
2 Settlement and Lateral Displacement

2.1 Immediate Settlement

2.1.1 Settlemet Calculation Points

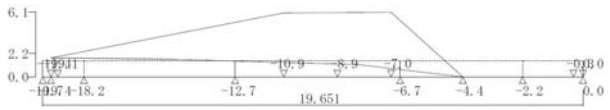
Settlemet Calculation Points

No	Calculation Point (m)	Name
1	-19.351	Box end (land side)
2	-19.101	Breast wall (land side)
3	-10.883	Levee end (land side)
4	-8.933	Levee center
5	-6.983	Levee end (river side)
6	-0.350	Breast wall (river side)
7	0.000	Box end (river side)



2.1.2 Summery of Immediate Settlement

No	Calculation Point (m)	Name	Immediate Settlement (mm)
1	-19.351	Box end (land side)	2.7
2	-19.101	Breast wall (land side)	3.1
3	-10.883	Levee end (land side)	17.2
4	-8.933	Levee center	17.9
5	-6.983	Levee end (river side)	14.7
6	-0.350	Breast wall (river side)	0.0
7	0.000	Box end (river side)	0.0



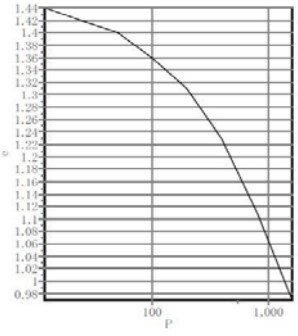


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

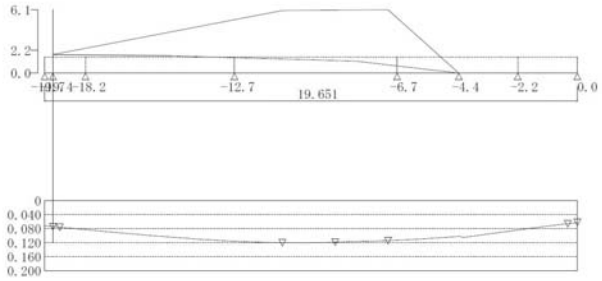
No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/m³)	Unit Weight (Saturated) (kN/m³)	Pre-Consolidation Stress q0 (kN/m²)	Elastic Modulus Es (kN/m²)
1	Adobe BL	Sand	5.662	17.500	18.500	0.0	6900.0
2	Dc4	Clay	22.112	17.500	18.500	0.0	15700.0

No	Concolidation Pressure P(kN/m²)	Void Ratio e
1	12.0000	1.4400
2	25.0000	1.4200
3	50.0000	1.4000
4	100.0000	1.3600
5	200.0000	1.3100
6	400.0000	1.2300
7	800.0000	1.1100
8	1600.0000	0.9700



2.2.2 Summery of Consolidation Settlement

No	Calculation Point (m)	Name	Consolidation Settlement (mm)
1	-19.351	Box end (land side)	74.3
2	-19.101	Breast wall (land side)	76.1
3	-10.883	Levee end (land side)	120.4
4	-8.933	Levee center	119.0
5	-6.983	Levee end (river side)	114.5
6	-0.350	Breast wall (river side)	66.0
7	0.000	Box end (river side)	62.8

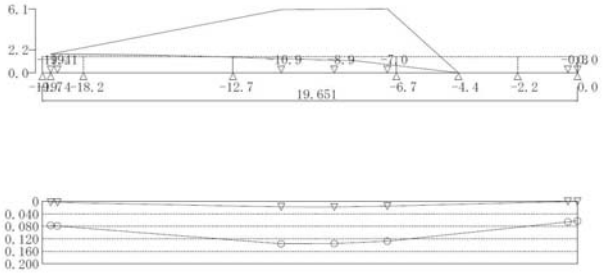


2.3 Residual Settlement

2.3.1 Sumarry of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vaue	Judge
1	-19.351	Box end (land side)	2.7	73.8	0.0	76.5	300.000	OK
2	-19.101	Breast wall (land side)	3.1	75.6	0.0	78.7	300.000	OK
3	-10.883	Levee end (land side)	17.2	118.6	0.0	135.8	300.000	OK
4	-8.933	Levee center	17.9	117.1	0.0	135.1	300.000	OK
5	-6.983	Levee end (river side)	14.7	112.7	0.0	127.4	300.000	OK
6	-0.350	Breast wall (river side)	0.0	65.7	0.0	65.7	300.000	OK
7	0.000	Box end (river side)	0.0	62.6	0.0	62.6	300.000	OK

The maximum of residual settlement is above 50.0(mm), herence the foundation is taken as flexible



▽ : Immediate Settlement
○ : Residual Settlement

3 Calculation of Box Culvert regarding Longitudal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B}\cdot\frac{d^4w}{dx^4}+k_v(w-w_g)=q \text{ (Swag)}$$

$$\frac{EA}{U}\cdot\frac{d^2u}{dx^2}+k_s(u-u_g)=p \text{ (Displacement in axial direction of Box Culvert)}$$

Thus,

w : Displacement of Box Culvert (Swag : cm {m})
w_g : Displacement of the Ground (Residual Settlement: cm {m})
k_v : Modulus of Sub grade Reaction in Vertical Direction (kgf/cm^3) {kN/m^3}
B : Width of Box Culvert (cm) {m}
EI : Rigidity of Box Culvert (kgf･cm^2) {kN･m^2}
q : Vertical External Force (kgf/cm^2) {kN/m^2}
u : Displacement on axial direction of Box Culvert (cm) {m}
u_g : Displacement of Ground (Lateral Displacement ; cm {m})
k_s : Modulus of Lateral Shear Sub grade Reaction (kgf/cm^3) {kN/m^3}
U : Circumference of Box Culvert (cm) {m}
EA : Rigidity of Box Culvert in axial direction (kgf) {kN}
p : Axial External Force (kgf/cm^2){kN/m^2}

3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{om}=\frac{\log\frac{(B+2h_n\cdot\tan\theta)\cdot L}{(L+2h_n\cdot\tan\theta)\cdot B}}{\Sigma\frac{1}{E_i}\log\frac{(B+2h_n\cdot\tan\theta)(L+2h_{n-1}\cdot\tan\theta)}{(L+2h_n\cdot\tan\theta)(B+2h_{n-1}\cdot\tan\theta)}}$$

In case of B=L

$$E_{om}=\frac{-\frac{1}{B+2h_n\cdot\tan\theta}+\frac{1}{B}}{\Sigma\frac{1}{E_i}\left(-\frac{1}{B+2h_n\cdot\tan\theta}+\frac{1}{B+2h_{n-1}\cdot\tan\theta}\right)}$$

Thus

Eom ; Converted Modulus of Deformation
B ; Loading Width = Width of Culvert
L ; Loading Length = Length of a span
hn ; Depth for Calculation
hn ; Depth from the ground to the bottom Elevation of Each Layer（m）
Ei ; Converted Modulus of Deformation of Each Layer(kN/m^2)
θ ; Angle of Load Dispersion（θ=30°）

Span1-Block1 Land Side

B			5.850 (m)
L			7.000 (m)
hn			17.550 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	17.550	17.550	62800.0
Total	17.550		
Eom			62800.0 (kN/m^2)

※Layer Thickness and Depths are the values based on subgrade Surface.

Span1-Block2　Land Side

B			3.750 (m)
L			7.000 (m)
hn			12.600 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	12.600	12.600	62800.0
Total	12.600		
Eom			62800.0 (kN/m²)

※Layer Thickness and Depths are values Calculated from the subgrade

Span2-Block1　Center

B			3.750 (m)
L			6.000 (m)
hn			11.250 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	11.250	11.250	62800.0
Total	11.250		
Eom			62800.0 (kN/m²)

※Layer and Depth is the values from the subgrade

Span3-Block1　River Side

B			3.750 (m)
L			6.651 (m)
hn			11.250 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	11.250	11.250	62800.0
Total	11.250		
Eom			62800.0 (kN/m²)

※Layer and Depth is the values from the subgrade

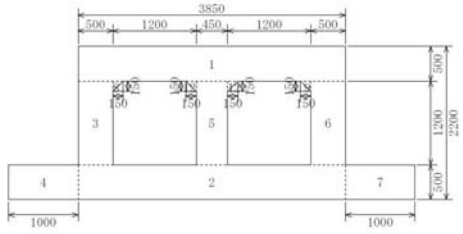
Span3-Block2　River Side

B			5.850 (m)
L			6.651 (m)
hn			17.550 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m²)
1	17.550	17.550	62800.0
Total	17.550		
Eom			62800.0 (kN/m²)

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

Span1-Block1　Land Side

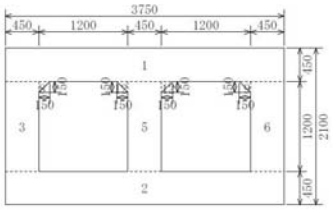


Position	Ai (m²)	Yi (m)	Ai･Yi (m³)	Ai･Yi² (m³)	Ioi (m⁴)
1	1.925	1.950	3.7538	7.3198	0.04010
2	1.925	0.250	0.4813	0.1203	0.04010
3	0.600	1.100	0.6600	0.7260	0.07200
4	0.500	0.250	0.1250	0.0313	0.01042
5	0.540	1.100	0.5940	0.6534	0.06480
6	0.600	1.100	0.6600	0.7260	0.07200
7	0.500	0.250	0.1250	0.0313	0.01042
8	0.011	1.650	0.0186	0.0306	0.00001
9	0.011	1.650	0.0186	0.0306	0.00001
12	0.023	1.650	0.0371	0.0613	0.00003
Total	6.635		6.4733	9.7305	0.30990

Yg = Σ(Ai･Yi)/ΣAi =　6.4733 / 6.635 = 0.9756 (m)

I　= Σ(Ai･Yi2)+ΣIoi - Yg2･ΣAi = 9.7305 + 0.30990 - 0.9518･6.635= 3.72499 (m⁴)

Span1-Block2　Land Side

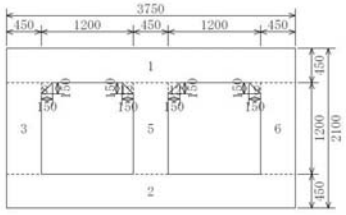


Position	Ai (m²)	Yi (m)	Ai･Yi (m³)	Ai･Yi² (m³)	Ioi (m⁴)
1	1.688	1.875	3.1641	5.9326	0.02848
2	1.688	0.225	0.3797	0.0854	0.02848
3	0.540	1.050	0.5670	0.5954	0.06480
5	0.540	1.050	0.5670	0.5954	0.06480
6	0.540	1.050	0.5670	0.5954	0.06480
8	0.011	1.600	0.0180	0.0288	0.00001
9	0.011	1.600	0.0180	0.0288	0.00001
12	0.023	1.600	0.0360	0.0576	0.00003
Total	5.040		5.3168	7.9193	0.25141

Yg = Σ(Ai・Yi)/ΣAi =5.3168 / 5.040 = 1.0549 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 7.9193 + 0.25141 - 1.1128・5.040= 2.56201 (m⁴)

Span2-Block1　Center

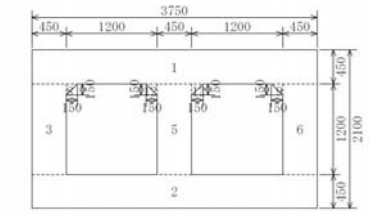


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	1.688	1.875	3.1641	5.9326	0.02848
2	1.688	0.225	0.3797	0.0854	0.02848
3	0.540	1.050	0.5670	0.5954	0.06480
5	0.540	1.050	0.5670	0.5954	0.06480
6	0.540	1.050	0.5670	0.5954	0.06480
8	0.011	1.600	0.0180	0.0288	0.00001
9	0.011	1.600	0.0180	0.0288	0.00001
12	0.023	1.600	0.0360	0.0576	0.00003
Total	5.040		5.3168	7.9193	0.25141

Yg = Σ(Ai・Yi)/ΣAi = 5.3168 / 5.040 = 1.0549 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 7.9193 + 0.25141 - 1.1128・5.040= 2.56201 (m^4)

Span3-Block1　River Side

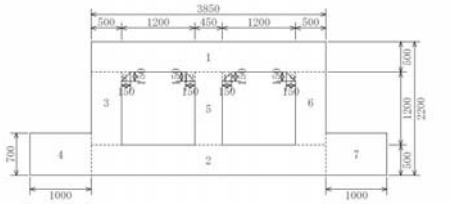


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	1.688	1.875	3.1641	5.9326	0.02848
2	1.688	0.225	0.3797	0.0854	0.02848
3	0.540	1.050	0.5670	0.5954	0.06480
5	0.540	1.050	0.5670	0.5954	0.06480
6	0.540	1.050	0.5670	0.5954	0.06480
8	0.011	1.600	0.0180	0.0288	0.00001
9	0.011	1.600	0.0180	0.0288	0.00001
12	0.023	1.600	0.0360	0.0576	0.00003
Total	5.040		5.3168	7.9193	0.25141

Yg = Σ(Ai・Yi)/ΣAi = 5.3168 / 5.040 = 1.0549 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg²・ΣAi = 7.9193 + 0.25141 - 1.1128・5.040= 2.56201 (m^4)

Span3-Block2　River Side



Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	1.925	1.950	3.7538	7.3198	0.04010
2	1.925	0.250	0.4813	0.1203	0.04010
3	0.600	1.100	0.6600	0.7260	0.07200
4	0.700	0.350	0.2450	0.0857	0.02858
5	0.540	1.100	0.5940	0.6534	0.06480
6	0.600	1.100	0.6600	0.7260	0.07200
7	0.700	0.350	0.2450	0.0857	0.02858
8	0.011	1.650	0.0186	0.0306	0.00001
9	0.011	1.650	0.0186	0.0306	0.00001
12	0.023	1.650	0.0371	0.0613	0.00003
Total	7.035		6.7133	9.8395	0.34623

Yg = Σ(Ai・Yi)/ΣAi = 6.7133 / 7.035 = 0.9543 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg²・ΣAi = 9.8395 + 0.34623 - 0.9106・7.035= 3.77955 (m^4)

3.2.3 Table of Modulus of Subgarade Reaction

Coefficient of Lateral Shear Reaction of Soil

$k_s = \lambda \cdot k_v$

Thus、

ks　: Coefficient of Lateral Shear Reaction of Soil (kN/m2)

λ　; Ratio between the coefficient of Lateral Shear Reaction of Soil and Vertical Sub grade Reaction(=0.333)

kv　: Coefficient of Vertical Sub grade Reaction

3.2.4 List of Modulus of Subgrade Reaction

Calculated Value

Normal Condition

Span Block	Position (m)	B (m)	k_v (kN/m^3)	k_s (kN/m^3)	$k_v \cdot B$ (kN/m^2)	$k_s \cdot B$ (kN/m^2)
1-1	-19.651～-18.151	5.850	21090.4	7023.1	123378.6	41085.1
1-2	-18.151～-12.651	3.750	24917.6	8297.6	93440.9	31115.8
2-1	-12.651～ -6.651	3.750	26400.4	8791.3	99001.6	32967.5
3-1	-6.651～ -2.200	3.750	25400.1	8458.2	95250.3	31718.3
3-2	-2.200～ 0.000	5.850	21498.8	7159.1	125767.7	41880.6

Seismic Condition

Span Block	Position (m)	B (m)	k_v (kN/m^3)	k_s (kN/m^3)	$k_v \cdot B$ (kN/m^2)	$k_s \cdot B$ (kN/m^2)
1-1	-19.651～-18.151	5.850	42180.7	14046.2	246757.3	82170.2
1-2	-18.151～-12.651	3.750	49835.2	16595.1	186881.8	62231.7
2-1	-12.651～ -6.651	3.750	52800.8	17582.7	198003.2	65935.1
3-1	-6.651～ -2.200	3.750	50800.2	16916.4	190500.6	63436.7
3-2	-2.200～ 0.000	5.850	42997.5	14318.2	251535.4	83761.3

Used Value

Normal Condition

Span Block	Position (m)	$k_v \cdot B$ (kN/m^2)	$k_s \cdot B$ (kN/m^2)
1-1	-19.651～-18.151	123378.6	41085.1
1-2	-18.151～-12.651	93440.9	31115.8
2-1	-12.651～ -6.651	99001.6	32967.5
3-1	-6.651～ -2.200	95250.3	31718.3
3-2	-2.200～ 0.000	125767.7	41880.6

Seismic Condition

Span Block	Position (m)	Reduction Ratio DE	$k_v \cdot B$ (kN/m^2)	$k_s \cdot B$ (kN/m^2)
1-1	-19.651～-18.151	1.000	246757.3	82170.2
1-2	-18.151～-12.651	1.000	186881.8	62231.7
2-1	-12.651～ -6.651	1.000	198003.2	65935.1
3-1	-6.651～ -2.200	1.000	190500.6	63436.7
3-2	-2.200～ 0.000	1.000	251535.4	83761.3

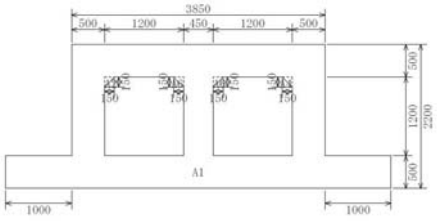
3.3 Load

3.3.1 Dead Load (Body Weight)

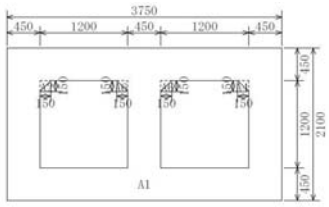
1) Weight of Main Body

W = (A1 + A2 + A3+ A4 + A5 + A6 + A7)･γc (kN/m)
A1: Cross Sectional Area (Excluding Haunch) (m^2)
A2: Area of Left Side Wall Upper Haunch (m^2)
A3: Area of Left Side Wall Lower Haunch (m^2)
A4: Area of Right Side Wall Upper Haunch (m^2)
A5: Area of Right Side Wall Lower Haunch (m^2)
A6: Area of Center Wall Upper Haunch (m^2)
A7: Area of Center Wall Lower Haunch (m^2)
γc: Unit Weight(Concrete) (kN/m^3)

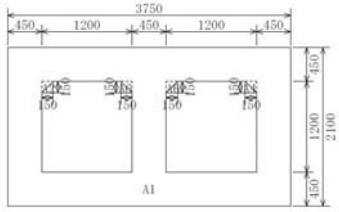
Span No. 1-1 Land Side
W = (6.590 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000)･ 24.000
= 159.240 (kN/m)



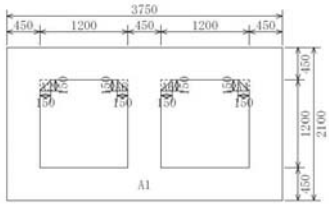
Span No. 1-2 Land Side
W = (4.995 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000)･ 24.000
= 120.960 (kN/m)



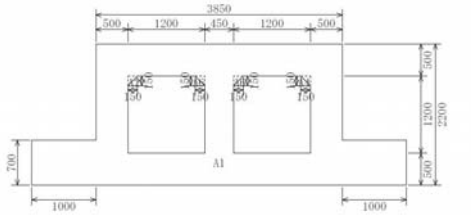
Span No. 2-1 Center
W = (4.995 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000)･ 24.000
= 120.960 (kN/m)



Span No. 3-1 River Side
W = (4.995 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000)･ 24.000
= 120.960 (kN/m)



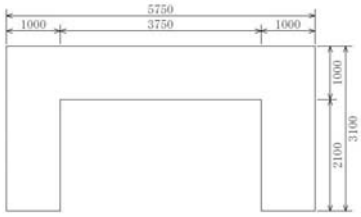
Span No. 3-2 River Side
W = (6.990 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000)･ 24.000
= 168.840 (kN/m)



2) Seepage Cutoff Wall Body Weight

A1 = X1･L2
A2 = L1･Y1･2
W = (A1 + A2)･B･γc (kN)
X1: Top Slab Width (m)
Y1: Left Wall Height (m)
Y2: Right Wall Height (m)
L1: Side Wall Width (m)
L2: Top Slab Height (m)
A1: Top Slab Area (m^2)
A2: Left Wall Area (m^2)
A3: Right Wall Area (m^2)
B: Thickness (m)
γc: Unit Weight (Concrete) (kN/m^3)

SpanNo.2-SpanDistance from Base Point (2.000)
A1 = 5.750･ 1.000
= 5.750 (m^2)
A2 = 1.000･ 2.100
= 2.100 (m^2)
A3 = 1.000･ 2.100
= 2.100 (m^2)
W = (5.750 + 2.100 + 2.100)･ 0.500･ 24.00
= 119.400 (kN)



3.3.2 Ground Displacement Load (Settlement、Lateral Displacement)

1) Equivalent Load for Ground Settlement

【Normal Condition】
Span1 Name of Span: [Land Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-19.651～-19.401	5.850	123378.6	73.6	75.9	-9081.411	-9369.018
1-(2)	-19.401～-19.151	5.850	123378.6	75.9	78.2	-9369.018	-9653.366
1-(3)	-19.151～-18.651	5.850	123378.6	78.2	82.9	-9653.366	-10223.621
1-(4)	-18.651～-18.151	5.850	123378.6	82.9	87.3	-10223.621	-10768.714
2-(5)	-18.151～-17.651	3.750	93440.9	87.3	91.6	-8155.695	-8559.328
2-(6)	-17.651～-17.151	3.750	93440.9	91.6	95.8	-8559.328	-8954.739
2-(7)	-17.151～-16.651	3.750	93440.9	95.8	100.0	-8954.739	-9342.518
2-(8)	-16.651～-16.151	3.750	93440.9	100.0	104.1	-9342.518	-9723.256
2-(9)	-16.151～-15.651	3.750	93440.9	104.1	108.1	-9723.256	-10100.631
2-(10)	-15.651～-15.151	3.750	93440.9	108.1	112.3	-10100.631	-10489.488
2-(11)	-15.151～-14.651	3.750	93440.9	112.3	116.9	-10489.488	-10925.297
2-(12)	-14.651～-14.151	3.750	93440.9	116.9	120.5	-10925.297	-11259.010
2-(13)	-14.151～-13.651	3.750	93440.9	120.5	123.4	-11259.010	-11528.731
2-(14)	-13.651～-13.151	3.750	93440.9	123.4	126.6	-11528.731	-11825.739
2-(15)	-13.151～-12.651	3.750	93440.9	126.6	129.3	-11825.739	-12077.427

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(16)	-12.651～-12.151	3.750	99001.6	129.3	131.5	-12796.155	-13018.826
1-(17)	-12.151～-11.651	3.750	99001.6	131.5	133.0	-13018.826	-13165.266
1-(18)	-11.651～-11.151	3.750	99001.6	133.0	134.7	-13165.266	-13338.137
1-(19)	-11.151～-10.651	3.750	99001.6	134.7	136.7	-13338.137	-13529.664
1-(20)	-10.651～-10.151	3.750	99001.6	136.7	137.0	-13529.664	-13565.229
1-(21)	-10.151～ -9.651	3.750	99001.6	137.0	136.2	-13565.229	-13483.086
1-(22)	-9.651～ -9.151	3.750	99001.6	136.2	135.4	-13483.086	-13399.987
1-(22)	-9.151～ -8.651	3.750	99001.6	135.4	134.5	-13399.987	-13320.325
1-(23)	-8.651～ -8.151	3.750	99001.6	134.5	133.7	-13320.325	-13240.942
1-(24)	-8.151～ -7.651	3.750	99001.6	133.7	133.0	-13240.942	-13165.527
1-(25)	-7.651～ -7.151	3.750	99001.6	133.0	129.3	-13165.527	-12799.317
1-(26)	-7.151～ -6.651	3.750	99001.6	129.3	123.9	-12799.317	-12268.537

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(28)	-6.651～ -6.511	3.750	95250.3	123.9	122.7	-11803.665	-11690.169
1-(29)	-6.511～ -6.151	3.750	95250.3	122.7	119.8	-11690.169	-11407.887
1-(30)	-6.151～ -5.651	3.750	95250.3	119.8	115.4	-11407.887	-10992.109
1-(31)	-5.651～ -5.151	3.750	95250.3	115.4	112.7	-10992.109	-10733.100
1-(32)	-5.151～ -4.651	3.750	95250.3	112.7	109.0	-10733.100	-10383.895
1-(33)	-4.651～ -4.151	3.750	95250.3	109.0	107.6	-10383.895	-10247.759
1-(34)	-4.151～ -3.651	3.750	95250.3	107.6	101.1	-10247.759	-9634.540
1-(35)	-3.651～ -3.151	3.750	95250.3	101.1	95.1	-9634.540	-9057.520
1-(36)	-3.151～ -2.651	3.750	95250.3	95.1	89.2	-9057.520	-8499.849
1-(37)	-2.651～ -2.200	3.750	95250.3	89.2	83.6	-8499.849	-7963.641
2-(38)	-2.200～ -2.151	5.850	125767.7	83.6	83.1	-10515.128	-10452.613
2-(39)	-2.151～ -1.651	5.850	125767.7	83.1	78.1	-10452.613	-9821.896
2-(40)	-1.651～ -1.151	5.850	125767.7	78.1	73.2	-9821.896	-9206.455
2-(41)	-1.151～ -0.651	5.850	125767.7	73.2	68.5	-9206.455	-8610.282
2-(42)	-0.651～ -0.151	5.850	125767.7	68.5	63.9	-8610.282	-8036.117
2-(43)	-0.151～ 0.000	5.850	125767.7	63.9	62.6	-8036.117	-7867.367



2) Equivalent Load for Ground Settlement

【Seismic Condition】

Span1 Name of Span: [Land Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-19.651～-19.401	5.850	246757.3	73.6	75.9	-18162.821	-18738.036
1-(2)	-19.401～-19.151	5.850	246757.3	75.9	78.2	-18738.036	-19306.732
1-(3)	-19.151～-18.651	5.850	246757.3	78.2	82.9	-19306.732	-20447.242
1-(4)	-18.651～-18.151	5.850	246757.3	82.9	87.3	-20447.242	-21537.428
2-(5)	-18.151～-17.651	3.750	186881.8	87.3	91.6	-16311.389	-17118.656
2-(6)	-17.651～-17.151	3.750	186881.8	91.6	95.8	-17118.656	-17909.479
2-(7)	-17.151～-16.651	3.750	186881.8	95.8	100.0	-17909.479	-18685.036
2-(8)	-16.651～-16.151	3.750	186881.8	100.0	104.1	-18685.036	-19446.513
2-(9)	-16.151～-15.651	3.750	186881.8	104.1	108.1	-19446.513	-20201.263
2-(10)	-15.651～-15.151	3.750	186881.8	108.1	112.3	-20201.263	-20978.975
2-(11)	-15.151～-14.651	3.750	186881.8	112.3	116.9	-20978.975	-21850.594
2-(12)	-14.651～-14.151	3.750	186881.8	116.9	120.5	-21850.594	-22518.020
2-(13)	-14.151～-13.651	3.750	186881.8	120.5	123.4	-22518.020	-23057.462
2-(14)	-13.651～-13.151	3.750	186881.8	123.4	126.6	-23057.462	-23651.479
2-(15)	-13.151～-12.651	3.750	186881.8	126.6	129.3	-23651.479	-24154.855

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(16)	-12.651～-12.151	3.750	198003.2	129.3	131.5	-25592.309	-26037.652
1-(17)	-12.151～-11.651	3.750	198003.2	131.5	133.0	-26037.652	-26330.533
1-(18)	-11.651～-11.151	3.750	198003.2	133.0	134.7	-26330.533	-26676.274
1-(19)	-11.151～-10.651	3.750	198003.2	134.7	136.7	-26676.274	-27059.328
1-(20)	-10.651～-10.151	3.750	198003.2	136.7	137.0	-27059.328	-27130.457
1-(21)	-10.151～ -9.651	3.750	198003.2	137.0	136.2	-27130.457	-26966.171
1-(22)	-9.651～ -9.151	3.750	198003.2	136.2	135.4	-26966.171	-26799.975
1-(23)	-9.151～ -8.651	3.750	198003.2	135.4	134.5	-26799.975	-26640.651
1-(24)	-8.651～ -8.151	3.750	198003.2	134.5	133.7	-26640.651	-26481.884
1-(25)	-8.151～ -7.651	3.750	198003.2	133.7	133.0	-26481.884	-26331.054
1-(26)	-7.651～ -7.151	3.750	198003.2	133.0	129.3	-26331.054	-25598.634
1-(27)	-7.151～ -6.651	3.750	198003.2	129.3	123.9	-25598.634	-24537.074

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(28)	-6.651～ -6.511	3.750	190500.6	123.9	122.7	-23607.331	-23380.338
1-(29)	-6.511～ -6.151	3.750	190500.6	122.7	119.8	-23380.338	-22815.774
1-(30)	-6.151～ -5.651	3.750	190500.6	119.8	115.4	-22815.774	-21984.218
1-(31)	-5.651～ -5.151	3.750	190500.6	115.4	112.7	-21984.218	-21466.200
1-(32)	-5.151～ -4.651	3.750	190500.6	112.7	109.0	-21466.200	-20767.790
1-(33)	-4.651～ -4.151	3.750	190500.6	109.0	107.6	-20767.790	-20495.517
1-(34)	-4.151～ -3.651	3.750	190500.6	107.6	101.1	-20495.517	-19269.079
1-(35)	-3.651～ -3.151	3.750	190500.6	101.1	95.1	-19269.079	-18115.040
1-(36)	-3.151～ -2.651	3.750	190500.6	95.1	89.2	-18115.040	-16999.699
1-(37)	-2.651～ -2.200	3.750	190500.6	89.2	83.6	-16999.699	-15927.282
2-(38)	-2.200～ -2.151	5.850	251535.4	83.6	83.1	-21030.256	-20905.226
2-(39)	-2.151～ -1.651	5.850	251535.4	83.1	78.1	-20905.226	-19643.792
2-(40)	-1.651～ -1.151	5.850	251535.4	78.1	73.2	-19643.792	-18412.910
2-(41)	-1.151～ -0.651	5.850	251535.4	73.2	68.5	-18412.910	-17220.565
2-(42)	-0.651～ -0.151	5.850	251535.4	68.5	63.9	-17220.565	-16072.234
2-(43)	-0.151～ 0.000	5.850	251535.4	63.9	62.6	-16072.234	-15734.733



3.3.3 Point Load from Breast Walls

1) Normal Condition (Case Number: 1)

Case of Normal Condition 1

Name of Normal Load:[Gate Piers and Breast Walls (Normal) 1]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-114.34	89.47	-20.72
3	Right Breast Wall	13.140	454.50	237.79	-87.40



2) Seismic Condition (Total Number: 2)

Case of Seismic Conditon 1 [Land Side →River Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-81.23	30.03	-19.33
3	Right Breast Wall	13.140	421.78	95.31	-64.54



Case of Seimic Condition 2 [River Side→Land Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-142.89	30.03	-8.29
3	Right Breast Wall	13.140	289.66	95.31	20.77



3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body(Normal)	1.0000
2	Fixed Load Data 2	Water Weight (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Engaging Load(Normal)1	Gate Structure ・Breast Wall (Normal)1	1.0000
6	Arbitrary Load(Normal)1	Surcharge in Normal Condition	1.0000

2) Seismic Condition

1) Case 1 [Seismic Condition: Land Side→River Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Arbitrary Load(Seismic)1	Surcharge in Seismic Condition	1.0000
6	Ingaging Load(Dead Load)1	Gate Structure ・Breast Wall (Dead Load)1	1.0000
7	Ingaging Load(Seismic)1	Seismic Load :Land Side →River Side	1.0000

2) Case 2 [Seismic Condition: River Side→Land Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load(Dead Load)2	Seismic Load	1.0000
6	Ingaging Load(Dead Load)2	Gate Structure ・Breast Wall (Dead Load)2	1.0000
7	Arbitrary Load(Seismic)1	Surcharge in Seismic Condition	1.0000

3.4 Displacement between Sluiceway and Adjoining Levee

3.4.1 Normal Condition

1) Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-11.5	-12.7	77.3	73.6	3.7	50.0	○	457.599
2	0.250	-11.5	-12.7	79.3	75.9	3.4	50.0	○	416.287
3	0.500	-11.5	-12.6	81.3	78.2	3.1	50.0	○	378.235
4	1.000	-11.5	-12.3	85.3	82.9	2.4	50.0	○	300.571
5	1.500	-11.5	-12.0	89.3	87.3	2.0	37.5	○	248.070
6	2.000	-11.5	-11.8	93.3	91.6	1.7	37.5	○	157.308
7	2.500	-11.5	-11.5	97.3	95.8	1.4	37.5	○	134.960
8	3.000	-11.5	-11.2	101.3	100.0	1.3	37.5	○	120.245
9	3.500	-11.5	-11.0	105.3	104.1	1.2	37.5	○	112.571
10	4.000	-11.5	-10.7	109.3	108.1	1.2	37.5	○	108.258
11	4.500	-11.5	-10.4	113.2	112.3	1.0	37.5	○	92.464
12	5.000	-11.5	-9.6	117.2	116.9	0.3	37.5	○	29.716
13	5.500	-11.5	-8.6	121.2	120.5	0.7	37.5	○	69.064
14	6.000	-11.5	-7.6	125.2	123.4	1.8	37.5	○	172.403
15	6.500	-11.5	-6.6	129.2	126.6	2.7	37.5	○	248.455
16	7.000	-11.5	-5.6	133.2	129.3	4.0	37.5	○	369.826

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground Spring (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	1.7	-5.6	136.6	129.3	7.4	37.5	○	730.138
2	0.500	1.7	-4.6	136.4	131.5	4.9	37.5	○	483.401
3	1.000	1.7	-3.6	136.1	133.0	3.2	37.5	○	312.894
4	1.500	1.7	-2.6	135.9	134.7	1.2	37.5	○	115.956
5	2.000	1.7	-1.4	135.7	136.7	-1.0	-50.0	○	-99.639
6	2.500	1.7	0.0	135.4	137.0	-1.6	-50.0	○	-159.275
7	3.000	1.7	1.5	135.2	136.2	-1.0	-50.0	○	-101.206
8	3.500	1.7	2.9	134.9	135.4	-0.4	-50.0	○	-42.185
9	4.000	1.7	4.3	134.7	134.5	0.1	37.5	○	13.397
10	4.500	1.7	5.7	134.4	133.7	0.7	37.5	○	68.698
11	5.000	1.7	7.2	134.2	133.0	1.2	37.5	○	120.028
12	5.500	1.7	8.8	134.0	129.3	4.7	37.5	○	462.153
13	6.000	1.7	9.8	133.7	123.9	9.8	37.5	○	968.848

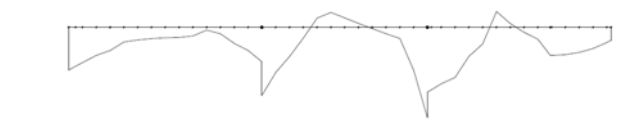
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	16.2	9.8	131.2	123.9	7.3	37.5	○	692.554
2	0.140	16.2	10.0	129.8	122.7	7.0	37.5	○	670.635
3	0.500	16.2	10.5	126.1	119.8	6.3	37.5	○	604.706
4	1.000	16.2	11.2	121.0	115.4	5.6	37.5	○	536.857
5	1.500	16.2	12.0	116.0	112.7	3.3	37.5	○	312.240
6	2.000	16.2	12.7	110.9	109.0	1.9	37.5	○	177.818
7	2.500	16.2	13.1	105.8	107.6	-1.8	-50.0	○	-169.673
8	3.000	16.2	13.0	100.7	101.1	-0.4	-50.0	○	-40.082
9	3.500	16.2	12.9	95.7	95.1	0.6	37.5	○	53.309
10	4.000	16.2	12.8	90.6	89.2	1.3	37.5	○	127.350
11	4.451	16.2	12.8	86.0	83.6	2.4	37.5	○	300.157
12	4.500	16.2	12.8	85.5	83.1	2.4	50.0	○	300.091
13	5.000	16.2	12.7	80.4	78.1	2.3	50.0	○	292.226
14	5.500	16.2	12.6	75.3	73.2	2.1	50.0	○	269.086
15	6.000	16.2	12.5	70.3	68.5	1.8	50.0	○	226.677
16	6.500	16.2	12.4	65.2	63.9	1.3	50.0	○	162.261
17	6.651	16.2	12.4	63.7	62.6	1.1	50.0	○	138.160

Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-10.7	-12.7	76.7	73.6	3.1	50.0	○	381.681
2	0.250	-10.7	-12.7	78.7	75.9	2.8	50.0	○	342.509
3	0.500	-10.7	-12.6	80.7	78.2	2.5	50.0	○	306.598
4	1.000	-10.7	-12.3	84.8	82.9	1.9	50.0	○	233.215
5	1.500	-10.7	-12.0	88.8	87.3	1.5	37.5	○	184.995
6	2.000	-10.7	-11.8	92.8	91.6	1.2	37.5	○	112.779
7	2.500	-10.7	-11.5	96.8	95.8	1.0	37.5	○	93.673
8	3.000	-10.7	-11.2	100.9	100.0	0.9	37.5	○	82.200
9	3.500	-10.7	-11.0	104.9	104.1	0.8	37.5	○	77.766
10	4.000	-10.7	-10.7	108.9	108.1	0.8	37.5	○	76.695
11	4.500	-10.7	-10.4	112.9	112.3	0.7	37.5	○	64.142
12	5.000	-10.7	-9.6	117.0	116.9	0.0	37.5	○	4.634
13	5.500	-10.7	-8.6	121.0	120.5	0.5	37.5	○	47.223
14	6.000	-10.7	-7.6	125.0	123.4	1.6	37.5	○	153.803
15	6.500	-10.7	-6.6	129.1	126.6	2.5	37.5	○	233.095
16	7.000	-10.7	-5.6	133.1	129.3	3.8	37.5	○	357.707

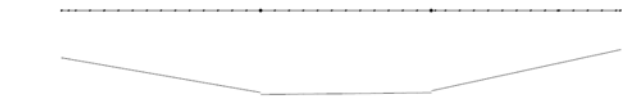
Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	1.7	-5.6	136.3	129.3	7.1	37.5	○	702.355
2	0.500	1.7	-4.6	136.1	131.5	4.6	37.5	○	455.618
3	1.000	1.7	-3.6	135.9	133.0	2.9	37.5	○	285.111
4	1.500	1.7	-2.6	135.6	134.7	0.9	37.5	○	88.173
5	2.000	1.7	-1.4	135.4	136.7	-1.3	-50.0	○	-127.422
6	2.500	1.7	0.0	135.1	137.0	-1.9	-50.0	○	-187.058
7	3.000	1.7	1.5	134.9	136.2	-1.3	-50.0	○	-128.989
8	3.500	1.7	2.9	134.6	135.4	-0.7	-50.0	○	-69.968
9	4.000	1.7	4.3	134.4	134.5	-0.1	-50.0	○	-14.386
10	4.500	1.7	5.7	134.2	133.7	0.4	37.5	○	40.915
11	5.000	1.7	7.2	133.9	133.0	0.9	37.5	○	92.245
12	5.500	1.7	8.8	133.7	129.3	4.4	37.5	○	434.370
13	6.000	1.7	9.8	133.4	123.9	9.5	37.5	○	941.065

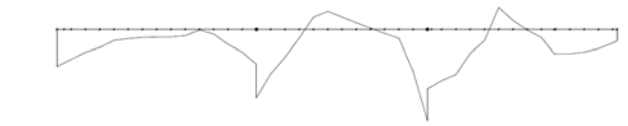
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	13.2	9.8	130.3	123.9	6.4	37.5	○	609.232
2	0.140	13.2	10.0	128.9	122.7	6.2	37.5	○	588.719
3	0.500	13.2	10.5	125.3	119.8	5.5	37.5	○	526.405
4	1.000	13.2	11.2	120.3	115.4	4.9	37.5	○	463.577
5	1.500	13.2	12.0	115.2	112.7	2.6	37.5	○	243.982
6	2.000	13.2	12.7	110.2	109.0	1.2	37.5	○	114.584
7	2.500	13.2	13.1	105.2	107.6	-2.4	-50.0	○	-227.884
8	3.000	13.2	13.0	100.2	101.1	-1.0	-50.0	○	-93.269
9	3.500	13.2	12.9	95.1	95.1	0.1	37.5	○	5.146
10	4.000	13.2	12.8	90.1	89.2	0.9	37.5	○	84.212
11	4.451	13.2	12.8	85.6	83.6	2.0	37.5	○	249.182
12	4.500	13.2	12.8	85.1	83.1	2.0	50.0	○	249.766
13	5.000	13.2	12.7	80.1	78.1	2.0	50.0	○	248.536
14	5.500	13.2	12.6	75.0	73.2	1.8	50.0	○	232.030
15	6.000	13.2	12.5	70.0	68.5	1.6	50.0	○	196.256
16	6.500	13.2	12.4	65.0	63.9	1.1	50.0	○	138.474
17	6.651	13.2	12.4	63.5	62.6	0.9	50.0	○	116.377

Displacement Diagram



Reaction Force of Ground



Reaction Force



2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-10.8	-12.7	76.7	73.6	3.1	50.0	○	378.724
2	0.250	-10.8	-12.7	78.7	75.9	2.8	50.0	○	339.683
3	0.500	-10.8	-12.6	80.7	78.2	2.5	50.0	○	303.902
4	1.000	-10.8	-12.3	84.7	82.9	1.9	50.0	○	230.780
5	1.500	-10.8	-12.0	88.8	87.3	1.5	37.5	○	182.821
6	2.000	-10.8	-11.8	92.8	91.6	1.2	37.5	○	111.330
7	2.500	-10.8	-11.5	96.8	95.8	1.0	37.5	○	92.423
8	3.000	-10.8	-11.2	100.9	100.0	0.9	37.5	○	81.147
9	3.500	-10.8	-11.0	104.9	104.1	0.8	37.5	○	76.911
10	4.000	-10.8	-10.7	108.9	108.1	0.8	37.5	○	76.037
11	4.500	-10.8	-10.4	112.9	112.3	0.7	37.5	○	63.682
12	5.000	-10.8	-9.6	117.0	116.9	0.0	37.5	○	4.372
13	5.500	-10.8	-8.6	121.0	120.5	0.5	37.5	○	47.159
14	6.000	-10.8	-7.6	125.0	123.4	1.6	37.5	○	153.936
15	6.500	-10.8	-6.6	129.1	126.6	2.5	37.5	○	233.426
16	7.000	-10.8	-5.6	133.1	129.3	3.8	37.5	○	358.236

Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	1.7	-5.6	136.3	129.3	7.1	37.5	○	702.355
2	0.500	1.7	-4.6	136.1	131.5	4.6	37.5	○	455.618
3	1.000	1.7	-3.6	135.9	133.0	2.9	37.5	○	285.111
4	1.500	1.7	-2.6	135.6	134.7	0.9	37.5	○	88.173
5	2.000	1.7	-1.4	135.4	136.7	-1.3	-50.0	○	-127.422
6	2.500	1.7	0.0	135.1	137.0	-1.9	-50.0	○	-187.058
7	3.000	1.7	1.5	134.9	136.2	-1.3	-50.0	○	-128.989
8	3.500	1.7	2.9	134.6	135.4	-0.7	-50.0	○	-69.968
9	4.000	1.7	4.3	134.4	134.5	-0.1	-50.0	○	-14.386
10	4.500	1.7	5.7	134.2	133.7	0.4	37.5	○	40.915
11	5.000	1.7	7.2	133.9	133.0	0.9	37.5	○	92.245
12	5.500	1.7	8.8	133.7	129.3	4.4	37.5	○	434.370
13	6.000	1.7	9.8	133.4	123.9	9.5	37.5	○	941.065

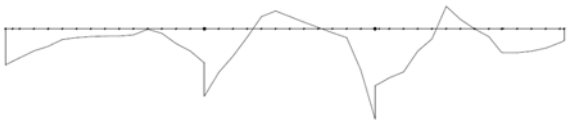
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	13.0	9.8	130.2	123.9	6.2	37.5	○	593.517
2	0.140	13.0	10.0	128.8	122.7	6.0	37.5	○	573.453
3	0.500	13.0	10.5	125.1	119.8	5.4	37.5	○	512.294
4	1.000	13.0	11.2	120.1	115.4	4.7	37.5	○	451.070
5	1.500	13.0	12.0	115.1	112.7	2.4	37.5	○	233.079
6	2.000	13.0	12.7	110.1	109.0	1.1	37.5	○	105.284
7	2.500	13.0	13.1	105.1	107.6	-2.5	-50.0	○	-235.580
8	3.000	13.0	13.0	100.1	101.1	-1.0	-50.0	○	-99.361
9	3.500	13.0	12.9	95.1	95.1	0.0	37.5	○	0.658
10	4.000	13.0	12.8	90.1	89.2	0.9	37.5	○	81.327
11	4.451	13.0	12.8	85.6	83.6	2.0	37.5	○	247.283
12	4.500	13.0	12.8	85.1	83.1	2.0	50.0	○	248.075
13	5.000	13.0	12.7	80.1	78.1	2.0	50.0	○	248.963
14	5.500	13.0	12.6	75.1	73.2	1.9	50.0	○	234.575
15	6.000	13.0	12.5	70.1	68.5	1.6	50.0	○	200.918
16	6.500	13.0	12.4	65.1	63.9	1.2	50.0	○	145.255
17	6.651	13.0	12.4	63.5	62.6	1.0	50.0	○	123.797

Displacement Diagram



Reaction Force of Ground



Reaction Force



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]
Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.005	0.000	0.000
2	0.250	12.264	62.480	8.025
3	0.250	240.933	-116.460	49.465
4	0.500	252.908	-63.900	27.119
5	1.000	272.979	12.290	15.831
6	1.500	287.411	55.939	33.978
7	2.000	294.074	67.863	65.563
8	2.500	296.477	66.559	99.630
9	3.000	294.622	55.989	130.571
10	3.500	288.511	39.821	154.680
11	4.000	278.149	20.657	169.887
12	4.500	263.538	-3.534	174.493
13	5.000	240.750	-47.360	163.073
14	5.500	204.072	-97.037	126.152
15	6.000	151.720	-111.042	71.977
16	6.500	83.696	-80.199	22.580
17	7.000	0.002	0.000	0.000

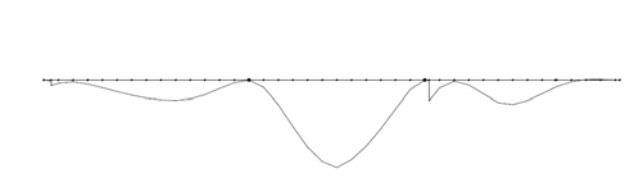
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	7.000	-0.002	0.000	0.000
2	7.500	111.911	229.013	62.390
3	8.000	207.219	353.715	211.623
4	8.500	285.927	386.556	400.791
5	9.000	346.465	316.264	580.985
6	9.500	385.436	177.164	705.584
7	10.000	401.018	37.673	758.085
8	10.000	401.019	-81.727	758.085
9	10.500	393.209	-191.946	688.438
10	11.000	362.008	-273.515	570.916
11	11.500	307.397	-327.363	419.546
12	12.000	228.553	-354.553	247.998
13	12.500	124.673	-283.379	81.393
14	13.000	-0.003	0.000	0.000

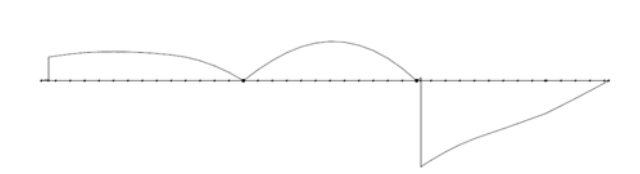
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	13.000	0.003	-0.001	0.000
2	13.140	28.274	74.598	5.260
3	13.140	-880.720	-400.982	180.060
4	13.500	-812.265	-224.968	68.101
5	14.000	-727.337	-13.949	9.784
6	14.500	-654.222	123.954	41.964
7	15.000	-592.922	172.097	118.776
8	15.500	-540.501	99.762	193.980
9	16.000	-490.348	-27.048	209.458
10	16.500	-438.787	-98.113	176.220
11	17.000	-385.822	-127.319	118.318
12	17.451	-336.848	-114.423	62.110
13	17.500	-329.734	-109.314	56.628
14	17.500	-329.723	-109.328	56.628
15	18.000	-256.111	-59.560	14.573
16	18.500	-180.653	-17.544	-4.217
17	19.000	-103.365	8.086	-5.695
18	19.500	-24.254	7.008	-0.576
19	19.651	-0.005	0.000	0.000

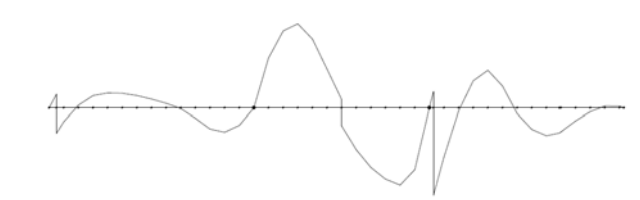
Bending Moment



Axial Force



Shear Force



3.5.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side →River Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.005	0.000	0.000
2	0.250	18.770	52.577	6.778
3	0.250	99.990	-66.923	71.338
4	0.500	118.471	-23.825	60.184
5	1.000	151.555	34.766	64.460
6	1.500	179.001	62.581	89.814
7	2.000	195.520	67.220	122.842
8	2.500	207.778	59.967	155.046
9	3.000	215.778	44.785	181.481
10	3.500	219.523	25.341	199.114
11	4.000	219.016	4.238	206.540
12	4.500	214.261	-20.557	202.731
13	5.000	201.328	-63.651	182.927
14	5.500	174.505	-111.259	138.321
15	6.000	132.009	-121.859	77.831
16	6.500	73.841	-86.275	24.155
17	7.000	0.002	0.000	0.000

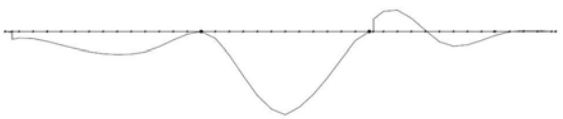
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	7.000	-0.002	0.000	0.000
2	7.500	111.911	229.013	62.390
3	8.000	207.219	353.715	211.623
4	8.500	285.927	386.556	400.791
5	9.000	346.465	316.264	580.985
6	9.500	385.436	177.164	705.584
7	10.000	401.018	37.673	758.085
8	10.000	401.019	-81.727	758.085
9	10.500	393.209	-191.946	688.438
10	11.000	362.008	-273.515	570.916
11	11.500	307.397	-327.363	419.546
12	12.000	228.553	-354.553	247.998
13	12.500	124.673	-283.379	81.393
14	13.000	-0.003	0.000	0.000

Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	13.000	0.003	-0.001	0.000
2	13.140	19.001	70.081	4.942
3	13.140	-402.773	-286.539	-112.748
4	13.500	-358.163	-121.654	-185.532
5	14.000	-306.353	75.069	-195.822
6	14.500	-266.356	200.027	-122.425
7	15.000	-238.174	236.577	-10.531
8	15.500	-218.871	154.000	94.296
9	16.000	-201.835	18.300	134.613
10	16.500	-183.392	-60.302	122.110
11	17.000	-163.545	-95.694	81.510
12	17.451	-144.443	-87.216	38.527
13	17.500	-141.614	-83.089	34.350
14	17.500	-141.603	-83.103	34.350
15	18.000	-111.720	-42.380	3.071
16	18.500	-79.990	-7.623	-9.018
17	19.000	-46.430	12.534	-6.978
18	19.500	-11.048	7.770	-0.632
19	19.651	-0.005	0.000	0.000

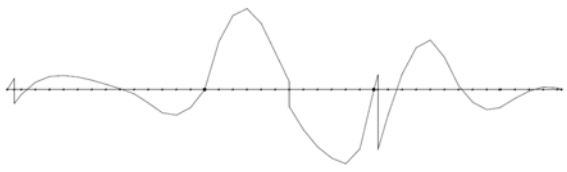
Bending Moment



Axial Force



Shear Force



Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.005	0.000	0.000
2	0.250	16.049	52.036	6.710
3	0.250	158.929	-60.544	57.170
4	0.500	174.689	-17.968	47.545
5	1.000	202.331	39.632	54.499
6	1.500	224.335	66.530	82.053
7	2.000	236.732	70.531	116.894
8	2.500	244.869	62.695	150.605
9	3.000	248.748	46.987	178.271
10	3.500	248.372	27.072	196.885
11	4.000	243.743	5.553	205.070
12	4.500	234.866	-19.600	201.826
13	5.000	217.813	-62.997	182.422
14	5.500	186.869	-110.853	138.079
15	6.000	140.251	-121.644	77.742
16	6.500	77.962	-86.196	24.138
17	7.000	0.002	0.000	0.000

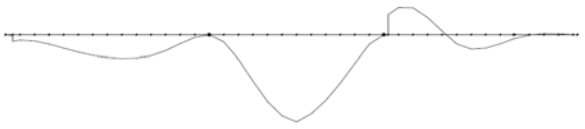
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	7.000	-0.002	0.000	0.000
2	7.500	111.911	229.013	62.390
3	8.000	207.219	353.715	211.623
4	8.500	285.927	386.556	400.791
5	9.000	346.465	316.264	580.985
6	9.500	385.436	177.164	705.584
7	10.000	401.018	37.673	758.085
8	10.000	401.019	-81.727	758.085
9	10.500	393.209	-191.946	688.438
10	11.000	362.008	-273.515	570.916
11	11.500	307.397	-327.363	419.546
12	12.000	228.553	-354.553	247.998
13	12.500	124.673	-283.379	81.393
14	13.000	-0.003	0.000	0.000

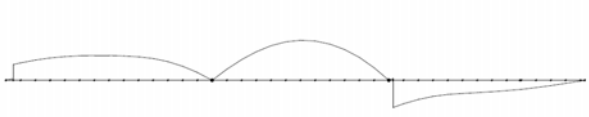
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	13.000	0.003	-0.001	0.000
2	13.140	16.486	68.654	4.842
3	13.140	-273.168	-255.866	-174.918
4	13.500	-235.024	-94.500	-237.300
5	14.000	-192.196	97.696	-235.162
6	14.500	-161.179	218.548	-151.496
7	15.000	-141.978	251.410	-31.281
8	15.500	-131.656	165.567	80.128
9	16.000	-123.601	27.021	125.500
10	16.500	-114.138	-54.007	116.733
11	17.000	-103.272	-91.404	78.762
12	17.451	-92.271	-84.374	37.375
13	17.500	-90.603	-80.427	33.330
14	17.500	-90.593	-80.441	33.330
15	18.000	-72.567	-41.255	2.976
16	18.500	-52.694	-7.478	-8.820
17	19.000	-30.992	12.254	-6.836
18	19.500	-7.467	7.622	-0.620
19	19.651	-0.005	0.000	0.000

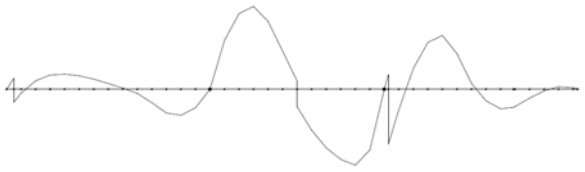
Bending Moment



Axial Force



Shear Force



3.6 Design of Flexible Joint

Opening

Opening = (Lateral Displacement of Span in Right Side) - (Lateral Displacement of Span in Left Side)

Bending Angle

θ = | θ1 - θ2 | - Initial Bending Angle

Thus、

θ1: Angle of Displacement (Left Side) (rad)

θ2: Angle of Displacement (Right Side) (rad)

θ: Average Angle of Displacement (rad)

Unevenness

Unevenness = (Vertical Displacement of Span in Right Side) - (Vertical Displacement of Span in Left Side)

3.6.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Check of Opening Allowable Opening : 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-11.5	
Span (2- 1)	1.7- (-11.5)	13.2 OK
Span (3- 2)	16.2- (1.7)	14.5 OK
EP	16.2	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.45750 -0.00798	0.02786 0.00049	0.48536 0.00847
Span (3- 2)	0.00000 0.00000	0.02788 0.00049	0.58183 0.01015	0.55395 0.00967

Check for Unevenness Allowable Unevenness 100.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-77.3	
Span (2- 1)	-136.6-(-133.2)	3.4 OK
Span (3- 2)	-131.2-(-133.7)	2.5 OK
EP	-63.7	

3.6.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-10.7	
Span (2- 1)	1.7- (-10.7)	12.4 OK
Span (3- 2)	13.2- (1.7)	11.5 OK
EP	13.2	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.46148 -0.00805	0.02786 0.00049	0.48933 0.00854
Span (3- 2)	0.00000 0.00000	0.02788 0.00049	0.57579 0.01005	0.54791 0.00956

Check for Unevenness Allowable Unevenness 100.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-76.7	
Span (2- 1)	-136.3-(-133.1)	3.3 OK
Span (3- 2)	-130.3-(-133.4)	3.1 OK
EP	-63.5	

Calculation Case2 - Load: [Seismic Condition Land Side →River Side]

Check for Opening Allowable Opening 100.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-10.8	
Span (2- 1)	1.7-(-10.8)	12.5 OK
Span (3- 2)	13.0-(1.7)	11.3 OK
EP	13.0	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.46172 -0.00806	0.02786 0.00049	0.48958 0.00854
Span (3- 2)	0.00000 0.00000	0.02788 0.00049	0.57386 0.01002	0.54598 0.00953

Check for Unevenness Allowable Unevenness 100.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-76.7	
Span (2- 1)	-136.3-(-133.1)	3.3 OK
Span (3- 2)	-130.2-(-133.4)	3.3 OK
EP	-63.5	

3.7 Stress Intensity Analysis

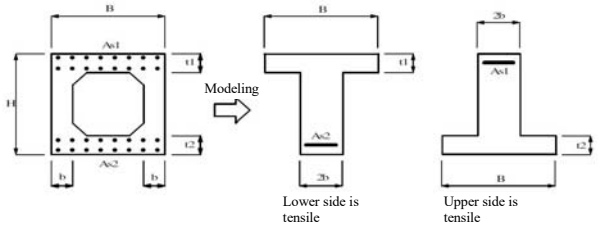
3.7.1 Calculation Condition

It is considered that double reinforced section which bending moment is acting on.
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.
Position of Neutral Axis

$$x=\frac{n\cdot(As\cdot d+As'\cdot d')+B\cdot t^2/2}{n\cdot(As+As')+B\cdot t}$$

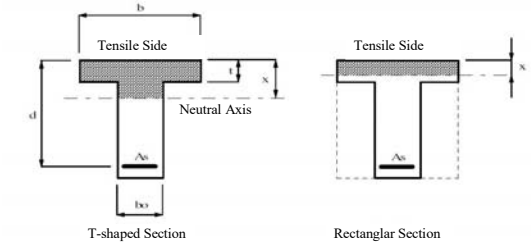
Thus,

x : Position of Neutral Axis (mm)
n : Ratio of Young modulus = 9.0
As : Area of Re-bar in tensile side (mm^2)
As' : Area of Re-bar in compressive side (mm^2)
d : Effective Height of Beam (mm)
d' : Distance from the compressive edge of concrete to the centric of Re-bar (mm)
B : Width of Flange (mm)
t : Thickness of Flange (mm)



The stress calculation is conducted as follows based on the position of neutral axis

1) In case the neutral axis is in web, the section is considered as T-shape.
2) In case the neutral axis is in top slab or Bottom slab, the section is considered as rectangle.



Calculation Condition (In Case Bottom Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation Section
1- 1	3.850	2.200	1.450	0.500	0.297	Rectangle
1- 2	3.750	2.100	1.350	0.450	0.277	Rectangle
2- 1	3.750	2.100	1.350	0.450	0.277	Rectangle
3- 1	3.750	2.100	1.350	0.450	0.277	Rectangle
3- 2	3.850	2.200	1.450	0.500	0.297	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side As(mm^2)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side As' (mm^2)
1- 1	3.850	2.200	1.928	6355.2	0.260	6355.2
1- 2	3.750	2.100	1.855	6355.2	0.233	6355.2
2- 1	3.750	2.100	1.855	6355.2	0.233	6355.2
3- 1	3.750	2.100	1.855	6355.2	0.233	6355.2
3- 2	3.850	2.200	1.928	6355.2	0.260	6355.2

Calculation Condition (In Case Top Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation
1- 1	3.850	2.200	1.450	0.500	0.297	Rectangle
1- 2	3.750	2.100	1.350	0.450	0.277	Rectangle
2- 1	3.750	2.100	1.350	0.450	0.277	Rectangle
3- 1	3.750	2.100	1.350	0.450	0.277	Rectangle
3- 2	3.850	2.200	1.450	0.500	0.297	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side	Position of Re-bar in Compressive	Area of Re-bar in Tensile Side
1- 1	3.850	2.200	1.940	6355.2	0.272	6355.2
1- 2	3.750	2.100	1.867	6355.2	0.245	6355.2
2- 1	3.750	2.100	1.867	6355.2	0.245	6355.2
3- 1	3.750	2.100	1.867	6355.2	0.245	6355.2
3- 2	3.850	2.200	1.940	6355.2	0.272	6355.2

3.7.2 Normal Condition

1) Calculation Case1 : Normal Condition

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.850	3.850	3.850	3.850
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1450.0	1450.0	1450.0	1450.0
Bending Moment		M	kN.m	49.465	0.000	33.978	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	91.2		62.5	
	Top Slab Inside	Aq2	mm^2	103.4		70.9	
	Bottom Slab Inside	Aq3	mm^2	103.4		70.9	
	Bottom Slab Outside	Aq4	mm^2	91.2		62.5	
Neutral Axis		X	m	0.227	----	0.227	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.06	----	0.04	----
		σs	N/mm^2	4.51	----	3.10	----
		σs'	N/mm^2	-0.33	----	-0.23	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	259.4	----	177.8	----
		inp	mm^2	6355.2	----	6355.2	----

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.750	3.750	3.750	3.750
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	1350.0	1350.0	1350.0	1350.0
Bending Moment		M	kN.m	174.493	0.000	99.630	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	336.4		191.0	
	Top Slab Inside	Aq2	mm^2	381.3		216.5	
	Bottom Slab Inside	Aq3	mm^2	381.3		216.5	
	Bottom Slab Outside	Aq4	mm^2	336.4		191.0	
Neutral Axis		X	m	0.224	----	0.224	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.23	----	0.13	----
		σs	N/mm^2	16.46	----	9.40	----
		σs'	N/mm^2	-1.25	----	-0.71	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	957.0	----	543.4	----
		inp	mm^2	6355.2	----	6355.2	----

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.750	3.750	3.750	3.750
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	1350.0	1350.0	1350.0	1350.0
Bending Moment		M	kN.m	758.085	0.000	758.085	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	1496.3		1496.3	
	Top Slab Inside	Aq2	mm^2	1695.8		1695.8	
	Bottom Slab Inside	Aq3	mm^2	1695.8		1695.8	
	Bottom Slab Outside	Aq4	mm^2	1496.3		1496.3	
Neutral Axis		X	m	0.224	----	0.224	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	1.01	----	1.01	----
		σs	N/mm^2	71.50	----	71.50	----
		σs'	N/mm^2	-5.43	----	-5.43	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	4256.0	----	4256.0	----
		inp	mm^2	6355.2	----	6355.2	----

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.750	3.750	3.750	3.750
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	1350.0	1350.0	1350.0	1350.0
Bending Moment		M	kN.m	209.458	0.000	5.260	180.060
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	404.7		9.9	347.3
	Top Slab Inside	Aq2	mm^2	458.7		11.3	393.6
	Bottom Slab Inside	Aq3	mm^2	458.7		11.3	393.6
	Bottom Slab Outside	Aq4	mm^2	404.7		9.9	347.3
Neutral Axis		X	m	0.224	----	0.224	0.224
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.28	----	0.01	0.24
		σs	N/mm^2	19.75	----	0.50	16.98
		σs'	N/mm^2	-1.50	----	-0.04	-1.29
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		
		req	mm^2	1151.2	----	28.3	987.8
		inp	mm^2	6355.2	----	6355.2	6355.2

Calculation Case1: Normal Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.850	3.850	3.850	3.850
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1450.0	1450.0	1450.0	1450.0
Bending Moment		M	kN.m	62.110	-5.695	0.000	62.110
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	114.7	10.4		114.7
	Top Slab Inside	Aq2	mm^2	130.0	11.8		130.0
	Bottom Slab Inside	Aq3	mm^2	130.0	11.8		130.0
	Bottom Slab Outside	Aq4	mm^2	114.7	10.4		114.7
Neutral Axis		X	m	0.227	0.228	----	0.227
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.08	0.01	----	0.08
		σs	N/mm^2	5.67	0.52	----	5.67
		σs'	N/mm^2	-0.42	-0.03	----	-0.42
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2			----	
		req	mm^2	326.2	29.6	----	326.2
		inp	mm^2	6355.2	6355.2	----	6355.2

3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.850	3.850	3.850	3.850
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1450.0	1450.0	1450.0	1450.0
Bending Moment		M	kN.m	89.814	0.000	89.814	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	124.9		124.9	
	Top Slab Inside	Aq2	mm^2	141.6		141.6	
	Bottom Slab Inside	Aq3	mm^2	141.6		141.6	
	Bottom Slab Outside	Aq4	mm^2	124.9		124.9	
Neutral Axis		X	m	0.227	----	0.227	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.11	----	0.11	----
		σs	N/mm^2	8.19	----	8.19	----
		σs'	N/mm^2	-0.60	----	-0.60	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	355.3	----	355.3	----
		inp	mm^2	6355.2	----	6355.2	----

Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.750	3.750	3.750	3.750
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	1350.0	1350.0	1350.0	1350.0
Bending Moment		M	kN.m	206.540	0.000	199.114	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	299.4		288.5	
	Top Slab Inside	Aq2	mm^2	339.3		326.9	
	Bottom Slab Inside	Aq3	mm^2	339.3		326.9	
	Bottom Slab Outside	Aq4	mm^2	299.4		288.5	
Neutral Axis		X	m	0.224	----	0.224	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.28	----	0.27	----
		σs	N/mm^2	19.48	----	18.78	----
		σs'	N/mm^2	-1.48	----	-1.43	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	851.5	----	820.6	----
		inp	mm^2	6355.2	----	6355.2	----

Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.750	3.750	3.750	3.750
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	1350.0	1350.0	1350.0	1350.0
Bending Moment		M	kN.m	758.085	0.000	758.085	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	1119.7		1119.7	
	Top Slab Inside	Aq2	mm^2	1269.0		1269.0	
	Bottom Slab Inside	Aq3	mm^2	1269.0		1269.0	
	Bottom Slab Outside	Aq4	mm^2	1119.7		1119.7	
Neutral Axis		X	m	0.224	----	0.224	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	1.01	----	1.01	----
		σs	N/mm^2	71.50	----	71.50	----
		σs'	N/mm^2	-5.43	----	-5.43	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	3185.0	----	3185.0	----
		inp	mm^2	6355.2	----	6355.2	----

Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.750	3.750	3.750	3.750
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	1350.0	1350.0	1350.0	1350.0
Bending Moment		M	kN.m	134.613	-195.822	4.942	-112.748
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	194.3	283.4	7.0	162.3
	Top Slab Inside	Aq2	mm^2	220.2	321.2	8.0	184.0
	Bottom Slab Inside	Aq3	mm^2	220.2	321.2	8.0	184.0
	Bottom Slab Outside	Aq4	mm^2	194.3	283.4	7.0	162.3
Neutral Axis		X	m	0.224	0.225	0.224	0.225
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.18	0.26	0.01	0.15
		σs	N/mm^2	12.70	18.47	0.47	10.64
		σs'	N/mm^2	-0.96	-1.14	-0.04	-0.66
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	552.7	806.1	20.0	461.8
		inp	mm^2	6355.2	6355.2	6355.2	6355.2

Calculation Case1: Seismic Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.850	3.850	3.850	3.850
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1450.0	1450.0	1450.0	1450.0
Bending Moment		M	kN.m	38.527	-9.018	0.000	38.527
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	53.3	12.4		53.3
	Top Slab Inside	Aq2	mm^2	60.4	14.1		60.4
	Bottom Slab Inside	Aq3	mm^2	60.4	14.1		60.4
	Bottom Slab Outside	Aq4	mm^2	53.3	12.4		53.3
Neutral Axis		X	m	0.227	0.228	----	0.227
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.05	0.01	----	0.05
		σs	N/mm^2	3.51	0.82	----	3.51
		σs'	N/mm^2	-0.26	-0.05	----	-0.26
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2			----	
		req	mm^2	151.7	35.3	----	151.7
		inp	mm^2	6355.2	6355.2	----	6355.2

2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.850	3.850	3.850	3.850
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1450.0	1450.0	1450.0	1450.0
Bending Moment		M	kN.m	82.053	0.000	82.053	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	114.0		114.0	
	Top Slab Inside	Aq2	mm^2	129.2		129.2	
	Bottom Slab Inside	Aq3	mm^2	129.2		129.2	
	Bottom Slab Outside	Aq4	mm^2	114.0		114.0	
Neutral Axis		X	m	0.227	----	0.227	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.10	----	0.10	----
		σs	N/mm^2	7.48	----	7.48	----
		σs'	N/mm^2	-0.55	----	-0.55	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	324.4	----	324.4	----
		inp	mm^2	6355.2	----	6355.2	----

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.750	3.750	3.750	3.750
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	1350.0	1350.0	1350.0	1350.0
Bending Moment		M	kN.m	205.070	0.000	178.271	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	297.2		258.0	
	Top Slab Inside	Aq2	mm^2	336.8		292.4	
	Bottom Slab Inside	Aq3	mm^2	336.8		292.4	
	Bottom Slab Outside	Aq4	mm^2	297.2		258.0	
Neutral Axis		X	m	0.224	----	0.224	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.27	----	0.24	----
		σs	N/mm^2	19.34	----	16.81	----
		σs'	N/mm^2	-1.47	----	-1.28	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	845.4	----	733.9	----
		inp	mm^2	6355.2	----	6355.2	----

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.750	3.750	3.750	3.750
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	1350.0	1350.0	1350.0	1350.0
Bending Moment		M	kN.m	758.085	0.000	758.085	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	1119.7		1119.7	
	Top Slab Inside	Aq2	mm^2	1269.0		1269.0	
	Bottom Slab Inside	Aq3	mm^2	1269.0		1269.0	
	Bottom Slab Outside	Aq4	mm^2	1119.7		1119.7	
Neutral Axis		X	m	0.224	----	0.224	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	1.01	----	1.01	----
		σs	N/mm^2	71.50	----	71.50	----
		σs'	N/mm^2	-5.43	----	-5.43	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	3185.0	----	3185.0	----
		inp	mm^2	6355.2	----	6355.2	----

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.750	3.750	3.750	3.750
Total Height		H	m	2.100	2.100	2.100	2.100
Web Width		b	mm	1350.0	1350.0	1350.0	1350.0
Bending Moment		M	kN.m	125.500	-237.300	4.842	-174.918
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	181.0	344.2	6.9	252.9
	Top Slab Inside	Aq2	mm^2	205.2	390.1	7.8	286.6
	Bottom Slab Inside	Aq3	mm^2	205.2	390.1	7.8	286.6
	Bottom Slab Outside	Aq4	mm^2	181.0	344.2	6.9	252.9
Neutral Axis		X	m	0.224	0.225	0.224	0.225
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.17	0.31	0.01	0.23
		σs	N/mm^2	11.84	22.39	0.46	16.50
		σs'	N/mm^2	-0.90	-1.38	-0.03	-1.02
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	515.0	979.0	19.6	719.3
		inp	mm^2	6355.2	6355.2	6355.2	6355.2

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	3.850	3.850	3.850	3.850
Total Height		H	m	2.200	2.200	2.200	2.200
Web Width		b	mm	1450.0	1450.0	1450.0	1450.0
Bending Moment		M	kN.m	37.374	-8.820	0.000	37.374
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15	90.0 D16- 15
	Inside of Top Slab	d2 As2	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17	90.0 D16- 17
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15	115.0 D16- 15
Total Area of Rebar		As	mm^2	12710.4	12710.4	12710.4	12710.4
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	51.7	12.1		51.7
	Top Slab Inside	Aq2	mm^2	58.6	13.7		58.6
	Bottom Slab Inside	Aq3	mm^2	58.6	13.7		58.6
	Bottom Slab Outside	Aq4	mm^2	51.7	12.1		51.7
Neutral Axis		X	m	0.227	0.228	0.227	0.228
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.05	0.01	----	0.05
		σs	N/mm^2	3.41	0.80	----	3.41
		σs'	N/mm^2	-0.25	-0.05	----	-0.25
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2			----	
		req	mm^2	147.1	34.5	----	147.1
		inp	mm^2	6355.2	6355.2	----	6355.2

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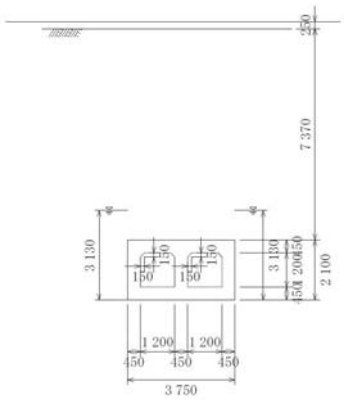
2.2.2.6 SLUICEWAY TYPE I

(2) BOX - TRANSVERSE

1 Calculation of Box Culvert in Transverse Direction

1.1 Design Condition

1.1.1 Dimension



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material			SD295	
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D19	250	1146.0	Left Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D19	250	1146.0	Center of Span	D16	250	794.4
	—	——			—	——	
Middle Corner	D19	250	1146.0	Middle Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D19	250	1146.0	Center of Span	D16	250	794.4
	—	——			—	——	
Right Corner	D19	250	1146.0	Right Corner	D16	250	794.4
	—	——			—	——	

Outside of Sidewall	Diameter	Pitch	Area (mm^2)	Inside of Sidewall	Diameter	Pitch	Area (mm^2)
Left Sidewall	D16	250	794.4	Left Sidewall	D13	250	506.8
	—	——			—	——	
Right Sidewall	D16	250	794.4	Right Sidewall	D13	250	506.8
	—	——			—	——	
Middle Sidewall	D13	250	506.8	Middle Sidewall	—	—	—
	—	——			—	—	

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D19	250	1146.0	Left Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D19	250	1146.0	Center of Span	D16	250	794.4
	—	——			—	——	
Middle Corner	D19	250	1146.0	Middle Corner	D16	250	794.4
	—	——			—	——	
Center of Span	D19	250	1146.0	Center of Span	D16	250	794.4
	—	——			—	——	
Right Corner	D19	250	1146.0	Right Corner	D16	250	794.4
	—	——			—	——	

■Cover

Location		Cover(mm)	Location		Cover(mm)
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Midwall		90.0	———		——

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Top Slab	100	0.0
Left Sidewall	100	0.0
Medium Sidewall	100	100.0
Middle Sidewall	100	0.0
Bottom Slab	100	0.0

1.1.4 Load

■Surcharge

	(kN/m^2)
Surcharge	10.000
Snow Load	0.000

■Dead Load (Water Level)

Case	External Water Level(m)	Internal Water Level(m)
1	3.130	0.000

External Water Level: Height from Bottom Surface of Bottom Slab
Internal Water Level: Height from Top Surface of Bottom Slab

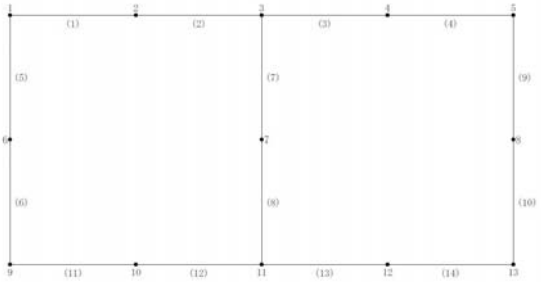
■Live Load

Intensity of Distribution Load Qw(kN/m^2)	10.000

1.2 Cross-section Calculation

1.2.1 Model

1) Frame Dimension



2) Coordinate

No	X(m)	Y(m)
1	0.000	1.650
2	0.825	1.650
3	1.650	1.650
4	2.475	1.650
5	3.300	1.650
6	0.000	0.825
7	1.650	0.825
8	3.300	0.825
9	0.000	0.000
10	0.825	0.000
11	1.650	0.000
12	2.475	0.000
13	3.300	0.000

3) Member Material and Sectional Characteristics

Member	Number	Point Number		Area (m^2)	Geometric Moment of Inertia (m^4)	Young Modules (kN/m^2)
		i Edge	j Edge			
Left Side of Top Slab (Left)	1	1	2	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Top Slab (Left)	2	2	3	4.500000E-001	7.593750E-003	2.310000E+007
Left Side of Top Slab (Right)	3	3	4	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Top Slab (Right)	4	4	5	4.500000E-001	7.593750E-003	2.310000E+007
Upper Side of Left Side Wall	5	1	6	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Left Side Wall	6	6	9	4.500000E-001	7.593750E-003	2.310000E+007
Upper Side Middle wall	7	3	7	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side Middle wall	8	7	11	4.500000E-001	7.593750E-003	2.310000E+007
Upper side of Right Wall	9	5	8	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Right Wall	10	8	13	4.500000E-001	7.593750E-003	2.310000E+007
Left Side of Bottom Slap (Left)	11	9	10	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slap (Left)	12	10	11	4.500000E-001	7.593750E-003	2.310000E+007
Left Side of Bottom Slap (Right)	13	11	12	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slap (Right)	14	12	13	4.500000E-001	7.593750E-003	2.310000E+007

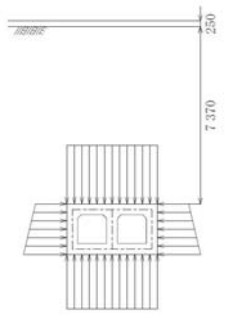
4) Supporting Point

Point	Horizontal (kN/m)	Vertical (kN/m)	Rotate (kN.m/rad)
9	-1	-1	0
13	0	-1	0

Note) -1 : Fixed, 0 : Free

1.2.2 Load

1) Dead Load (case-1) [RWL]



Weight of Box Culvert

(1) Top Slab
w = 0.450 × 24.00 = 10.80 (kN/m^2)

(2) Left Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m^2)

(3) Middle Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m^2)

(4) Right Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m^2)

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level) = 1.000 × 0.250 × 22.60 = 5.65 (kN/m^2)
Embankment (Above Water Level) =1.000 × 6.340× 18.00 = 114.12 (kN/m^2)
Embankment (Below Water Level) =1.000 × 1.030 × 9.20 = 9.48 (kN/m^2)
Water Pressure = 1.030 × 9.80 = 10.09 (kN/m^2)

Σwd = 139.34 (kN/m^2)

(2) Surcharge Load at Road
Surcharge = 10.000 (kN/m^2)
Snow Load= 0.00 (kN/m^2)

Σqd = 10.000 (kN/m^2)

(3) Load Acting on Top Slab
Uniformly Distributed Load
w = 139.34 + 10.00 = 149.34 (kN/m^2)

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

pi = Ko×(qd + Yo×γa + Zu×γ + (Zo - Zu)×γ') + (Zo - Zu)×γw

Ko : Coefficient of Earth Pressure at Rest = 0.500

Zo:Depth of Calculation Point from Embankment Top(m)

(1)Left Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m^2)
p_1	Top Surface of Top Slab	7.370	79.72
p_2	Center of Top Slab	7.595	82.96
p_3	Center of Bottom Slab	9.245	106.72
p_4	Bottom Surface of Bottom Slab	9.470	109.96

(2)Right Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m^2)
p_1	Top Surface of Top Slab	7.370	79.72
p_2	Center of Top Slab	7.595	82.96
p_3	Center of Bottom Slab	9.245	106.72
p_4	Bottom Surface of Bottom Slab	9.470	109.96

Uplift and Buoyancy

This Act on Bottom Slab Upward

$$U = 3.130 \times 3.750 \times 9.80 = 115.03 \ (kN/m)$$

$$w = \frac{-115.03}{3.750} = -30.67 \ (kN/m^2)$$

Summary of Acting Forces

Item			V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/
Weight of Body		Top Slab	41.58		1.875		77.96
		Left Side Wall	12.96		0.225		2.92
		Middle Side Wall	12.96		1.875		24.30
		Right Side Wall	12.96		3.525		45.68
Surcharge		Distribution Load	560.03		1.875		1050.05
Earth Pressure and Water Pressure	Left Side Wall	Distribution		199.16		0.994	198.00
	Right Side Wall	Distribution		-199.16		0.994	-198.00
Uplift/Buoyancy			-115.03		1.875		-215.68
Total			525.46				985.23

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 1.875 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$Me = \Sigma V \times e = 0.00 \ (kN.m/m)$$

$$q1 = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 140.12 \ (kN/m^2)$$

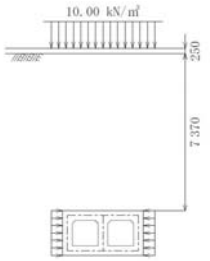
$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 140.12 \ (kN/m^2)$$

$$q1' = q1 + \frac{qr - q1}{B} \times \frac{T}{2} = 140.12 \ (kN/m^2)$$

$$qr' = qr + \frac{q1 - qr}{B} \times \frac{T}{2} = 140.12 \ (kN/m^2)$$

Thus, T : Thickness of Side Wall
q1 : Subgrade Reaction Intensity on Left Edge
qr : Subgrade Reaction Intensity on Right Edge
q1': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface qL= 10.000 (kN/m²)

Load

(1)Vertical Load Effecting Top Slab
wl = qL= 10.00 (kN/m²)

(2)Horizontal Load Acting on Left Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

(3)Horizontal Load Effecting on Right Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

Summary of Acting Force

		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Top Slab	Distribution	37.50		1.875		70.31
Left Side Wall	Distribution		10.50		1.050	11.03
Right Side Wall	Distribution		-10.50		1.050	-11.03
Total		37.50				70.31

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 1.875 \text{ (m)}$$

$$e = \frac{B}{2} - X = 0.000 \text{ (m)}$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$ql = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$ql' = ql + \frac{qr - ql}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$qr' = qr + \frac{ql - qr}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

Thus、T : Thickness of Side Wall
ql : Subgrade Reaction Intensity on Left Edge
qr : Subgrade Reaction Intensity on Right Edge
ql': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

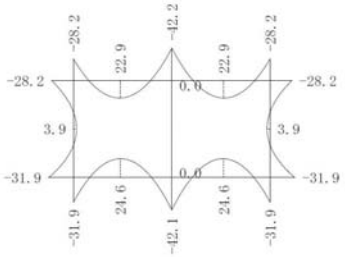
Dead Load + Live Load

Load Number	Beginning Member Number	End Member Number	Load Intensity at i Edge	Load Intensity at j Edge	Distance from i Edge (m)	Distance from j Edge (m)	Load Width (m)
14	1	4	-10.80	-10.80	0.000	0.000	3.300
14	5	6	-10.80	-10.80	0.225	0.225	1.200
14	7	8	-10.80	-10.80	0.225	0.225	1.200
14	9	10	-10.80	-10.80	0.225	0.225	1.200
14	1	4	-149.34	-149.34	0.000	0.000	3.300
13	5	6	82.96	106.72	0.000	0.000	1.650
13	9	10	-82.96	-106.72	0.000	0.000	1.650
14	11	14	30.67	30.67	0.000	0.000	3.300
14	1	4	-10.00	-10.00	0.000	0.000	3.300
13	5	6	5.00	5.00	0.000	0.000	1.650
13	9	10	-5.00	-5.00	0.000	0.000	1.650
14	11	14	150.12	150.12	0.000	0.000	3.300

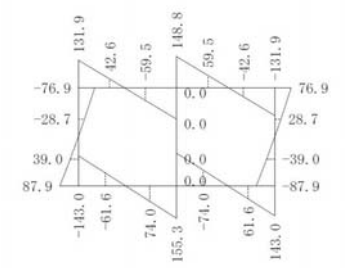
Load Number
13: Member Distribution Load (X Direction)
14: Member Distribution Load (Y Direction)

1.2.4 Calculation Results of Frame Analysis

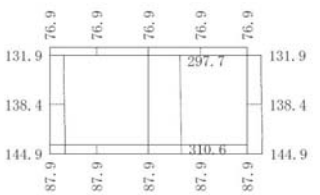
Bending Moment



Shear Force



Axial Force



1.2.5 Stress Intensity Calculation

■Bending Stress Intensity

Top Slab

Item		Unit	Left Corner	Center of Span	Mid-Corner	Center of Span	Right Corner
Bending Moment	M	kN.m	-28.232	22.887	-42.211	22.887	-28.232
Axial Force	N	kN	0.000	0.000	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0	90.0	90.0
Required Area of Re-Bar	External	mm²	591.3	0.0	894.2	0.0	591.3
	Internal	mm²	0.0	476.8	0.0	476.8	0.0
Re-Bar	External	mm²	D19 @ 250 D—@—— 1146.0	D19 @ 250 D—@—— 1146.0	D19 @ 250 D—@—— 1146.0	D19 @ 250 D—@—— 1146.0	D19 @ 250 D—@—— 1146.0
	Internal	mm²	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
Neutral Axis	X	m	0.076	0.065	0.076	0.065	0.076
Stress Intensity	σc	N/mm²	2.21	2.08	3.30	2.08	2.21
	σs	N/mm²	73.65	85.16	110.12	85.16	73.65
	σs'	N/mm²	0.00	0.00	0.00	0.00	0.00
Allowable Stress	σca	N/mm²	8.20	8.20	8.20	8.20	8.20
	σsa	N/mm²	140.00	140.00	140.00	140.00	140.00
	σsa'	N/mm²	-186.00	-186.00	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm²			720.0		
	req	mm²	788.3	635.7	1192.3	635.7	788.3
	inp	mm²	1146.0	794.4	1146.0	794.4	1146.0
Case	——	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

Left Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-28.232	3.910	-31.900
Axial Force	N	kN	131.893	138.373	144.853
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	35.9	0.0	62.5
	Internal	mm^2	0.0	0.0	0.0
Re-Bar Arrangement	External	mm^2	D19 @ 250 D—@—— 1146.0	D16 @ 250 D—@—— 794.4	D19 @ 250 D—@—— 1146.0
	Internal	mm^2	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8
Neutral Axis	X	m	0.171	0.797	0.167
Stress Intensity	σc	N/mm^2	1.77	0.43	2.03
	σs	N/mm^2	17.55	0.00	21.11
	σs'	N/mm^2	0.00	-2.10	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	47.8	0.0	83.3
	inp	mm^2	1146.0	506.8	1146.0
Case	——	———	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Middle Side Wall

		Unit	Upper side Edge	Under Side Edge
Bending Moment	M	kN.m	0.000	0.000
Axial Force	N	kN	297.675	310.635
Section Width	b	m	1.000	1.000
Section Height	h	m	0.450	0.450
Outside Cover	d1	mm	90.0	90.0
Inside Cover	d2	mm	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0
	Internal	mm^2	0.0	0.0
Re-Bar	External	mm^2	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8
	Internal	mm^2	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8
Neutral Axis	X	m	0.000	0.000
Stress Intensity	σc	N/mm^2	0.67	0.70
	σs	N/mm^2	0.00	0.00
	σs'	N/mm^2	-5.83	-6.08
Allowable Stress	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2		
	req	mm^2	0.0	0.0
	inp	mm^2	506.8	506.8
Case	——	———	Dead-1+Live-1	Dead-1+Live-1

Right Side Wall

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-28.232	3.910	-31.900
Axial Force	N	kN	131.893	138.373	144.853
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	35.9	0.0	62.5
	Internal	mm^2	0.0	0.0	0.0
Re-Bar	External	mm^2	D19 @ 250 D—@—— 1146.0	D16 @ 250 D—@—— 794.4	D19 @ 250 D—@—— 1146.0
	Internal	mm^2	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8
Neutral Axis	X	m	0.171	0.797	0.167
Stress Intensity	σc	N/mm^2	1.77	0.43	2.03
	σs	N/mm^2	17.55	0.00	21.11
	σs'	N/mm^2	0.00	-2.10	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	47.8	0.0	83.3
	inp	mm^2	1146.0	506.8	1146.0
Case	——	———	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

Bottom Slab

Item		Unit	Left Corner	Center of Span	Mid-Corner	Center of Span	Right Corner
Bending Moment	M	kN.m	-31.900	24.642	-42.065	24.642	-31.900
Axial Force	N	kN	0.000	0.000	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450	0.450	0.450
Outside Cover	d1	mm	115.0	115.0	115.0	115.0	115.0
Inside Cover	d2	mm	90.0	90.0	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	723.2	0.0	962.0	0.0	723.2
	Internal	mm^2	0.0	514.3	0.0	514.3	0.0
Re-Bar	External	mm^2	D19 @ 250 D—@—— 1146.0	D19 @ 250 D—@—— 1146.0	D19 @ 250 D—@—— 1146.0	D19 @ 250 D—@—— 1146.0	D19 @ 250 D—@—— 1146.0
	Internal	mm^2	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
Neutral Axis	X	m	0.073	0.065	0.073	0.065	0.073
Stress Intensity	σc	N/mm^2	2.80	2.24	3.69	2.24	2.80
	σs	N/mm^2	89.65	91.69	118.21	91.69	89.65
	σs'	N/mm^2	0.00	0.00	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			670.0		
	req	mm^2	964.3	685.7	1282.6	685.7	964.3
	inp	mm^2	1146.0	794.4	1146.0	794.4	1146.0
Case	——	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

■Shear Stress Intensity

$$\tau m = \frac{S}{b \times d} \leqq \tau a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm2)	τa (N/mm2)	Cases	L (m)
Top Slap	Left τ Point	42.570	360.0	0.118	0.457	Dead-1+Live-1	0.525
	Left and Right τ Point	-59.514	360.0	0.165	0.457	Dead-1+Live-1	0.525
	Right and Left τ Point	59.514	360.0	0.165	0.457	Dead-1+Live-1	0.525
	Right τ Point	-42.570	360.0	0.118	0.457	Dead-1+Live-1	0.525
Left Side Wall	Upper τ Point	-28.714	360.0	0.080	0.457	Dead-1+Live-1	0.525
	Lower τ Point	39.041	360.0	0.108	0.495	Dead-1+Live-1	0.450
Middle wall	Upper τ Point	0.000	360.0	0.000	0.360	Dead-1+Live-1	0.600
	Lower τ Point	0.000	360.0	0.000	0.360	Dead-1+Live-1	0.450
Right Side Wall	Upper τ Point	28.714	360.0	0.080	0.457	Dead-1+Live-1	0.525
	Lower τ Point	-39.041	360.0	0.108	0.495	Dead-1+Live-1	0.450
Bottom Slab	Left τ Point	-61.638	360.0	0.171	0.478	Dead-1+Live-1	0.450
	Left Right τ Point	73.959	360.0	0.205	0.478	Dead-1+Live-1	0.450
	Right and Left τ Point	-73.959	360.0	0.205	0.478	Dead-1+Live-1	0.450
	Right τ Point	61.638	360.0	0.171	0.478	Dead-1+Live-1	0.450

Note) τ Point: Check point for shear stress intensity
L: Distance from grid point of corner

2.2.2.6 SLUICEWAY TYPE I

(3) BREAST WALL - LAND SIDE

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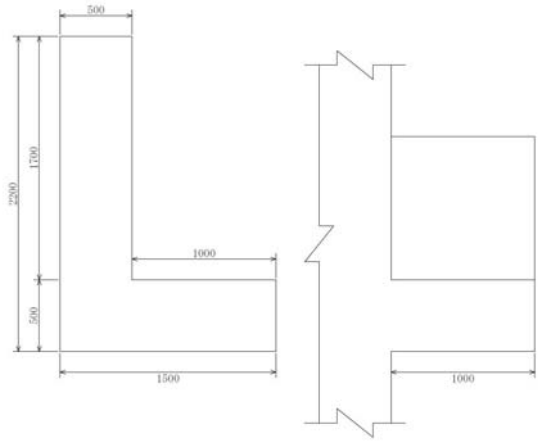
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1 Calculation of Land Side Breast Wall

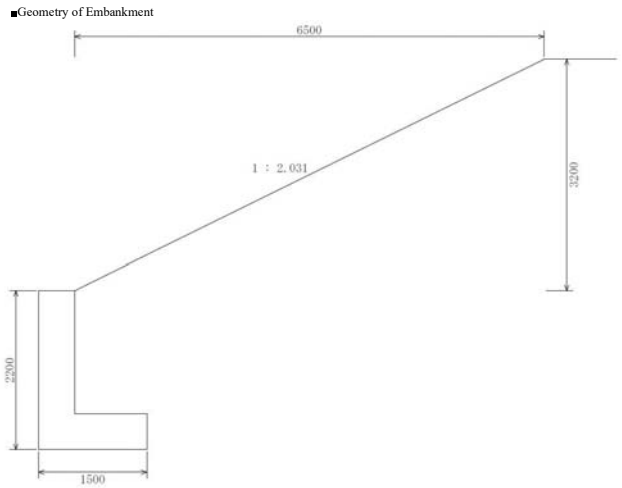
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φres	○	30
Peak Angle of Internal Friction	φpeak	○	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm²/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D16	250	794.4
	Bottom Face	115.0	D16	250	794.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

1.1.4 Loads

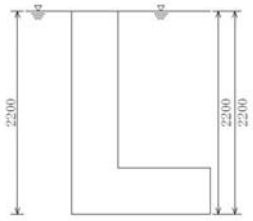
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

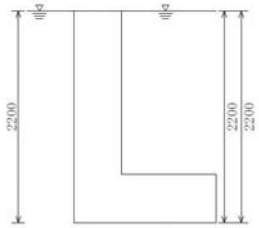
	(m)
Toe	2.200
Heel	2.200



1-2) Seismic Condition Number of Cases [1]

<Case 1>

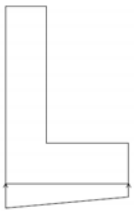
	(m)
Toe	2.200
Heel	2.200
Direction	Back → Front



2) Subgrade Reaction

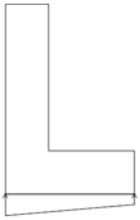
2-1) Normal <Case 1>

	(kN/m²), (m)
Toe	78.22
Heel	42.41
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m²), (m)
Toe	65.24
Heel	31.62
Load Width	0.000



3) Surcharge Load

Normal	kN/m²	10.00
Seismic	kN/m²	5.00

4) Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W = 26.623 (kN/m)

※ξ_{EA} (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (26.623+ 10.00× 2.300)/ 1.700

= 15.661 (kN/m^2)

Earth Pressure at the Top

p1 = q0'・Ko = 15.661 × 0.500 = 7.830 (kN/m^2)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.000+ 7.830

= 7.830 (kN/m^2)

Earth Pressure at Junction

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500×(20.00- 9.80)× 1.700+ 7.830

= 16.500 (kN/m^2)

Design Earth Pressure

P = p3

=16.500 (kN/m^2)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

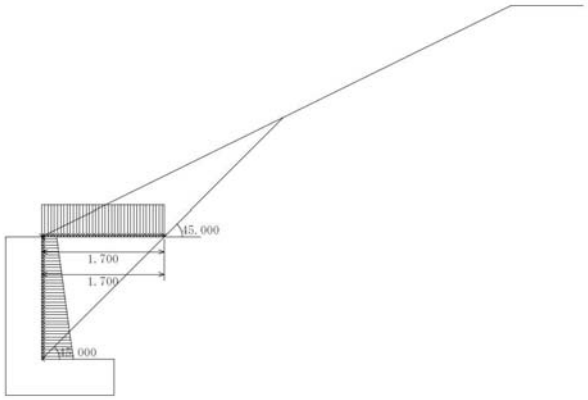
q_0 : Surcharge (kN/m^2)

w_{q0} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 1.700 9.80 = 16.660 (kN/m^2)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

(2) Seismic Condition-1

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.500 × 24.00 × 0.20 = 2.400

Thus、

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	0.000	(m)
Embankment Height under the water level surface	h2	=	1.700	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_t	=	19.00	(kN/m^3)
Unit Weight of Soil (Dry)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	0.000	(m)
Width of Converted Load	B	=	1.866	(m)
Internal Friction Angle of Soil	φ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh	=	0.303	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}(kh)$	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}(kh')$	=	16.855	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$\cot(\xi_{EA}-\alpha) = 0.85094$

Thus,

$$\cot(\xi_{EA}-0.00^\circ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 16.855^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 16.855^\circ)}}$$

$\cot(\xi_{EA}'-\alpha) = 1.09764$

Thus,

$$\cot(\xi_{EA}'-0.00^\circ) = \frac{1}{\tan(\xi_{EA}')} = 1.09764$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{1.09764}\right) = 42.335^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$= 0.4733$

In case φ-α-θ_o< 0, sin(φ-α-θ_o) = 0.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 16.855^\circ - 0.00^\circ)}{\cos(16.855^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 16.855^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 16.855^\circ)}{\cos(0.00^\circ + 16.855^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$= 0.5726$

In case φ-α-θ'$_o$< 0, sin(φ-α-θ'$_o$) = 0.

Weight of Embankment W = 28.025 (kN/m)

Converted Load q0' = (W + q0・wq0) / B

= (28.025+ 5.00× 0.000) / 1.866

= 15.019 (kN/m^2)

Earth Pressure at the Top

P1 = q0'・K_{EA} = 15.019× 0.4733 = 7.108 (kN/m^2)

Earth Pressure at Water Level

$P2 = K_{EA} \cdot \gamma_t \cdot h1 + p1$

$= 0.4733 \times 19.00 \times 0.000 + 7.108$

$= 7.108$ (kN/m^2)

Earth Pressure at Junction

$P3 = K_{EA} \cdot (\gamma_{sat}-\gamma_w) \cdot h2 + p2$

$= 0.5726 \times (20.00- 9.80) \times 1.700 + 7.108$

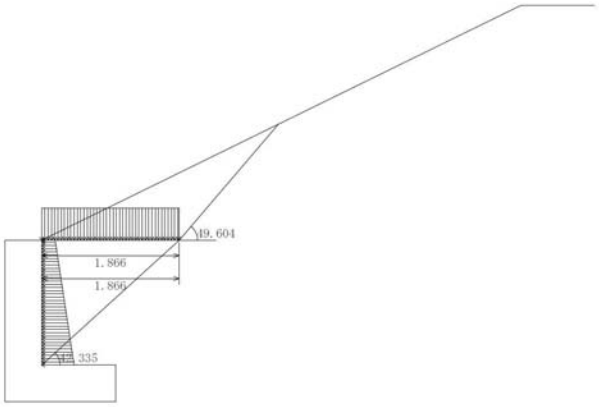
$= 17.036$ (kN/m^2)

Design Earth Pressure

$P_{HE} = P3 \cdot \cos\delta = 17.036 \times \cos(0.00°)$

$= 17.036$ (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$Ph = hh \cdot \gamma_w = 1.700 \times 9.80 = 16.660$ (kN/m^2)

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^2)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m^2)	L (m)	P･l^2/2 (kN.m/m)
Water Pressure	16.66	1.000	8.33
Earth Pressure	16.50	1.000	8.25
Σ	33.16	----	16.58
Bending Moment M (kN.m/m) Σ(P・l^2/2) = 16.58			
Shear Force S (kN/m) Σ(P・l) = 33.16			

2) Seismic Condition-1

	P (kN/m^2)	L (m)	P･l^2/2 (kN.m/m)
Inertia force	2.40	1.000	1.20
Water Pressure	16.66	1.000	8.33
Earth Pressure	17.04	1.000	8.52
Σ	36.10	----	18.05
Bending Moment M (kN.m/m) Σ(P・l^2/2) = 18.05			
Shear Force S (kN/m) Σ(P・l) = 36.10			

1.2.3 Stress Calculation

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Front	mm^2	D16 - 4.00 =794.4
	Back	mm^2	D16 - 4.00 =794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	16.58
Re-bar	d1 As1	mm mm^2	410.0 794.4
Required Area of Re-bar	Back	mm^2	299.7
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm^2	1.23
	σs	N/mm^2	53.96
Allowable Value	σca	N/mm^2	8.20
	σsa	N/mm^2	140.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	399.6
	inp	mm^2	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	18.05
Re-bar	d1 As1	mm mm^2	410.0 794.4
Required Area of Re-bar	Back	mm^2	244.7
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm^2	1.34
	σs	N/mm^2	58.74
Allowable Value	σca	N/mm^2	12.30
	σsa	N/mm^2	186.00
Minimum Area of Re-Bar	min	mm^2	
	req	mm^2	326.3
	inp	mm^2	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	33.16
Re-bar	d1 As1	mm mm^2	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.081
Allowable Value	τa	N/mm^2	0.360
	τa2	N/mm^2	1.600

■Seismic Condition-1

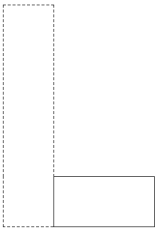
	Symbol	Unit	Junction
Shear Force	S	kN	36.10
Re-bar	d1 As1	mm mm^2	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.088
Allowable Value	τa	N/mm^2	0.540
	τa2	N/mm^2	2.400

1.3 Calculation of Heel Slab

1.3.1 Load

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

Thus,

Sw : Weight of Body (kN/m^2)

h :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

1-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.700× 20.00 = 34.000

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.492× 19.00 + 1.700× 20.00 = 43.354

Thus、

Pw1 :Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

1-3) Subgrade Reaction Force

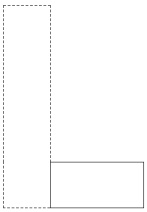
	Intensity of subgrade reaction (kN/m^2)
Base	66.28
Edge	42.41

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.200× 9.80	21.560
Edge	2.200× 9.80	21.560

(2) **) Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

Thus、

Sw : Weight of Wall (kN/m^2)

H :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.700× 20.00 = 34.000

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.492× 19.00 + 1.700× 20.00 = 43.354

Thus、

Pw1 :Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	54.03
Edge	31.62

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.200× 9.80	21.560
Edge	2.200× 9.80	21.560

1.3.2 Summary of Cross Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-34.00	1.000	-17.00
Uplift Force	21.56	1.000	10.78
Intensity of Subgrade Reaction	66.28	1.000	33.14
Σ	41.84	----	20.92
Bending Moment M(kN.m/m) Σ(P・l^2/2) = 20.92			
Shear Force S(kN/m) Σ(P・l) = 41.84			

1-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-43.35	1.000	-21.68
Uplift Force	21.56	1.000	10.78
Intensity of Subgrade Reaction	42.41	1.000	21.20
Σ	8.62	----	4.31
Bending Moment M (kN.m/m) Σ(P・l^2/2) = 4.31			
Shear Force S (kN/m) Σ(P・l) =8.62			

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-34.00	1.000	-17.00
Uplift Force	21.56	1.000	10.78
Intensity of Subgrade Reaction	54.03	1.000	27.02
Σ	29.59	----	14.80
Bending Moment M (kN.m/m) Σ(P・l^2/2) = 14.80			
Shear Force S (kN/m) Σ(P・l) = 29.59			

2-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-43.35	1.000	-21.68
Uplift Force	21.56	1.000	10.78
Intensity of Subgrade Reaction	31.62	1.000	15.81
Σ	-2.17	----	-1.09
Bending Moment M (kN.m/m) Σ(P・l²/2) = -1.09			
Shear Force S (kN/m) Σ(P・l) = -2.17			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Upper	mm²	D16 - 4.00 =794.4
	Lower	mm²	D16 - 4.00 =794.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	20.92	4.31
Re-bar	d1 As1	mm mm²	385.0 794.4	385.0 794.4
Required Area of Re-bar	Lower	mm²	405.5	81.6
Neutral Axis	X	m	0.067	0.067
Stress Intensity	σc	N/mm²	1.71	0.35
	σs	N/mm²	72.65	14.96
Allowable Value	σca	N/mm²	8.20	8.20
	σsa	N/mm²	140.00	140.00
Minimum of Re-bar Area	min	mm²		
	req	mm²	540.7	108.7
	inp	mm²	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	14.80	-1.09
Re-bar	d1 As1	mm mm²	385.0 794.4	90.0 794.4
Required Area of Re-bar	Upper	mm²		14.4
	Lower	mm²	213.4	
Neutral Axis	X	m	0.067	0.070
Stress Intensity	σc	N/mm²	1.21	0.08
	σs	N/mm²	51.38	3.54
Allowable Value	σca	N/mm²	12.30	12.30
	σsa	N/mm²	186.00	186.00
Minimum of Re-bar Area	min	mm²		
	req	mm²	284.5	19.2
	inp	mm²	794.4	794.4

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	41.84	8.62
Re-bar	d1 As1	mm mm²	385.0 794.4	385.0 794.4
Effective Height	d	mm	385.0	385.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.109	0.022
Allowable Value	τa	N/mm²	0.360	0.360
	τa2	N/mm²	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	29.59	-2.17
Re-bar	d1 As1	mm mm²	385.0 794.4	90.0 794.4
ffective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.077	0.005
Allowable Value	τa	N/mm²	0.540	0.540
	τa2	N/mm²	2.400	2.400

2.2.2.6 SLUICEWAY TYPE I

(4) BREAST WALL - RIVER SIDE

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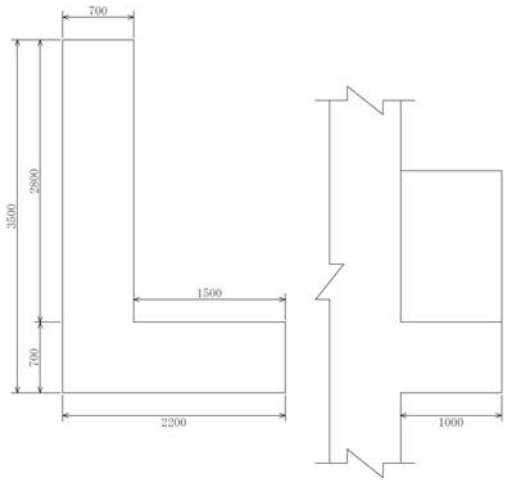
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1 Calculation of River Side Breast Wall

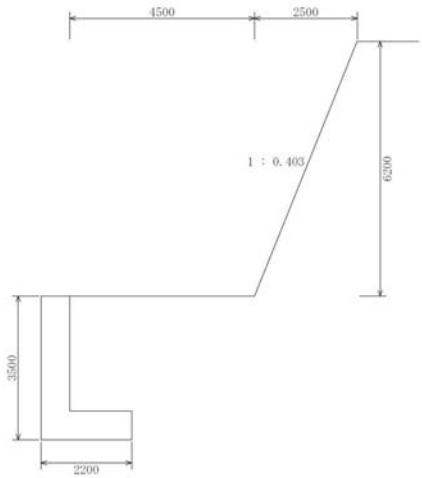
1.1 Design Condition

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 **Material and Design Parameters**

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φres	°	30
Peak Angle of Internal Friction	φpeak	°	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 **Reinforcement Arrangement**

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm²/m)
all	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D16	250	794.4
	Bottom Face	115.0	D16	250	794.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 **Loads**

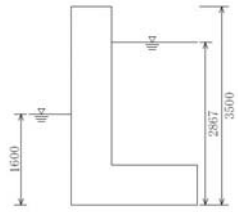
■Basic Load

1)Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

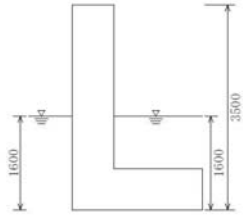
	(m)
Toe	1.600
Heel	2.867



1-2) Seismic Condition Number of Cases [1]

<Case 1>

	(m)
Toe	1.600
Heel	1.600
Direction	Back → Front



2)Subgrade Reaction

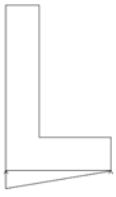
2-1) Normal <Case 1>

	(kN/m²), (m)
Toe	161.74
Heel	12.13
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m²), (m)
Toe	140.84
Heel	4.72
Load Width	0.000



3)Surcharge Load

Normal	kN/m²	10.00
Seismic	kN/m²	5.00

4)Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W =0.000 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (0.000+ 10.00× 0.000)/ 2.800

= 0.000 (kN/m²)

Earth Pressure at the Top

p1 = q0'・Ko = 0.000× 0.500 = 0.000 (kN/m²)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.633+ 0.000

= 6.014 (kN/m²)

Earth Pressure at Bottom Surface of Base

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500× (20.00- 9.80)× 2.167+ 6.014

= 17.065 (kN/m²)

Design Earth Pressure

P = p3

= 17.065 (kN/m²)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

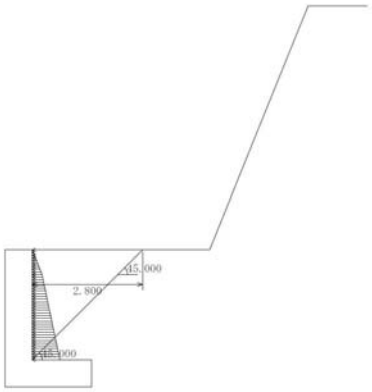
q_0 : Surcharge (kN/m²)

w_{qo} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Loads Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 2.167× 9.80 =21.237 (kN/m²)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m²)

(2) Seismic Condition-1

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.700 × 24.00 × 0.20 = 3.360

Thus、

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m³)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	1.900	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_t	=	19.00	(kN/m³)
Surcharge	q0	=	5.00	(kN/m²)
Load width of Surcharge	wq0	=	0.000	(m)
Width of Converted Load	B	=	2.447	(m)
Internal Friction Angle of Soil	ϕ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}(kh)$	=	11.310	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$\cot(\xi_{EA}-\alpha) = 0.85094$

Thus,

$$\cot(\xi_{EA}-0.00^\circ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 13.229^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 13.229^\circ)}}$$

$\cot(\xi_{EA}'-\alpha) = 0.92236$

In case φ-α-θ_o< 0, sin(φ-α-θ_o) = 0.

Weight of Embankment	W	W = 0.000 (kN/m)
Converted Load	q0'	q0' = (W + q0・wq0) / B
		= (0.000+ 5.00× 0.000) / 2.447
		= 0.000 (kN/m²)

Earth Pressure at the Top

P1 = q0'・K_{EA} = 0.000× 0.4733 = 0.000 (kN/m²)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 1.900+ 0.000

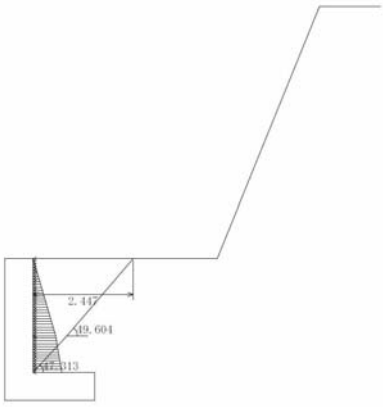
= 17.085 (kN/m²)

Design Earth Pressure

P_{HE} = P2 ・cosδ=21.715×cos (0.00°)

= 21.715 (kN/m²)

■Figure of Converted Load Acting on Breast Wall



1.2.2 **Summary of Cross-sectional Internal Forces**

1) Normal Condition-1

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Water Pressure	21.24	1.000	10.62
Earth Pressure	17.07	1.000	8.53
Σ	38.30	----	19.15
Bending Moment M (kN.m/m) Σ(P・l²/2) = 19.15			
Shear Force S (kN/m) Σ(P・l) = 38.30			

2) Seismic Condition-1

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Inertia force	3.36	1.000	1.68
Earth Pressure	8.82	1.000	4.41
Σ	21.71	1.000	10.86
Bending Moment M (kN.m/m) Σ(P・l²/2) = 16.95			
Shear Force S (kN/m) Σ(P・l) = 33.89			

1.2.3 **Stress Calculation**

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Front	mm²	D16 - 4.00 = 794.4
	Back	mm²	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	19.15
Re-bar	d1 As1	mm mm²	610.0 794.4
Required Area of Re-bar	Back	mm²	230.3
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm²	0.76
	σs	N/mm²	41.48
Allowable Value	σca	N/mm²	8.20
	σsa	N/mm²	140.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	307.1
	inp	mm²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	16.95
Re-bar	d1 As1	mm mm²	610.0 794.4
Required Area of Re-bar	Back	mm²	152.7
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm²	0.67
	σs	N/mm²	36.71
Allowable Value	σca	N/mm²	12.30
	σsa	N/mm²	186.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	203.6
	inp	mm²	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	38.30
Re-bar	d1 As1	mm mm²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.063
Allowable Value	τa	N/mm²	0.360
	τa2	N/mm²	1.600

■Seismic Condition-1

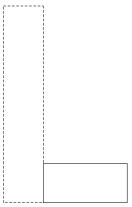
	Symbol	Unit	Junction
Shear Force	S	kN	33.89
Re-bar	d1 As1	mm mm²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.056
Allowable Value	τa	N/mm²	0.540
	τa2	N/mm²	2.400

1.3 **Calculation of Bottom Slab**

1.3.1 **Load**

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γc= 0.700 × 24.00 = 16.800

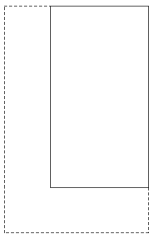
Thus,

Sw : Weight of Body (kN/m²)

h :Height of Bottom Slab (m)

γc : Unit Weight of Concrete (kN/m³)

1-2) Weight of the Embankment



Pw1 = (h1・γt+ h2・γsat) = 0.633× 19.00 + 2.167× 20.00 = 55.367

Pw2 = (h1・γt+ h2・γsat) = 0.633× 19.00 + 2.167× 20.00 = 55.367

Thus、

Pw1 : Wight of Embankment at basis (kN/m²)

Pw2 : Weight of Embankment at edge (kN/m²)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γt : Wet Unit Weight of Soil (kN/m³)

γsat : Unit Weight of Soil underwater (kN/m³)

1-3) Subgrade Reaction Force

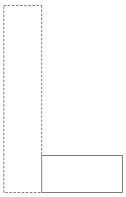
	Intensity of subgrade reaction (kN/m²)
Base	114.14
Edge	12.13

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m²)
Base	2.003× 9.80	19.631
Edge	2.867× 9.80	28.097

(2) **Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

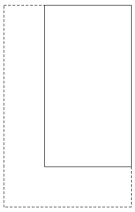
Thus、

Sw : Weight of Body (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 1.900× 19.00 + 0.900× 20.00 = 54.100

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 1.900× 19.00 + 0.900× 20.00 = 54.100

Thus、

Pw1 : Wight of Embankment at basis (kN/m²)

Pw2 : Weight of Embankment at edge (kN/m²)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	97.53
Edge	4.72

1.3.2 **Summary of Cross Sectional Force**

1) Normal Condition-1

1-1) Junction Section

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-55.37	1.000	-27.68
Uplift Force	19.63	1.000	9.82
Intensity of Subgrade Reaction	114.14	1.000	57.07
Σ	61.60	----	30.80
Bending Moment M (kN.m/m) Σ(P・l²/2) = 30.80			
Shear Force S (kN/m) Σ(P・l) = 61.60			

1-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-55.37	1.000	-27.68
Uplift Force	28.10	1.000	14.05
Intensity of Subgrade Reaction	12.13	1.000	6.07
Σ	-31.94	----	-15.97
Bending Moment M (kN.m/m) Σ(P・l²/2) = -15.97			
Shear Force S (kN/m) Σ(P・l) = -31.94			

2) Seismic Condition-1

2-1) Base

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-54.10	1.000	-27.05
Intensity of Subgrade Reaction	15.68	1.000	7.84
Σ	97.53	1.000	48.76
Bending Moment M (kN.m/m) Σ(P・l²/2) = 21.15			
Shear Force S (kN/m) Σ(P・l) = 42.31			

2-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-54.10	1.000	-27.05
Intensity of Subgrade Reaction	15.68	1.000	7.84
Σ	4.72	1.000	2.36
Bending Moment M (kN.m/m) Σ(P・l²/2) = -25.25			
Shear Force S (kN/m) Σ(P・l) = -50.50			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Upper	mm^2	D16 - 4.00 = 794.4
	Lower	mm^2	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	30.80	-15.97
Re-bar	d1 As1	mm mm^2	585.0 794.4	90.0 794.4
Required Area of Re-bar	Upper	mm^2		191.6
	Lower	mm^2	389.5	
Neutral Axis	X	m	0.085	0.087
Stress Intensity	σc	N/mm^2	1.31	0.64
	σs	N/mm^2	69.63	34.59
Allowable Value	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	519.4	255.5
	inp	mm^2	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	21.15	-25.25
Re-bar	d1 As1	mm mm^2	585.0 794.4	90.0 794.4
Required Area of Re-bar	Upper	mm^2		228.6
	Lower	mm^2	199.4	
Neutral Axis	X	m	0.085	0.087
Stress Intensity	σc	N/mm^2	0.90	1.00
	σs	N/mm^2	47.83	54.69
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	265.9	304.7
	inp	mm^2	794.4	794.4

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	61.60	-31.94
Re-bar	d1 As1	mm mm^2	585.0 794.4	90.0 794.4
Effective Height	d	mm	585.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.105	0.052
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	42.31	-50.50
Re-bar	d1 As1	mm mm^2	585.0 794.4	90.0 794.4
Effective Height	d	mm	585.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.072	0.083
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400

2.2.2.7 SLUICEWAY TYPE J

(1) BOX - LONGITUDINAL

Structural Calculation of Sluiceway Type-J

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1 Design Condition

1.1 Design Condition

1.1.1 Basic Condition

1) Culvert Shape:Rectanglar

2) Culvert Type: Double Holes

3) Allowable Displacement

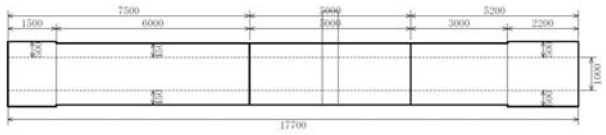
Residual Settlement : 300.0 (mm)
Residual Settlement for Rigid Support : 50.0 (mm)
Relative Displacement Base Width : 1.0 (%)
± : 50.0 (mm)

4) Type of Joint : Flexible Joint

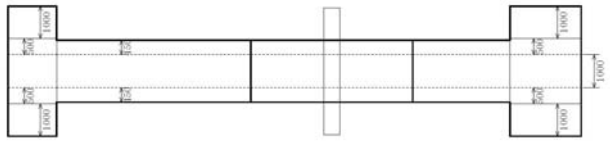
5) Allowable Opening : 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

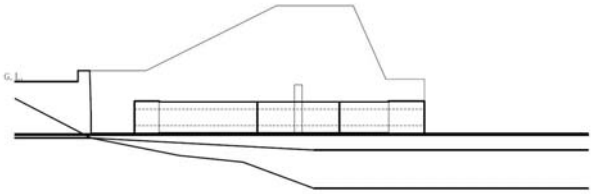
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Leeve Cross-section



1.2 Shape of Culvert Body

1.2.1 Span and Block

1) Spans

Number of Spans: 3
Total Length of Spans: 17.700 (m)

Span No	Name of Span	Length of Span (m)	Number of Blocks
1	Land Side	7.500	2
2	Center	5.000	1
3	River Side	5.200	2

2) Blocks

Span/ Block	Length of Block (m)	Depth for Subgrade Reaction(m)
1- 1	1.500	12.000
1- 2	6.000	5.700
2- 1	5.000	5.700
3- 1	3.000	5.700
3- 2	2.200	11.700

1.2.2 Sectional Dimension

1) Dimension (Block)

Span/ Block	Left Inside Width X2 (m)	Inside Height Y2 (m)
1- 1	1.000	1.000
1- 2	1.000	1.000
2- 1	1.000	1.000
3- 1	1.000	1.000
3- 2	1.000	1.000

Span/ Block	Thickness of Left Side Wall X1(m)	Thickness of Top Slab Y1(m)	Thickness of Bottom Slab Y3(m)	Height of Overhang Y4(m)	Length of Left Overhang B1(m)
1- 1	0.500	0.500	0.500	0.500	1.000
1- 2	0.450	0.450	0.450	0.000	0.000
2- 1	0.450	0.450	0.450	0.000	0.000
3- 1	0.450	0.450	0.450	0.000	0.000
3- 2	0.500	0.500	0.500	0.700	1.000

1.3 Reinforcement

Main Re-bar

Span No	Block No	Flange		Reinforcing Bar				
		Portion	b (mm)	t (mm)	Outside Diameter@Pitch (Number)	Outside Cover (mm)	Inside Diameter@Pitch (Number)	Inside Cover (mm)
1	1	Top Slab	2000.0	500.0	D16@250(6)	90.0	D16@250(8)	90.0
		Bottom Slab	2000.0	500.0	D16@250(6)	115.0	D16@250(8)	90.0
	2	Top Slab	1900.0	450.0	D22@250(6)	90.0	D22@250(8)	90.0
		Bottom Slab	1900.0	450.0	D22@250(6)	115.0	D22@250(8)	90.0
2	1	Top Slab	1900.0	450.0	D22@250(6)	90.0	D22@250(8)	90.0
		Bottom Slab	1900.0	450.0	D22@250(6)	115.0	D22@250(8)	90.0
3	1	Top Slab	1900.0	450.0	D19@250(6)	90.0	D19@250(8)	90.0
		Bottom Slab	1900.0	450.0	D19@250(6)	115.0	D19@250(8)	90.0
	2	Top Slab	2000.0	500.0	D19@250(6)	90.0	D19@250(8)	90.0
		Bottom Slab	2000.0	500.0	D19@250(6)	115.0	D19@250(8)	90.0

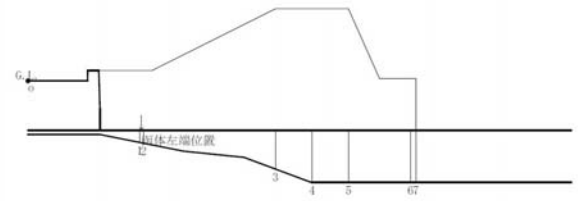
2 Settlement and Lateral Displacement

2.1 Immediate Settlement

2.1.1 Settlemet Calculation Points

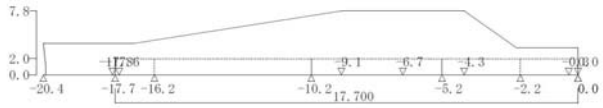
Settlemet Calculation Points

No	Calculation Point (m)	Name
1	-17.800	Box end (land side)
2	-17.550	Breast wall (land side)
3	-9.050	Levee end (land side)
4	-6.700	Levee center
5	-4.350	Levee end (river side)
6	-0.350	Breast wall (river side)
7	0.000	Box end (river side)



2.1.2 Summery of Immediate Settlement

No	Calculation Point (m)	Name	Immediate Settlement (mm)
1	-17.800	Box end (land side)	22.8
2	-17.550	Breast wall (land side)	23.1
3	-9.050	Levee end (land side)	33.8
4	-6.700	Levee center	35.4
5	-4.350	Levee end (river side)	32.1
6	-0.350	Breast wall (river side)	9.4
7	0.000	Box end (river side)	6.8



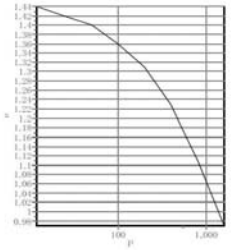


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

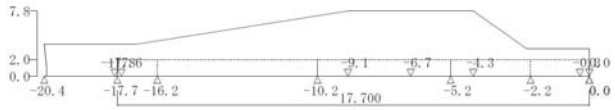
No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/m³)	Unit Weight (Saturated) (kN/m³)	Pre-Consolidation Stress q0 (kN/m²)	Elastic Modulus Es (kN/m²)
1	Adobe BL	Sand	3.151	17.500	18.500	0.0	6900.0
2	Dc4	Clay	3.410	17.500	18.500	0.0	15700.0

No	Concolidation Pressure P(kN/m²)	Void Ratio e
1	12.0000	1.4400
2	25.0000	1.4200
3	50.0000	1.4000
4	100.0000	1.3600
5	200.0000	1.3100
6	400.0000	1.2300
7	800.0000	1.1100
8	1600.0000	0.9700



2.2.2 Summery of Consolidation Settlement

No	Calculation Point (m)	Name	Consolidation Settlement (mm)
1	-17.800	Box end (land side)	20.9
2	-17.550	Breast wall (land side)	22.3
3	-9.050	Levee end (land side)	106.1
4	-6.700	Levee center	139.0
5	-4.350	Levee end (river side)	129.5
6	-0.350	Breast wall (river side)	56.6
7	0.000	Box end (river side)	42.8



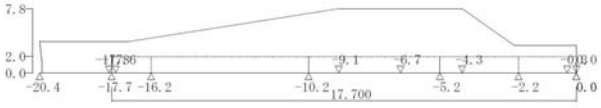


2.3 Residual Settlement

2.3.1 Sumarry of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vaue	Judge
1	-17.800	Box end (land side)	22.8	18.6	0.0	41.4	300.000	OK
2	-17.550	Breast wall (land side)	23.1	20.0	0.0	43.1	300.000	OK
3	-9.050	Levee end (land side)	33.8	102.0	0.0	135.8	300.000	OK
4	-6.700	Levee center	35.4	135.0	0.0	170.4	300.000	OK
5	-4.350	Levee end (river side)	32.1	125.5	0.0	157.5	300.000	OK
6	-0.350	Breast wall (river side)	9.4	54.6	0.0	64.0	300.000	OK
7	0.000	Box end (river side)	6.8	41.8	0.0	48.6	300.000	OK

The maximum of residual settlement is above 50.0(mm), herence the foundation is taken as flexible





▽ : Immediate Settlement
○ : Residual Settlement

3 Calculation of Box Culvert regarding Longitudal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B}\cdot\frac{d^4w}{dx^4}+k_v(w-w_g)=q \text{ (Swag)}$$

$$\frac{EA}{U}\cdot\frac{d^2u}{dx^2}+k_s(u-u_g)=p \text{ (Displacement in axial direction of Box Culvert)}$$

Thus,

w : Displacement of Box Culvert (Swag : cm {m})
w_g : Displacement of the Ground (Residual Settlement: cm {m})
k_v : Modulus of Sub grade Reaction in Vertical Direction (kgf/cm^3) {kN/m^3}
B : Width of Box Culvert (cm) {m}
EI : Rigidity of Box Culvert (kgf･cm^2) {kN･m^2}
q : Vertical External Force (kgf/cm^2) {kN/m^2}
u : Displacement on axial direction of Box Culvert (cm) {m}
u_g : Displacement of Ground (Lateral Displacement ; cm {m})
k_s : Modulus of Lateral Shear Sub grade Reaction (kgf/cm^3) {kN/m^3}
U : Circumference of Box Culvert (cm) {m}
EA : Rigidity of Box Culvert in axial direction (kgf) {kN}
p : Axial External Force (kgf/cm^2) {kN/m^2}

3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{om}=\frac{\log\frac{(B+2h_n\cdot\tan\theta)\cdot L}{(L+2h_n\cdot\tan\theta)\cdot B}}{\Sigma\frac{1}{E_i}\log\frac{(B+2h_i\cdot\tan\theta)(L+2h_{i-1}\cdot\tan\theta)}{(L+2h_i\cdot\tan\theta)(B+2h_{i-1}\cdot\tan\theta)}}$$

In case of B=L

$$E_{om}=\frac{-\frac{1}{B+2h_n\cdot\tan\theta}+\frac{1}{B}}{\Sigma\frac{1}{E_i}\left(-\frac{1}{B+2h_i\cdot\tan\theta}+\frac{1}{B+2h_{i-1}\cdot\tan\theta}\right)}$$

Thus,

Eom ; Converted Modulus of Deformation
B ; Loading Width = Width of Culvert
L ; Loading Length = Length of a span
hn ; Depth for Calculation
hn ; Depth from the ground to the bottom Elevation of Each Layer（m）
Ei ; Converted Modulus of Deformation of Each Layer(kN/m^2)
θ ; Angle of Load Dispersion（θ=30°）

Span1-Block1 Land Side

B			4.000 (m)
L			7.500 (m)
hn			12.000 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	12.000	12.000	62800.0
Total	12.000		
Eom	62800.0 (kN/m^2)		

※Layer Thickness and Depths are the values based on subgrade Surface.

Span1-Block2 Land Side

B			1.900 (m)
L			7.500 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	5.700	5.700	62800.0
Total	5.700		
Eom	62800.0 (kN/m2)		

※Layer Thickness and Depths are values Calculated from the subgrade

Span2-Block1 Center

B			1.900 (m)
L			5.000 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	5.700	5.700	62800.0
Total	5.700		
Eom	62800.0 (kN/m2)		

※Layer and Depth is the values from the subgrade

Span3-Block1 River Side

B			1.900 (m)
L			5.200 (m)
hn			5.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	5.700	5.700	62800.0
Total	5.700		
Eom	62800.0 (kN/m2)		

※Layer and Depth is the values from the subgrade

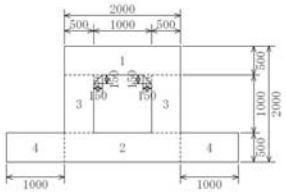
Span3-Block2 River Side

B			4.000 (m)
L			5.200 (m)
hn			11.700 (m)
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m^2)
1	11.700	11.700	62800.0
Total	11.700		
Eom	62800.0 (kN/m2)		

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

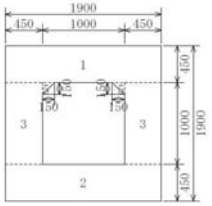
Span1-Block1 Land Side



Position	Ai (m^2)	Yi (m)	Ai･Yi (m^3)	Ai･Yi^2 (m^3)	Ioi (m^4)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.023	1.450	0.0326	0.0473	0.00003
Total	4.023		3.2826	4.2348	0.14586

Yg = Σ(Ai･Yi)/ΣAi = 3.2826 / 4.023 = 0.8161 (m)
I = Σ(Ai･Yi2)+ΣIoi - Yg2･ΣAi = 4.2348 + 0.14586 - 0.6660･4.023= 1.70183 (m^4)

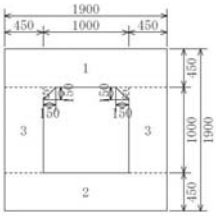
Span1-Block2 Land Side



Position	Ai (m^2)	Yi (m)	Ai･Yi (m^3)	Ai･Yi^2 (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.633 = 0.9538 (m)
I = Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.633= 1.00722 (m^4)

Span2-Block1　Center

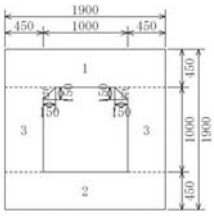


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.632 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.633= 1.00722 (m^4)

Span3-Block1　River Side

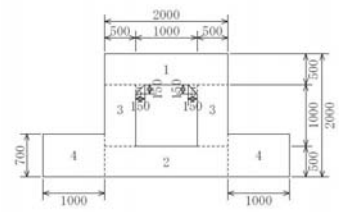


Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

Yg = Σ(Ai・Yi)/ΣAi = 2.5110 / 2.633 = 0.9538 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 3.2984 + 0.10388 - 0.9098・2.633 = 1.00722 (m^4)

Span3-Block2　River Side



Position	Ai (m^2)	Yi (m)	Ai・Yi (m^3)	Ai・Yi² (m^3)	Ioi (m^4)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.400	0.350	0.4900	0.1715	0.05717
5	0.023	1.450	0.0326	0.0473	0.00003
Total	4.423		3.5226	4.3438	0.18219

Yg = Σ(Ai・Yi)/ΣAi = 3.5226 / 4.423 = 0.7965 (m)

I　= Σ(Ai・Yi2)+ΣIoi - Yg2・ΣAi = 4.3438 + 0.18219 - 0.6344・4.423 = 1.72015 (m^4)

3.2.3 Table of Modulus of Subgarade Reaction

Coefficient of Lateral Shear Reaction of Soil

$k_s = \lambda \cdot k_v$

Thus、

ks　: Coefficient of Lateral Shear Reaction of Soil (kN/m2)

λ　; Ratio between the coefficient of Lateral Shear Reaction of Soil and Vertical Sub grade Reaction (=0.333)

kv　: Coefficient of Vertical Sub grade Reaction

3.2.4 List of Modulus of Subgrade Reaction

Calculated Value

Normal Condition

Span Block	Position (m)	B (m)	k_v (kN/m^3)	k_s (kN/m^3)	$k_v \cdot B$ (kN/m^2)	$k_s \cdot B$ (kN/m^2)
1-1	-17.700～-16.200	4.000	23700.6	7892.3	94802.3	31569.2
1-2	-16.200～-10.200	1.900	31332.8	10433.8	59532.3	19824.2
2-1	-10.200～ -5.200	1.900	36478.2	12147.2	69308.5	23079.7
3-1	-5.200～ -2.200	1.900	35945.6	11969.9	68296.6	22742.8
3-2	-2.200～ 0.000	4.000	27189.8	9054.2	108759.1	36216.8

Seismic Condition

Span Block	Position (m)	B (m)	k_v (kN/m^3)	k_s (kN/m^3)	$k_v \cdot B$ (kN/m^2)	$k_s \cdot B$ (kN/m^2)
1-1	-17.700～-16.200	4.000	47401.1	15784.6	189604.6	63138.3
1-2	-16.200～-10.200	1.900	62665.5	20867.6	119064.5	39648.5
2-1	-10.200～ -5.200	1.900	72956.3	24294.5	138617.0	46159.5
3-1	-5.200～ -2.200	1.900	71891.2	23939.8	136593.2	45485.5
3-2	-2.200～ 0.000	4.000	54379.5	18108.4	217518.2	72433.6

Used Value

Normal Condition

Span Block	Position (m)	$k_v \cdot B$ (kN/m^2)	$k_s \cdot B$ (kN/m^2)
1-1	-17.700～-16.200	94802.3	31569.2
1-2	-16.200～-10.200	59532.3	19824.2
2-1	-10.200～ -5.200	69308.5	23079.7
3-1	-5.200～ -2.200	68296.6	22742.8
3-2	-2.200～ 0.000	108759.1	36216.8

Seismic Condition

Span Block	Position (m)	Reduction Ratio DE	$k_v \cdot B$ (kN/m^2)	$k_s \cdot B$ (kN/m^2)
1-1	-17.700～-16.200	1.000	189604.6	63138.3
1-2	-16.200～-10.200	1.000	119064.5	39648.5
2-1	-10.200～ -5.200	1.000	138617.0	46159.5
3-1	-5.200～ -2.200	1.000	136593.2	45485.5
3-2	-2.200～ 0.000	1.000	217518.2	72433.6

3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

W = (A1 + A2 + A3) ・γc (kN/m)

A1: Cross Sectional Area (Excluding Hunch) (m^2)

A2: Area of Upper Side Hunch (m^2)

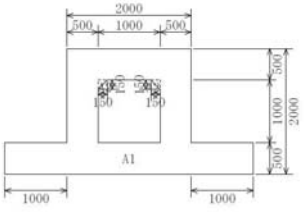
A3: Area of Lower Side Hunch (m^2)

γc: Unit Weight (Concrete) (kN/m^3)

Span No.　1-1　Land Side

W = (　4.000 +　　0.023 +　　0.000)・ 24.000

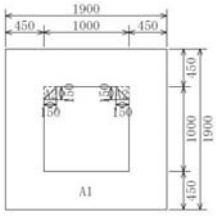
=　　96.540 (kN/m)



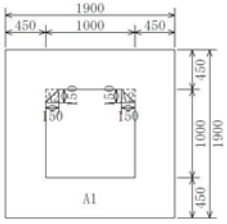
Span No.　1-2　Land Side

W = (　2.610 +　　0.023 +　　0.000)・ 24.000

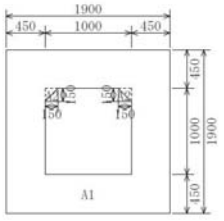
=　　63.180 (kN/m)



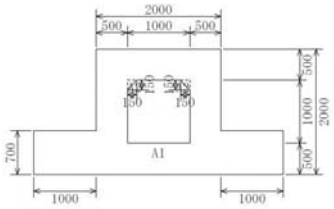
Span No. 2-1 Center
W = (2.610 + 0.023 + 0.000) · 24.000
= 63.180 (kN/m)



Span No. 3-1 River Side
W = (2.610 + 0.023 + 0.000) · 24.000
= 63.180 (kN/m)



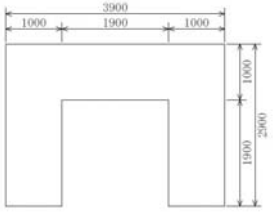
Span No. 3-2 River Side
W = (4.400 + 0.023 + 0.000 + 0.000) · 24.000
= 106.140 (kN/m)



2) Seepage Cutoff Wall Body Weight

A1 = X1・L2
A2 = L1・Y1・2
W = (A1 + A2) ・B・γc (kN)
X1: Top Slab Width (m)
Y1: Side Wall Height (m)
L1: Side Wall Width (m)
L2: Top Slab Height (m)
A1: Top Slab Area (m^2)
A2: Side Wall Area (m^2)
B: Thickness (m)
γc: Unit Weight (Concrete) (kN/m^3)

SpanNo.2-SpanDistance from Base Point (2.400)
A1 = 3.900・ 1.000
= 3.900 (m^2)
A2 = 1.000・ 1.900・2
= 3.800 (m^2)
W = (3.900 + 3.800)・ 0.500・ 24.00
= 92.400 (kN)



3.3.2 Ground Displacement Load (Settlement、Lateral Displacement)

1) Equivalent Load for Ground Settlement

【Normal Condition】
Span1 Name of Span: [Land Side]

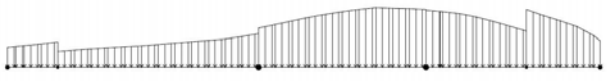
Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-17.700～-17.450	4.000	94802.3	42.1	43.8	-3989.002	-4151.567
1-(2)	-17.450～-17.200	4.000	94802.3	43.8	45.5	-4151.567	-4311.168
1-(3)	-17.200～-16.700	4.000	94802.3	45.5	49.1	-4311.168	-4650.337
1-(4)	-16.700～-16.200	4.000	94802.3	49.1	53.4	-4650.337	-5058.141
2-(5)	-16.200～-15.700	1.900	59532.3	53.4	57.9	-3176.322	-3446.301
2-(6)	-15.700～-15.200	1.900	59532.3	57.9	62.2	-3446.301	-3702.646
2-(7)	-15.200～-14.700	1.900	59532.3	62.2	65.8	-3702.646	-3916.757
2-(8)	-14.700～-14.200	1.900	59532.3	65.8	68.8	-3916.757	-4096.305
2-(9)	-14.200～-13.700	1.900	59532.3	68.8	71.6	-4096.305	-4263.183
2-(10)	-13.700～-13.200	1.900	59532.3	71.6	76.4	-4263.183	-4548.815
2-(11)	-13.200～-12.700	1.900	59532.3	76.4	80.9	-4548.815	-4814.717
2-(12)	-12.700～-12.200	1.900	59532.3	80.9	85.3	-4814.717	-5079.368
2-(13)	-12.200～-11.700	1.900	59532.3	85.3	89.8	-5079.368	-5343.636
2-(14)	-11.700～-11.200	1.900	59532.3	89.8	94.2	-5343.636	-5608.489
2-(15)	-11.200～-10.700	1.900	59532.3	94.2	102.6	-5608.489	-6109.086
2-(16)	-10.700～-10.200	1.900	59532.3	102.6	112.4	-6109.086	-6690.816

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(17)	-10.200～ -9.700	1.900	69308.5	112.4	122.3	-7789.567	-8476.839
1-(18)	-9.700～ -9.200	1.900	69308.5	122.3	132.5	-8476.839	-9181.259
1-(19)	-9.200～ -8.700	1.900	69308.5	132.5	142.9	-9181.259	-9901.002
1-(20)	-8.700～ -8.200	1.900	69308.5	142.9	151.3	-9901.002	-10484.207
1-(21)	-8.200～ -7.700	1.900	69308.5	151.3	158.7	-10484.207	-10998.132
1-(22)	-7.700～ -7.200	1.900	69308.5	158.7	165.3	-10998.132	-11453.517
1-(23)	-7.200～ -6.700	1.900	69308.5	165.3	170.4	-11453.517	-11809.875
1-(24)	-6.700～ -6.200	1.900	69308.5	170.4	168.6	-11809.875	-11683.094
1-(25)	-6.200～ -5.700	1.900	69308.5	168.6	167.5	-11683.094	-11610.909
1-(26)	-5.700～ -5.200	1.900	69308.5	167.5	165.0	-11610.909	-11438.933

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m^2)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(27)	-5.200～ -4.780	1.900	68296.6	165.0	161.9	-11271.923	-11055.528
1-(28)	-4.780～ -4.700	1.900	68296.6	161.9	161.1	-11055.528	-11003.722
1-(29)	-4.700～ -4.200	1.900	68296.6	161.1	155.5	-11003.722	-10617.221
1-(30)	-4.200～ -3.700	1.900	68296.6	155.5	145.8	-10617.221	-9957.077
1-(31)	-3.700～ -3.200	1.900	68296.6	145.8	133.2	-9957.077	-9099.945
1-(32)	-3.200～ -2.700	1.900	68296.6	133.2	119.2	-9099.945	-8142.851
1-(33)	-2.700～ -2.200	1.900	68296.6	119.2	104.9	-8142.851	-7163.407
2-(34)	-2.200～ -1.700	4.000	108759.1	104.9	94.3	-11407.385	-10254.282
2-(35)	-1.700～ -1.200	4.000	108759.1	94.3	84.8	-10254.282	-9219.349
2-(36)	-1.200～ -0.700	4.000	108759.1	84.8	74.4	-9219.349	-8094.063
2-(37)	-0.700～ -0.200	4.000	108759.1	74.4	57.9	-8094.063	-6299.185
2-(38)	-0.200～ 0.000	4.000	108759.1	57.9	48.6	-6299.185	-5290.965



2) Equivalent Load for Ground Settlement

【Seismic Condition】

Span1 Name of Span: [Land Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-17.700～-17.450	4.000	189604.6	42.1	43.8	-7978.005	-8303.133
1-(2)	-17.450～-17.200	4.000	189604.6	43.8	45.5	-8303.133	-8622.336
1-(3)	-17.200～-16.700	4.000	189604.6	45.5	49.1	-8622.336	-9300.675
1-(4)	-16.700～-16.200	4.000	189604.6	49.1	53.4	-9300.675	-10116.283
2-(5)	-16.200～-15.700	1.900	119064.5	53.4	57.9	-6352.643	-6892.602
2-(6)	-15.700～-15.200	1.900	119064.5	57.9	62.2	-6892.602	-7405.292
2-(7)	-15.200～-14.700	1.900	119064.5	62.2	65.8	-7405.292	-7833.515
2-(8)	-14.700～-14.200	1.900	119064.5	65.8	68.8	-7833.515	-8192.610
2-(9)	-14.200～-13.700	1.900	119064.5	68.8	71.6	-8192.610	-8526.366
2-(10)	-13.700～-13.200	1.900	119064.5	71.6	76.4	-8526.366	-9097.630
2-(11)	-13.200～-12.700	1.900	119064.5	76.4	80.9	-9097.630	-9629.434
2-(12)	-12.700～-12.200	1.900	119064.5	80.9	85.3	-9629.434	-10158.736
2-(13)	-12.200～-11.700	1.900	119064.5	85.3	89.8	-10158.736	-10687.272
2-(14)	-11.700～-11.200	1.900	119064.5	89.8	94.2	-10687.272	-11216.979
2-(15)	-11.200～-10.700	1.900	119064.5	94.2	102.6	-11216.979	-12218.173
2-(16)	-10.700～-10.200	1.900	119064.5	102.6	112.4	-12218.173	-13381.632

Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(17)	-10.200～ -9.700	1.900	138617.0	112.4	122.3	-15579.134	-16953.677
1-(18)	-9.700～ -9.200	1.900	138617.0	122.3	132.5	-16953.677	-18362.518
1-(19)	-9.200～ -8.700	1.900	138617.0	132.5	142.9	-18362.518	-19802.004
1-(20)	-8.700～ -8.200	1.900	138617.0	142.9	151.3	-19802.004	-20968.414
1-(21)	-8.200～ -7.700	1.900	138617.0	151.3	158.7	-20968.414	-21996.264
1-(22)	-7.700～ -7.200	1.900	138617.0	158.7	165.3	-21996.264	-22907.034
1-(23)	-7.200～ -6.700	1.900	138617.0	165.3	170.4	-22907.034	-23619.750
1-(24)	-6.700～ -6.200	1.900	138617.0	170.4	168.6	-23619.750	-23366.188
1-(25)	-6.200～ -5.700	1.900	138617.0	168.6	167.5	-23366.188	-23221.818
1-(26)	-5.700～ -5.200	1.900	138617.0	167.5	165.0	-23221.818	-22877.866

Span3 Name of Span: [River Side]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(27)	-5.200～ -4.780	1.900	136593.2	165.0	161.9	-22543.846	-22111.057
1-(28)	-4.780～ -4.700	1.900	136593.2	161.9	161.1	-22111.057	-22007.444
1-(29)	-4.700～ -4.200	1.900	136593.2	161.1	155.5	-22007.444	-21234.443
1-(30)	-4.200～ -3.700	1.900	136593.2	155.5	145.8	-21234.443	-19914.154
1-(31)	-3.700～ -3.200	1.900	136593.2	145.8	133.2	-19914.154	-18199.890
1-(32)	-3.200～ -2.700	1.900	136593.2	133.2	119.2	-18199.890	-16285.702
1-(33)	-2.700～ -2.200	1.900	136593.2	119.2	104.9	-16285.702	-14326.813
2-(34)	-2.200～ -1.700	4.000	217518.2	104.9	94.3	-22814.770	-20508.565
2-(35)	-1.700～ -1.200	4.000	217518.2	94.3	84.8	-20508.565	-18438.698
2-(36)	-1.200～ -0.700	4.000	217518.2	84.8	74.4	-18438.698	-16188.125
2-(37)	-0.700～ -0.200	4.000	217518.2	74.4	57.9	-16188.125	-12598.371
2-(38)	-0.200～ 0.000	4.000	217518.2	57.9	48.6	-12598.371	-10581.931



3.3.3 Point Load from Breast Walls

1) Normal Condition (Case Number: 1)

Case of Normal Condition 1

Name of Normal Load: [Gate Piers and Breast Walls (Normal) 1]

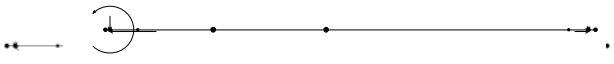
Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-40.40	93.20	-47.97
3	Right Breast Wall	12.920	482.56	249.90	-96.38



2) Seismic Condition (Total Number: 2)

Case of Seismic Conditon 1 [Land Side →River Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-5.53	9.09	-20.15
3	Right Breast Wall	12.920	434.93	99.95	-67.36



Case of Seimic Condition 2 [River Side→Land Side]

Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN･m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-62.33	9.09	-6.90
3	Right Breast Wall	12.920	311.14	99.95	13.36



3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
2	Fixed Load Data 2	Water Weight (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Engaging Load (Normal)1	Gate Structure ･Breast Wall (Normal)1	1.0000
6	Engaging Load (Normal)1	Gate Structure ･Breast Wall (Normal)1	1.0000

2) Seismic Condition

1) Case 1 [Seismic Condition: Land Side→River Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Dead Load)1	Gate Structure ･Breast Wall (Dead Load)1	1.0000
6	Ingaging Load (Seismic)1	Seismic Load :Land Side →River Side	1.0000

2) Case 2 [Seismic Condition: River Side→Land Side]

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data1	Weight of Culvert Body (Normal)	1.0000
3	Fixed Load Data 3	Ground Displacement –Settlement (Normal)	1.0000
4	Fixed Load Data 4	Ground Displacement –Lateral (Normal)	1.0000
5	Ingaging Load (Dead Load)2	Seismic Load	1.0000
6	Ingaging Load (Dead Load)2	Gate Structure ･Breast Wall (Dead Load)2	1.0000

3.4 Displacement between Sluiceway and Adjoining Levee

3.4.1 Normal Condition

1) Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-16.4	-26.1	42.6	42.1	0.5	40.0	○	51.991
2	0.250	-16.4	-25.6	44.7	43.8	0.9	40.0	○	85.350
3	0.500	-16.4	-25.1	46.8	45.5	1.3	40.0	○	121.672
4	1.000	-16.4	-23.8	50.9	49.1	1.8	40.0	○	174.349
5	1.500	-16.4	-22.2	55.0	53.4	1.7	19.0	○	158.392
6	2.000	-16.4	-20.6	59.2	57.9	1.3	19.0	○	75.551
7	2.500	-16.4	-18.9	63.3	62.2	1.1	19.0	○	65.273
8	3.000	-16.4	-17.3	67.4	65.8	1.6	19.0	○	97.230
9	3.500	-16.4	-15.7	71.6	68.8	2.8	19.0	○	163.753
10	4.000	-16.4	-14.1	75.7	71.6	4.1	19.0	○	242.949
11	4.500	-16.4	-12.5	79.8	76.4	3.4	19.0	○	203.393
12	5.000	-16.4	-10.9	84.0	80.9	3.1	19.0	○	183.570
13	5.500	-16.4	-9.3	88.1	85.3	2.8	19.0	○	165.001
14	6.000	-16.4	-7.7	92.2	89.8	2.5	19.0	○	146.817
15	6.500	-16.4	-6.1	96.4	94.2	2.2	19.0	○	128.049
16	7.000	-16.4	-4.5	100.5	102.6	-2.1	-50.0	○	-126.462
17	7.500	-16.4	-2.9	104.6	112.4	-7.8	-50.0	○	-462.105

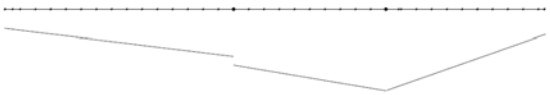
Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground Spring (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	6.9	-2.9	124.3	112.4	11.9	19.0	○	822.297
2	0.500	6.9	-1.3	130.0	122.3	7.7	19.0	○	535.171
3	1.000	6.9	0.3	135.8	132.5	3.3	19.0	○	230.895
4	1.500	6.9	2.3	141.6	142.9	-1.3	-50.0	○	-88.705
5	2.000	6.9	4.5	147.3	151.3	-3.9	-50.0	○	-271.772
6	2.500	6.9	6.8	153.1	158.7	-5.6	-50.0	○	-385.563
7	3.000	6.9	9.0	158.9	165.3	-6.4	-50.0	○	-440.821
8	3.500	6.9	11.2	164.7	170.4	-5.7	-50.0	○	-397.057
9	4.000	6.9	13.5	170.4	168.6	1.9	19.0	○	129.841
10	4.500	6.9	15.7	176.2	167.5	8.7	19.0	○	602.140
11	5.000	6.9	17.9	182.0	165.0	16.9	19.0	○	1174.229

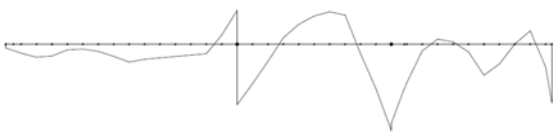
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	33.4	17.9	180.8	165.0	15.7	19.0	○	1073.898
2	0.420	33.4	19.8	170.7	161.9	8.8	19.0	○	601.734
3	0.500	33.4	20.1	168.8	161.1	7.6	19.0	○	522.387
4	1.000	33.4	22.2	156.8	155.5	1.3	19.0	○	89.173
5	1.500	33.4	23.7	144.8	145.8	-1.0	-50.0	○	-70.397
6	2.000	33.4	25.2	132.8	133.2	-0.5	-50.0	○	-32.983
7	2.500	33.4	26.7	120.8	119.2	1.5	19.0	○	104.394
8	3.000	33.4	28.0	108.8	104.9	3.9	19.0	○	420.597
9	3.500	33.4	28.9	96.8	94.3	2.5	40.0	○	268.336
10	4.000	33.4	29.7	84.7	84.8	0.0	-50.0	○	-2.095
11	4.500	33.4	30.5	72.7	74.4	-1.7	-50.0	○	-182.172
12	5.000	33.4	31.3	60.7	57.9	2.8	40.0	○	307.340
13	5.200	33.4	31.6	55.9	48.6	7.3	40.0	○	793.414

Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-15.9	-26.1	41.9	42.1	-0.1	-50.0	○	-12.080
2	0.250	-15.9	-25.6	44.0	43.8	0.2	40.0	○	23.588
3	0.500	-15.9	-25.1	46.1	45.5	0.7	40.0	○	62.220
4	1.000	-15.9	-23.8	50.3	49.1	1.3	40.0	○	119.517
5	1.500	-15.9	-22.2	54.5	53.4	1.1	19.0	○	108.180
6	2.000	-15.9	-20.6	58.7	57.9	0.8	19.0	○	46.920
7	2.500	-15.9	-18.9	62.9	62.2	0.7	19.0	○	39.543
8	3.000	-15.9	-17.3	67.0	65.8	1.2	19.0	○	74.401
9	3.500	-15.9	-15.7	71.2	68.8	2.4	19.0	○	143.824
10	4.000	-15.9	-14.1	75.4	71.6	3.8	19.0	○	225.919
11	4.500	-15.9	-12.5	79.6	76.4	3.2	19.0	○	189.263
12	5.000	-15.9	-10.9	83.8	80.9	2.9	19.0	○	172.339
13	5.500	-15.9	-9.3	88.0	85.3	2.6	19.0	○	156.669
14	6.000	-15.9	-7.7	92.1	89.8	2.4	19.0	○	141.384
15	6.500	-15.9	-6.1	96.3	94.2	2.1	19.0	○	125.515
16	7.000	-15.9	-4.5	100.5	102.6	-2.1	-50.0	○	-126.097
17	7.500	-15.9	-2.9	104.7	112.4	-7.7	-50.0	○	-458.841

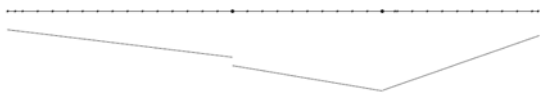
Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	6.9	-2.9	124.1	112.4	11.7	19.0	○	812.718
2	0.500	6.9	-1.3	129.9	122.3	7.6	19.0	○	525.592
3	1.000	6.9	0.3	135.7	132.5	3.2	19.0	○	221.316
4	1.500	6.9	2.3	141.4	142.9	-1.4	-50.0	○	-98.285
5	2.000	6.9	4.5	147.2	151.3	-4.1	-50.0	○	-281.351
6	2.500	6.9	6.8	153.0	158.7	-5.7	-50.0	○	-395.143
7	3.000	6.9	9.0	158.8	165.3	-6.5	-50.0	○	-450.400
8	3.500	6.9	11.2	164.5	170.4	-5.9	-50.0	○	-406.637
9	4.000	6.9	13.5	170.3	168.6	1.7	19.0	○	120.261
10	4.500	6.9	15.7	176.1	167.5	8.5	19.0	○	592.560
11	5.000	6.9	17.9	181.8	165.0	16.8	19.0	○	1164.650

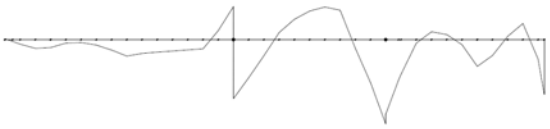
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	28.4	17.9	180.1	165.0	15.0	19.0	○	1026.940
2	0.420	28.4	19.8	170.0	161.9	8.2	19.0	○	556.763
3	0.500	28.4	20.1	168.1	161.1	7.0	19.0	○	477.793
4	1.000	28.4	22.2	156.1	155.5	0.7	19.0	○	46.946
5	1.500	28.4	23.7	144.2	145.8	-1.6	-50.0	○	-110.258
6	2.000	28.4	25.2	132.2	133.2	-1.0	-50.0	○	-70.474
7	2.500	28.4	26.7	120.2	119.2	1.0	19.0	○	69.273
8	3.000	28.4	28.0	108.3	104.9	3.4	19.0	○	368.445
9	3.500	28.4	28.9	96.3	94.3	2.0	40.0	○	219.960
10	4.000	28.4	29.7	84.3	84.8	-0.4	-50.0	○	-46.693
11	4.500	28.4	30.5	72.4	74.4	-2.1	-50.0	○	-222.994
12	5.000	28.4	31.3	60.4	57.9	2.5	40.0	○	270.296
13	5.200	28.4	31.6	55.6	48.6	7.0	40.0	○	757.881

Displacement Diagram



Reaction Force of Ground



Reaction Force



2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-16.1	-26.1	42.9	42.1	0.8	40.0	○	75.485
2	0.250	-16.1	-25.6	44.9	43.8	1.1	40.0	○	107.105
3	0.500	-16.1	-25.1	47.0	45.5	1.5	40.0	○	141.688
4	1.000	-16.1	-23.8	51.1	49.1	2.0	40.0	○	190.888
5	1.500	-16.1	-22.2	55.2	53.4	1.8	19.0	○	171.454
6	2.000	-16.1	-20.6	59.3	57.9	1.4	19.0	○	81.569
7	2.500	-16.1	-18.9	63.4	62.2	1.2	19.0	○	69.107
8	3.000	-16.1	-17.3	67.5	65.8	1.7	19.0	○	98.880
9	3.500	-16.1	-15.7	71.5	68.8	2.7	19.0	○	163.220
10	4.000	-16.1	-14.1	75.6	71.6	4.0	19.0	○	240.232
11	4.500	-16.1	-12.5	79.7	76.4	3.3	19.0	○	198.493
12	5.000	-16.1	-10.9	83.8	80.9	3.0	19.0	○	176.486
13	5.500	-16.1	-9.3	87.9	85.3	2.6	19.0	○	155.734
14	6.000	-16.1	-7.7	92.0	89.8	2.3	19.0	○	135.367
15	6.500	-16.1	-6.1	96.1	94.2	1.9	19.0	○	114.416
16	7.000	-16.1	-4.5	100.2	102.6	-2.4	-50.0	○	-142.278
17	7.500	-16.1	-2.9	104.3	112.4	-8.1	-50.0	○	-480.104

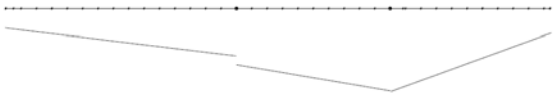
Span2 Name of Span: [Center]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	6.9	-2.9	124.1	112.4	11.7	19.0	○	812.718
2	0.500	6.9	-1.3	129.9	122.3	7.6	19.0	○	525.592
3	1.000	6.9	0.3	135.7	132.5	3.2	19.0	○	221.316
4	1.500	6.9	2.3	141.4	142.9	-1.4	-50.0	○	-98.285
5	2.000	6.9	4.5	147.2	151.3	-4.1	-50.0	○	-281.351
6	2.500	6.9	6.8	153.0	158.7	-5.7	-50.0	○	-395.143
7	3.000	6.9	9.0	158.8	165.3	-6.5	-50.0	○	-450.400
8	3.500	6.9	11.2	164.5	170.4	-5.9	-50.0	○	-406.637
9	4.000	6.9	13.5	170.3	168.6	1.7	19.0	○	120.261
10	4.500	6.9	15.7	176.1	167.5	8.5	19.0	○	592.560
11	5.000	6.9	17.9	181.8	165.0	16.8	19.0	○	1164.650

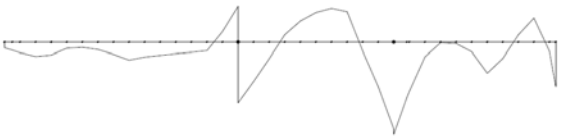
Span3 Name of Span: [River Side]

Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	28.0	17.9	183.2	165.0	18.1	19.0	○	1237.273
2	0.420	28.0	19.8	172.7	161.9	10.9	19.0	○	741.720
3	0.500	28.0	20.1	170.7	161.1	9.6	19.0	○	657.917
4	1.000	28.0	22.2	158.3	155.5	2.9	19.0	○	196.862
5	1.500	28.0	23.7	145.9	145.8	0.1	19.0	○	9.455
6	2.000	28.0	25.2	133.5	133.2	0.3	19.0	○	19.037
7	2.500	28.0	26.7	121.1	119.2	1.9	19.0	○	128.585
8	3.000	28.0	28.0	108.7	104.9	3.8	19.0	○	414.810
9	3.500	28.0	28.9	96.3	94.3	2.0	40.0	○	218.242
10	4.000	28.0	29.7	83.9	84.8	-0.9	-50.0	○	-96.495
11	4.500	28.0	30.5	71.5	74.4	-3.0	-50.0	○	-320.878
12	5.000	28.0	31.3	59.1	57.9	1.1	40.0	○	124.330
13	5.200	28.0	31.6	54.1	48.6	5.4	40.0	○	592.682

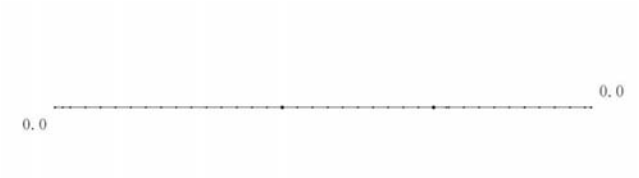
Displacement Diagram



Reaction Force of Ground



Reaction Force



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]
Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.008	0.000	0.000
2	0.250	74.748	-9.362	-1.344
3	0.250	155.532	-195.762	94.596
4	0.500	226.417	-196.415	45.385
5	1.000	353.592	-175.469	-48.682
6	1.500	457.404	-145.343	-128.551
7	2.000	506.683	-137.969	-198.879
8	2.500	540.062	-139.143	-267.940
9	3.000	557.543	-134.897	-337.114
10	3.500	559.129	-106.031	-398.731
11	4.000	544.825	-40.736	-437.071
12	4.500	514.634	34.470	-437.811
13	5.000	468.559	94.831	-405.070
14	5.500	406.603	145.594	-344.575
15	6.000	328.768	187.168	-261.003
16	6.500	235.055	219.505	-158.942
17	7.000	125.465	183.521	-52.878
18	7.500	0.001	0.000	0.000

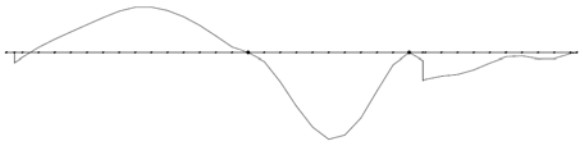
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	7.500	0.000	0.000	0.000
2	8.000	104.652	302.987	81.735
3	8.500	190.821	458.124	278.358
4	9.000	255.986	457.292	513.877
5	9.500	296.537	330.794	714.718
6	10.000	311.385	130.080	832.312
7	10.000	311.388	37.680	832.312
8	10.500	300.528	-205.295	791.563
9	11.000	263.964	-451.144	626.545
10	11.500	201.690	-554.328	364.199
11	12.000	113.702	-407.712	113.848
12	12.500	-0.004	0.000	0.000

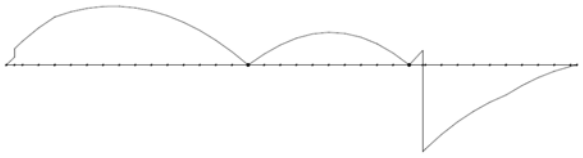
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	12.500	0.004	0.000	0.000
2	12.920	139.265	321.324	74.419
3	12.920	-825.846	-178.475	267.179
4	13.000	-801.355	-139.335	254.511
5	13.500	-661.725	-22.823	222.997
6	14.000	-542.216	-54.509	206.989
7	14.500	-440.018	-116.733	163.400
8	15.000	-355.138	-135.260	97.541
9	15.500	-286.372	-79.512	40.521
10	16.000	-196.131	34.862	32.534
11	16.500	-120.677	43.562	57.777
12	17.000	-60.027	-60.364	57.331
13	17.500	-14.194	-86.932	10.313
14	17.700	-0.011	0.000	0.000

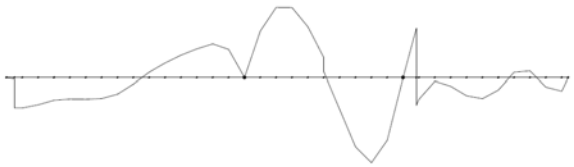
Bending Moment



Axial Force



Shear Force



3.5.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side →River Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.008	0.000	0.000
2	0.250	78.320	-22.345	-2.978
3	0.250	83.834	-114.635	58.272
4	0.500	158.292	-127.703	27.779
5	1.000	292.611	-129.886	-37.809
6	1.500	403.568	-120.621	-100.197
7	2.000	457.334	-123.140	-160.696
8	2.500	495.199	-132.782	-224.519
9	3.000	517.166	-135.580	-292.333
10	3.500	523.239	-112.333	-355.755
11	4.000	513.421	-51.233	-398.354
12	4.500	487.716	21.201	-405.095
13	5.000	446.128	80.214	-379.385
14	5.500	388.658	131.053	-326.238
15	6.000	315.309	174.127	-249.621
16	6.500	226.082	209.387	-153.408
17	7.000	120.979	177.751	-51.376
18	7.500	0.001	0.000	0.000

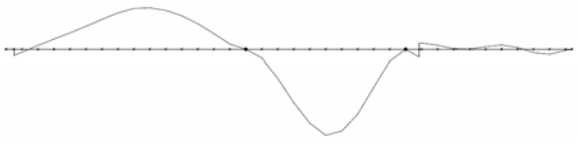
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	7.500	0.000	0.000	0.000
2	8.000	104.652	302.987	81.735
3	8.500	190.821	458.124	278.358
4	9.000	255.986	457.292	513.877
5	9.500	296.537	330.794	714.718
6	10.000	311.385	130.080	832.312
7	10.000	311.388	37.680	832.312
8	10.500	300.528	-205.295	791.563
9	11.000	263.964	-451.144	626.545
10	11.500	201.690	-554.328	364.199
11	12.000	113.702	-407.712	113.848
12	12.500	-0.004	0.000	0.000

Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	12.500	0.004	0.000	0.000
2	12.920	105.025	316.264	73.365
3	12.920	-329.896	-67.295	-58.335
4	13.000	-311.928	-29.148	-62.148
5	13.500	-213.061	80.946	-40.158
6	14.000	-134.314	42.479	-5.961
7	14.500	-72.879	-26.891	-2.828
8	15.000	-28.761	-52.926	-25.628
9	15.500	-0.758	-5.047	-43.432
10	16.000	24.571	93.381	-18.150
11	16.500	35.112	85.561	32.246
12	17.000	30.850	-35.462	48.549
13	17.500	11.771	-79.702	9.589
14	17.700	-0.011	0.000	0.000

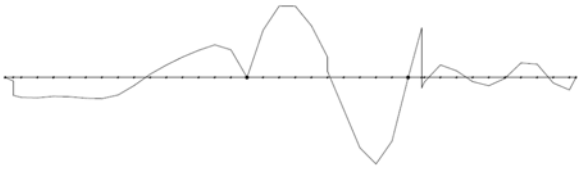
Bending Moment



Axial Force



Shear Force



Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	0.000	-0.008	0.000	0.000
2	0.250	75.625	-0.754	-0.258
3	0.250	137.938	-261.564	158.802
4	0.500	209.700	-254.069	94.168
5	1.000	338.628	-218.209	-24.920
6	1.500	444.193	-175.012	-122.815
7	2.000	494.573	-158.804	-205.720
8	2.500	529.053	-152.301	-283.232
9	3.000	547.634	-141.535	-357.306
10	3.500	550.321	-107.306	-420.853
11	4.000	537.118	-37.803	-458.730
12	4.500	508.028	40.453	-457.192
13	5.000	463.054	102.708	-420.939
14	5.500	402.199	154.208	-356.273
15	6.000	325.465	195.363	-268.450
16	6.500	232.853	226.124	-162.637
17	7.000	124.365	187.409	-53.898
18	7.500	0.001	0.000	0.000

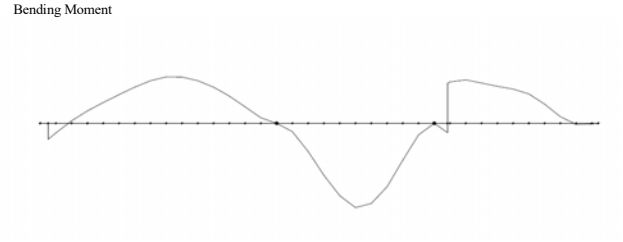
Span2 Name of Span: [Center]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	7.500	0.000	0.000	0.000
2	8.000	104.652	302.987	81.735
3	8.500	190.821	458.124	278.358
4	9.000	255.986	457.292	513.877
5	9.500	296.537	330.794	714.718
6	10.000	311.385	130.080	832.312
7	10.000	311.388	37.680	832.312
8	10.500	300.528	-205.295	791.563
9	11.000	263.964	-451.144	626.545
10	11.500	201.690	-554.328	364.199
11	12.000	113.702	-407.712	113.848
12	12.500	-0.004	0.000	0.000

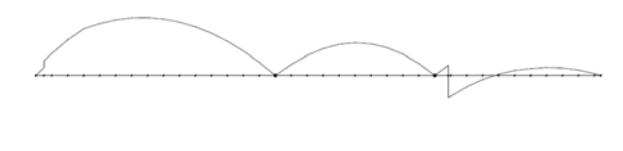
Span3 Name of Span: [River Side]

Number	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	12.500	0.004	0.000	0.000
2	12.920	97.030	402.402	91.844
3	12.920	-214.102	-209.587	-394.626
4	13.000	-197.656	-156.296	-409.214
5	13.500	-108.307	39.284	-428.768
6	14.000	-39.078	70.506	-397.322
7	14.500	12.840	55.033	-366.042
8	15.000	47.440	67.104	-337.696
9	15.500	65.926	137.297	-289.249
10	16.000	76.099	246.116	-189.149
11	16.500	71.485	223.544	-65.026
12	17.000	52.067	62.627	11.343
13	17.500	17.833	-46.648	6.216
14	17.700	-0.011	0.000	0.000

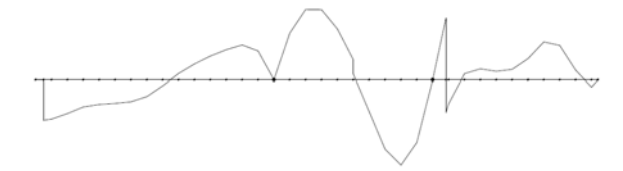
Bending Moment



Axial Force



Shear Force



3.6 Design of Flexible Joint

Opening

Opening = (Lateral Displacement of Span in Right Side) - (Lateral Displacement of Span in Left Side)

Bending Angle

θ = |θ1 - θ2| - Initial Bending Angle

Thus、

θ1: Angle of Displacement (Left Side) (rad)

θ2: Angle of Displacement (Right Side) (rad)

θ: Average Angle of Displacement (rad)

Unevenness

Unevenness = (Vertical Displacement of Span in Right Side) - (Vertical Displacement of Span in Left Side)

3.6.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Check of Opening Allowable Opening: 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-16.4	
Span (2- 1)	6.9- (-16.4)	23.3 OK
Span (3- 2)	33.4- (6.9)	26.5 OK
EP	33.4	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.47368 -0.00827	-0.66158 -0.01155	0.18790 0.00328
Span (3- 2)	0.00000 0.00000	-0.66153 -0.01155	1.37536 0.02400	2.03688 0.03555

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-42.6	
Span (2- 1)	-124.3- (-104.6)	19.6 OK
Span (3- 2)	-180.8- (-182.0)	1.2 OK
EP	-55.9	

3.6.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-15.9	
Span (2- 1)	6.9- (-15.9)	22.9 OK
Span (3- 2)	28.4- (6.9)	21.4 OK
EP	28.4	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.47926 -0.00836	-0.66158 -0.01155	0.18232 0.00318
Span (3- 2)	0.00000 0.00000	-0.66153 -0.01155	1.37139 0.02394	2.03292 0.03548

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-41.9	
Span (2- 1)	-124.1- (-104.7)	19.4 OK
Span (3- 2)	-180.1- (-181.8)	1.8 OK
EP	-55.6	

Calculation Case2 - Load: [Seismic Condition Land Side →River Side]

Check for Opening Allowable Opening 200.0(mm)

Position	Lateral Displacement δx (mm)	Opening (mm)
BP	-16.1	
Span (2- 1)	6.9- (-16.1)	23.0 OK
Span (3- 2)	28.0- (6.9)	21.0 OK
EP	28.0	

Check for Bending Angle

Position	Initial Bending Angle (Degree) (rad)	θ1(Degree) (rad)	θ2(Degree) (rad)	Bending Angle θ(Degree) (rad)
Span (2- 1)	0.00000 0.00000	-0.46948 -0.00819	-0.66158 -0.01155	0.19210 0.00335
Span (3- 2)	0.00000 0.00000	-0.66153 -0.01155	1.42208 0.02482	2.08360 0.03637

Check for Unevenness Allowable Unevenness 200.0(mm)

Position	Vertical Displacement δy (mm)	Unevenness (mm)
BP	-42.9	
Span (2- 1)	-124.1- (-104.3)	19.8 OK
Span (3- 2)	-183.2- (-181.8)	1.3 OK
EP	-54.1	

3.7 Stress Intensity Analysis

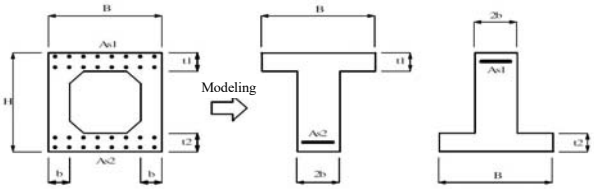
3.7.1 Calculation Condition

It is considered that double reinforced section which bending moment is acting on.
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.
Position of Neutral Axis

$$x=\frac{n\cdot(As\cdot d+As'\cdot d')+B\cdot t^2/2}{n\cdot(As+As')+B\cdot t}$$

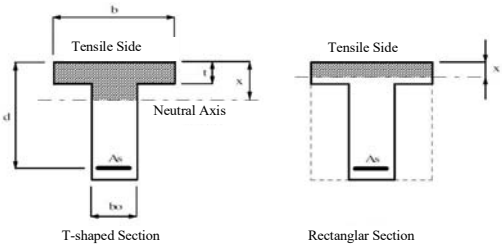
Thus,

- x : Position of Neutral Axis (mm)
- n : Ratio of Young modulus = 9.0
- As : Area of Re-bar in tensile side (mm^2)
- As' : Area of Re-bar in compressive side (mm^2)
- d : Effective Height of Beam (mm)
- d' : Distance from the compressive edge of concrete to the centric of Re-bar (mm)
- B : Width of Flange (mm)
- t : Thickness of Flange (mm)



The stress calculation is conducted as follows based on the position of neutral axis

1) In case the neutral axis is in web, the section is considered as T-shape.
2) In case the neutral axis is in top slab or Bottom slab, the section is considered as rectangle.



T-shaped Section Rectanglar Section

Calculation Condition (In Case Bottom Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculation Section
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.299	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.299	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.281	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.300	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side As(mm^2)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side As' (mm^2)
1- 1	2.000	2.000	1.716	2780.4	0.273	2780.4
1- 2	1.900	1.900	1.645	5419.4	0.244	5419.4
2- 1	1.900	1.900	1.645	5419.4	0.244	5419.4
3- 1	1.900	1.900	1.645	4011.0	0.244	4011.0
3- 2	2.000	2.000	1.716	4011.0	0.273	4011.0

Calculation Condition (In Case Top Slab is Tensile)

Dimension

Span Block	Width B (m)	Height H (m)	Width 2b(m)	Thickness t (m)	Neutral Axis x (m)	Calculatio n
1- 1	2.000	2.000	1.000	0.500	0.285	Rectangle
1- 2	1.900	1.900	0.900	0.450	0.299	Rectangle
2- 1	1.900	1.900	0.900	0.450	0.299	Rectangle
3- 1	1.900	1.900	0.900	0.450	0.281	Rectangle
3- 2	2.000	2.000	1.000	0.500	0.300	Rectangle

Re-bar

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side	Position of Re-bar in Compressive	Area of Re-bar in Tensile Side
1- 1	2.000	2.000	1.727	2780.4	0.284	2780.4
1- 2	1.900	1.900	1.656	5419.4	0.255	5419.4
2- 1	1.900	1.900	1.656	5419.4	0.255	5419.4
3- 1	1.900	1.900	1.656	4011.0	0.255	4011.0
3- 2	2.000	2.000	1.727	4011.0	0.284	4011.0

3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width Total Height Web Width Bending Moment		B H b M	m m mm kN.m	2.000 2.000 1000.0 94.596	2.000 2.000 1000.0 -128.551	2.000 2.000 1000.0 -128.551	2.000 2.000 1000.0 0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	183.0	249.9	249.9	
	Top Slab Inside	Aq2	mm^2	244.1	333.1	333.1	
	Bottom Slab Inside	Aq3	mm^2	244.1	333.1	333.1	
	Bottom Slab Outside	Aq4	mm^2	183.0	249.9	249.9	
Neutral Axis		X	m	0.199	0.201	0.201	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.29	0.40	0.40	----
		σs	N/mm^2	22.36	30.41	30.41	----
		σs'	N/mm^2	-1.45	-1.52	-1.52	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2				----
		req	mm^2	569.5	777.3	777.3	----
		inp	mm^2	2780.4	2780.4	2780.4	----

Calculation Case1: Normal Condition

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-437.811	-398.731	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		908.5	825.3	
	Top Slab Inside	Aq2	mm^2		1211.3	1100.4	
	Bottom Slab Inside	Aq3	mm^2		1211.3	1100.4	
	Bottom Slab Outside	Aq4	mm^2		908.5	825.3	
Neutral Axis		X	m	----	0.266	0.266	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	1.08	0.98	----
		σs	N/mm^2	----	56.48	51.44	----
		σs'	N/mm^2	----	-5.52	-5.03	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	2826.4	2567.5	----
		inp	mm^2	----	5419.4	5419.4	----

Calculation Case1: Normal Condition

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	832.312	0.000	832.312	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	1760.7		1760.7	
	Top Slab Inside	Aq2	mm^2	2347.6		2347.6	
	Bottom Slab Inside	Aq3	mm^2	2347.6		2347.6	
	Bottom Slab Outside	Aq4	mm^2	1760.7		1760.7	
Neutral Axis		X	m	0.264	0.264	----	0.264
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	2.07	----	2.07	----
		σs	N/mm^2	107.17	----	107.17	----
		σs'	N/mm^2	-12.29	----	-12.29	----
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2	4441.5	----	4441.5	----
		req	mm^2	5477.8	----	5477.8	----
		inp	mm^2	5419.4	----	5419.4	----

Calculation Case1: Normal Condition

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	267.179	0.000	74.419	267.179
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	547.2		149.1	547.2
	Top Slab Inside	Aq2	mm^2	729.5		198.8	729.5
	Bottom Slab Inside	Aq3	mm^2	729.5		198.8	729.5
	Bottom Slab Outside	Aq4	mm^2	547.2		149.1	547.2
Neutral Axis		X	m	0.233	----	0.233	0.233
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.77	----	0.21	0.77
		σs	N/mm^2	45.99	----	12.81	45.99
		σs'	N/mm^2	-4.23	----	-1.18	-4.23
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----		
		req	mm^2	1702.3	----	463.9	1702.3
		inp	mm^2	4011.0	----	4011.0	4011.0

Calculation Case1: Normal Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	57.777	0.000	0.000	40.521
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	111.1			77.7
	Top Slab Inside	Aq2	mm^2	148.2			103.6
	Bottom Slab Inside	Aq3	mm^2	148.2			103.6
	Bottom Slab Outside	Aq4	mm^2	111.1			77.7
Neutral Axis		X	m	0.234	----	----	0.234
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.15	----	----	0.11
		σs	N/mm^2	9.58	----	----	6.72
		σs'	N/mm^2	-0.84	----	----	-0.59
Allowable Stress Intensity		σca	N/mm^2	8.20	8.20	8.20	8.20
		σsa'	N/mm^2	140.00	140.00	140.00	140.00
		σsa'	N/mm^2	-140.00	-140.00	-140.00	-140.00
Minimum Area of Re-Bar		min	mm^2		----	----	
		req	mm^2	345.7	----	----	241.6
		inp	mm^2	4011.0	----	----	4011.0

3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	58.272	-100.197	-100.197	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	84.1	145.5	145.5	
	Top Slab Inside	Aq2	mm^2	112.2	194.0	194.0	
	Bottom Slab Inside	Aq3	mm^2	112.2	194.0	194.0	
	Bottom Slab Outside	Aq4	mm^2	84.1	145.5	145.5	
Neutral Axis		X	m	0.199	0.201	0.201	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.18	0.31	0.31	----
		σs	N/mm^2	13.78	23.70	23.70	----
		σs'	N/mm^2	-0.89	-1.19	-1.19	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				----
		req	mm^2	261.7	452.6	452.6	----
		inp	mm^2	2780.4	2780.4	2780.4	----

Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-405.095	-355.755	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		626.7	548.7	
	Top Slab Inside	Aq2	mm^2		835.6	731.6	
	Bottom Slab Inside	Aq3	mm^2		835.6	731.6	
	Bottom Slab Outside	Aq4	mm^2		626.7	548.7	
Neutral Axis		X	m	----	0.266	0.266	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	1.00	0.88	----
		σs	N/mm^2	----	52.26	45.90	----
		σs'	N/mm^2	----	-5.11	-4.49	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	1949.7	1707.1	----
		inp	mm^2	----	5419.4	5419.4	----

Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	832.312	0.000	832.312	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	1312.7		1312.7	
	Top Slab Inside	Aq2	mm^2	1750.2		1750.2	
	Bottom Slab Inside	Aq3	mm^2	1750.2		1750.2	
	Bottom Slab Outside	Aq4	mm^2	1312.7		1312.7	
Neutral Axis		X	m	0.264	----	0.264	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	2.07	----	2.07	----
		σs	N/mm^2	107.17	----	107.17	----
		σs'	N/mm^2	-12.29	----	-12.29	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	4083.9	----	4083.9	----
		inp	mm^2	5419.4	----	5419.4	----

Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	73.365	-62.148	73.365	-58.335
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	110.3	93.2	110.3	87.5
	Top Slab Inside	Aq2	mm^2	147.0	124.3	147.0	116.6
	Bottom Slab Inside	Aq3	mm^2	147.0	124.3	147.0	116.6
	Bottom Slab Outside	Aq4	mm^2	110.3	93.2	110.3	87.5
Neutral Axis		X	m	0.233	0.234	0.233	0.234
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.21	0.18	0.21	0.17
		σs	N/mm^2	12.63	10.71	12.63	10.06
		σs'	N/mm^2	-1.16	-0.81	-1.16	-0.76
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	343.0	290.1	343.0	272.1
		inp	mm^2	4011.0	4011.0	4011.0	4011.0

Calculation Case1: Seismic Condition

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	48.549	-43.432	32.246	-43.432
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	70.0	62.5	46.3	62.5
	Top Slab Inside	Aq2	mm^2	93.3	83.4	61.8	83.4
	Bottom Slab Inside	Aq3	mm^2	93.3	83.4	61.8	83.4
	Bottom Slab Outside	Aq4	mm^2	70.0	62.5	46.3	62.5
Neutral Axis		X	m	0.234	0.236	0.234	0.236
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.13	0.11	0.08	0.11
		σs	N/mm^2	8.05	7.21	5.35	7.21
		σs'	N/mm^2	-0.70	-0.52	-0.47	-0.52
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	217.7	194.5	144.1	194.5
		inp	mm^2	4011.0	4011.0	4011.0	4011.0

2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	158.802	-122.815	-122.815	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 As2	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar		As	mm^2	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	232.1	178.8	178.8	
	Top Slab Inside	Aq2	mm^2	309.4	238.4	238.4	
	Bottom Slab Inside	Aq3	mm^2	309.4	238.4	238.4	
	Bottom Slab Outside	Aq4	mm^2	232.1	178.8	178.8	
Neutral Axis		X	m	0.199	0.201	0.201	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.49	0.38	0.38	----
		σs	N/mm^2	37.54	29.05	29.05	----
		σs'	N/mm^2	-2.44	-1.46	-1.46	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				----
		req	mm^2	722.0	556.2	556.2	----
		inp	mm^2	2780.4	2780.4	2780.4	----

Span1-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	0.000	-458.730	-420.853	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2		711.9	651.7	
	Top Slab Inside	Aq2	mm^2		949.2	868.9	
	Bottom Slab Inside	Aq3	mm^2		949.2	868.9	
	Bottom Slab Outside	Aq4	mm^2		711.9	651.7	
Neutral Axis		X	m	----	0.266	0.266	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	----	1.13	1.04	----
		σs	N/mm^2	----	59.18	54.29	----
		σs'	N/mm^2	----	-5.79	-5.31	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2	----			----
		req	mm^2	----	2214.8	2027.5	----
		inp	mm^2	----	5419.4	5419.4	----

Span2-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	832.312	0.000	832.312	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6	90.0 D22- 6
	Inside of Top Slab	d2 As2	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8	90.0 D22- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6	115.0 D22- 6
Total Area of Rebar		As	mm^2	10838.8	10838.8	10838.8	10838.8
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	1312.7		1312.7	
	Top Slab Inside	Aq2	mm^2	1750.2		1750.2	
	Bottom Slab Inside	Aq3	mm^2	1750.2		1750.2	
	Bottom Slab Outside	Aq4	mm^2	1312.7		1312.7	
Neutral Axis		X	m	0.264	----	0.264	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	2.07	----	2.07	----
		σs	N/mm^2	107.17	----	107.17	----
		σs'	N/mm^2	-12.29	----	-12.29	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2		----		----
		req	mm^2	4083.9	----	4083.9	----
		inp	mm^2	5419.4	----	5419.4	----

Span3-Block1

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	1.900	1.900	1.900	1.900
Total Height		H	m	1.900	1.900	1.900	1.900
Web Width		b	mm	900.0	900.0	900.0	900.0
Bending Moment		M	kN.m	91.844	-428.768	91.844	-394.626
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	138.4	664.3	138.4	610.1
	Top Slab Inside	Aq2	mm^2	184.5	885.7	184.5	813.5
	Bottom Slab Inside	Aq3	mm^2	184.5	885.7	184.5	813.5
	Bottom Slab Outside	Aq4	mm^2	138.4	664.3	138.4	610.1
Neutral Axis		X	m	0.233	0.234	0.233	0.234
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.26	1.22	0.26	1.12
		σs	N/mm^2	15.81	73.92	15.81	68.03
		σs'	N/mm^2	-1.45	-5.58	-1.45	-5.14
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				
		req	mm^2	430.5	2066.7	430.5	1898.2
		inp	mm^2	4011.0	4011.0	4011.0	4011.0

Span3-Block2

Item		Symbol	Unit	Mmax	Mmin	Mmax	Mmin
Total Width		B	m	2.000	2.000	2.000	2.000
Total Height		H	m	2.000	2.000	2.000	2.000
Web Width		b	mm	1000.0	1000.0	1000.0	1000.0
Bending Moment		M	kN.m	11.343	-289.249	-189.149	0.000
Rebar Area	Outside of Top Slab	d1 As1	mm	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6	90.0 D19- 6
	Inside of Top Slab	d2 As2	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Inside of Bottom Inside	d3 As3	mm	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8	90.0 D19- 8
	Outside of Bottom Inside	d4 As4	mm	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6	115.0 D19- 6
Total Area of Rebar		As	mm^2	8022.0	8022.0	8022.0	8022.0
Required Area of Re-bar	Top Slab Outside	Aq1	mm^2	16.2	427.2	277.2	
	Top Slab Inside	Aq2	mm^2	21.6	569.7	369.6	
	Bottom Slab Inside	Aq3	mm^2	21.6	569.7	369.6	
	Bottom Slab Outside	Aq4	mm^2	16.2	427.2	277.2	
Neutral Axis		X	m	0.234	0.236	0.236	----
Ratio of Young Modules		n		9.0	9.0	9.0	9.0
Stress Intensity		σc	N/mm^2	0.03	0.75	0.49	----
		σs	N/mm^2	1.88	48.01	31.39	----
		σs'	N/mm^2	-0.16	-3.46	-2.26	----
Allowable Stress Intensity		σca	N/mm^2	12.30	12.30	12.30	12.30
		σsa'	N/mm^2	186.00	186.00	186.00	186.00
		σsa'	N/mm^2	-186.00	-186.00	-186.00	-186.00
Minimum Area of Re-Bar		min	mm^2				----
		req	mm^2	50.4	1329.2	862.3	----
		inp	mm^2	4011.0	4011.0	4011.0	----

2.2.2.7 SLUICEWAY TYPE J

(2) BOX - TRANSVERSE

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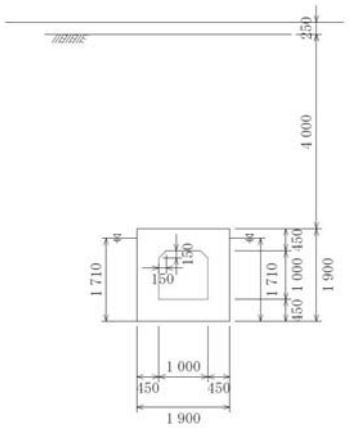
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1 Calculation of Box Culvert in Transverse Direction

1.1 Design Condition

1.1.1 Dimension



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil(Wet)	γt	kN/m³	19.00
Soil(Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material			SD295	
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
Right Corner	D16	247	804.0	Right Corner	D16	250	794.4

Outside of Sidewall	Diameter	Pitch	Area (mm^2)	Inside of Sidewall	Diameter	Pitch	Area (mm^2)
Left Sidewall	D16	250	794.4	Left Sidewall	D13	250	506.8
Right Sidewall	D16	250	794.4	Right Sidewall	D13	250	506.8

Outside of Top Slab	Diameter	Pitch	Area (mm^2)	Inside of Top Slab	Diameter	Pitch	Area (mm^2)
Left Corner	D16	250	794.4	Left Corner	D16	250	794.4
Center of Span	D16	250	794.4	Right Corner	D16	250	794.4
Right Corner	D16	250	794.4	Right Corner	D16	250	794.4

■Cover

Location		Cover(mm)	Location		Cover(mm)
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Midwall		—	—		—

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm^2/m)
Top Slab	100	0.0
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Load

■Surcharge

	(kN/m^2)
Surcharge	10.000
Snow Load	0.000

■Dead Load (Water Level)

Case	External Water Level(m)	Internal Water Level(m)
1	1.710	0.000

External Water Level: Height from Bottom Surface of Bottom Slab
Internal Water Level: Height from Top Surface of Bottom Slab

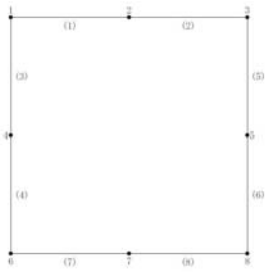
■Live Load

Intensity of Distribution Load Qw(kN/m^2)	10.000

1.2 Cross-section Calculation

1.2.1 Model

1) Frame Dimension



2) Coordinate

No	X(m)	Y(m)
1	0.000	1.450
2	0.725	1.450
3	1.450	1.450
4	0.000	0.725
5	1.450	0.725
6	0.000	0.000
7	0.725	0.000
8	1.450	0.000

3) Member Material and Sectional Characteristics

Member	Number	Point Number		Area (m^2)	Geometric Moment of Inertia (m^4)	Young Modules (kN/m^2)
		i Edge	j Edge			
Left Side of Top Slab	1	1	2	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Top Slab	2	2	3	4.500000E-001	7.593750E-003	2.310000E+007
Upper Side of Left Side Wall	3	1	4	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Left Side Wall	4	4	6	4.500000E-001	7.593750E-003	2.310000E+007
Upper side of Right Wall	5	3	5	4.500000E-001	7.593750E-003	2.310000E+007
Downer Side of Right Wall	6	5	8	4.500000E-001	7.593750E-003	2.310000E+007
Left Side of Bottom Slap	7	6	7	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slap	8	7	8	4.500000E-001	7.593750E-003	2.310000E+007

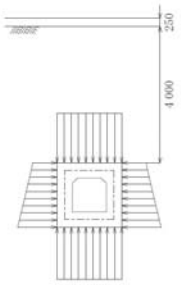
4) Supporting Point

Point	Horizontal (kN/m)	Vertical (kN/m)	Rotate (kN.m/rad)
6	-1	-1	0
8	0	-1	0

Note) -1: Fixed, 0: Free

1.2.2 Load

1) Dead Load (case-1) [RWL]



Weight of Box Culvert

(1) Top Slab
w = 0.450 × 24.00 = 10.80 (kN/m²)

(2) Left Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

(3) Right Side Wall
w = 0.450 × 24.00 = 10.80 (kN/m²)

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level) = 1.000 × 0.250 × 22.60 = 5.65 (kN/m²)
Embankment (Above Water Level) =1.000 × 4.000 × 18.00 = 72.00 (kN/m²)

Σwd = 77.65 (kN/m²)

(2) Surcharge Load at Road
Surcharge = 10.000 (kN/m²)
Snow Load= 0.00 (kN/m²)

Σqd = 10.000 (kN/m²)

(3) Load Acting on Top Slab
Uniformly Distributed Load
w = 77.65 + 10.00 = 87.65 (kN/m²)

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

pi = Ko×(qd + Yo×γa + Zu×γ + (Zo - Zu)×γ') + (Zo - Zu)×γw

Ko: Coefficient of Earth Pressure at Rest = 0.500

Zo:Depth of Calculation Point from Embankment Top(m)

(1)Left Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	4.000	43.83
p_2	Center of Top Slab	4.190	45.54
p_3	Top Plate Slab	4.225	46.04
p_4	Center of Bottom Slab	5.675	66.92
p_5	Bottom Surface of Bottom Slab	5.900	70.16

(2)Right Side Wall

Symbol	Calculation Point	Zo (m)	p (kN/m²)
p_1	Top Surface of Top Slab	4.000	43.83
p_2	Center of Top Slab	4.190	45.54
p_3	Top Plate Slab	4.225	46.04
p_4	Center of Bottom Slab	5.675	66.92
p_5	Bottom Surface of Bottom Slab	5.900	70.16

Uplift and Buoyancy

This Act on Bottom Slab Upward

$$U = 1.710 \times 1.900 \times 9.80 = 31.84 \ (kN/m)$$

$$w = \frac{-31.84}{1.900} = -16.76 \ (kN/m^2)$$

Summary of Acting Forces

Item			V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Weight of Body		Top Slab	21.06		0.950		20.01
		Left Side Wall	10.80		0.225		2.43
		Right Side Wall	10.80		1.675		18.09
Surcharge		Distribution Load	166.54		0.950		158.21
Earth Pressure and Water Pressure	Left Side Wall	Distribution		8.49		1.804	15.32
		Distribution		98.92		0.794	78.57
	Right Side Wall	Distribution		-8.49		1.804	-15.32
		Distribution		-98.92		0.794	-78.57
Uplift/Buoyancy			-31.84		0.950		-30.25
Total			177.35				168.49

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$q1 = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 93.34 \ (kN/m^2)$$

$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 93.34 \ (kN/m^2)$$

$$q1' = q1 + \frac{qr - q1}{B} \times \frac{T}{2} = 93.34 \ (kN/m^2)$$

$$qr' = qr + \frac{q1 - qr}{B} \times \frac{T}{2} = 93.34 \ (kN/m^2)$$

Thus, T : Thickness of Side Wall

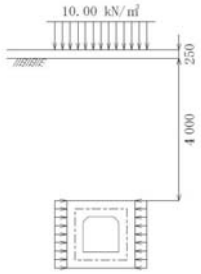
q1 : Subgrade Reaction Intensity on Left Edge

qr : Subgrade Reaction Intensity on Right Edge

q1': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface qL= 10.000 (kN/m²)

Load

(1)Vertical Load Effecting Top Slab
wl = qL= 10.00 (kN/m²)

(2)Horizontal Load Acting on Left Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

(3)Horizontal Load Effecting on Right Side Wall
Converted Uniformly Distributed Load
wl = 10.00 (kN/m²)
p = Ko×wl = 0.500 × 10.00 = 5.00 (kN/m²)

Summary of Acting Force

		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Top Slab	Distribution	19.00		0.950		18.05
Left Side Wall	Distribution		9.50		0.950	9.03
Right Side Wall	Distribution		-9.50		0.950	-9.03
Total		19.00				18.05

Subgrade Reaction Force

(1) Force Acting Position and Eccentric Distance

$$X = \frac{\Sigma M}{\Sigma V} = 0.950 \ (m)$$

$$e = \frac{B}{2} - X = 0.000 \ (m)$$

(2) Subgrade Reaction Intensity

Me = ΣV × e = 0.00 (kN.m/m)

$$ql = \frac{\Sigma V}{B} + \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$qr = \frac{\Sigma V}{B} - \frac{6 \times Me}{B^2} = 10.00\ (kN/m^2)$$

$$ql' = ql + \frac{qr - ql}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

$$qr' = qr + \frac{ql - qr}{B} \times \frac{T}{2} = 10.00\ (kN/m^2)$$

Thus、T : Thickness of Side Wall

ql : Subgrade Reaction Intensity on Left Edge

qr : Subgrade Reaction Intensity on Right Edge

ql': Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

qr': Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

Dead Load + Live Load

Load Number	Beginning Member Number	End Member Number	Load Intensity at i Edge	Load Intensity at j Edge	Distance from i Edge (m)	Distance from j Edge (m)	Load Width (m)
14	1	2	-10.80	-10.80	0.000	0.000	1.450
14	3	4	-10.80	-10.80	0.225	0.225	1.000
14	5	6	-10.80	-10.80	0.225	0.225	1.000
14	1	2	-87.65	-87.65	0.000	0.000	1.450
13	3	4	46.04	66.92	0.000	0.000	1.450
13	5	6	-46.04	-66.92	0.000	0.000	1.450
14	7	8	16.76	16.76	0.000	0.000	1.450
14	1	2	-10.00	-10.00	0.000	0.000	1.450
13	3	4	5.00	5.00	0.000	0.000	1.450
13	5	6	-5.00	-5.00	0.000	0.000	1.450
14	7	8	103.34	103.34	0.000	0.000	1.450

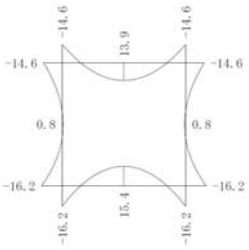
Load Number

13: Member Distribution Load (X Direction)

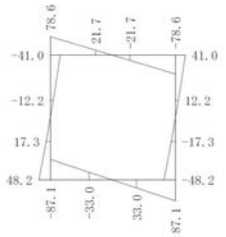
14: Member Distribution Load (Y Direction)

1.2.4 Calculation Results of Frame Analysis

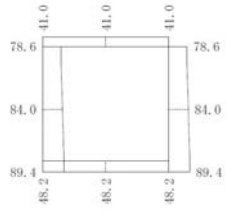
Bending Moment



Shear Force



Axial Force



1.2.5 Stress Intensity Calculation

■Bending Stress Intensity

Top Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-14.603	13.899	-14.603
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	301.3	0.0	301.3
	Internal	mm^2	0.0	286.5	0.0
Re-Bar	External	mm^2	D16 @ 250 D─ @── 794.4	D16 @ 250 D─ @── 794.4	D16 @ 247 D─ @── 804.0
	Internal	mm^2	D16 @ 250 D─ @── 794.4	D16 @ 250 D─ @── 794.4	D16 @ 250 D─ @── 794.4
Neutral Axis	X	m	0.065	0.065	0.065
Stress Intensity	σc	N/mm^2	1.33	1.26	1.32
	σs	N/mm^2	54.33	51.71	53.70
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	401.8	382.1	401.8
	inp	mm^2	794.4	794.4	804.0
Case	──	──	Dead-1+Live-1	Dead-1+Liva-1	Dead-1+Liev-1

※Axial force is not considered.

Left Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-14.603	0.761	-16.191
Axial Force	N	kN	78.626	84.026	89.426
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar Arrangement	External	mm^2	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
	Internal	mm^2	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8
Neutral Axis	X	m	0.186	1.849	0.193
Stress Intensity	σc	N/mm^2	0.91	0.21	0.99
	σs	N/mm^2	7.60	0.00	7.74
	σs'	N/mm^2	0.00	-1.53	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	794.4	506.8	794.4
Case	——	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Right Side Wall

		Unit	Upper side Edge	Center	Under Side Edge
Bending Moment	M	kN.m	-14.603	0.761	-16.191
Axial Force	N	kN	78.626	84.026	89.426
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	90.0	90.0	90.0
Inside Cover	d2	mm	90.0	90.0	90.0
Required Area of Re-Bar	External	mm^2	0.0	0.0	0.0
	Internal	mm^2	0.0	0.0	0.0
Re-Bar	External	mm^2	D16 @ 247 D—@—— 804.0	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
	Internal	mm^2	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8	D13 @ 250 D—@—— 506.8
Neutral Axis	X	m	0.187	1.849	0.193
Stress Intensity	σc	N/mm^2	0.91	0.21	0.99
	σs	N/mm^2	7.56	0.00	7.74
	σs'	N/mm^2	0.00	-1.53	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	0.0	0.0	0.0
	inp	mm^2	804.0	506.8	794.4
Case	——	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

Bottom Slab

Item		Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	kN.m	-16.191	15.374	-16.191
Axial Force	N	kN	0.000	0.000	0.000
Section Width	b	m	1.000	1.000	1.000
Section Height	h	m	0.450	0.450	0.450
Outside Cover	d1	mm	115.0	115.0	115.0
Inside Cover	d2	mm	90.	90.0	90.0
Required Area of Re-Bar	External	mm^2	360.9	0.0	360.9
	Internal	mm^2	0.0	317.6	0.0
Re-Bar	External	mm^2	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
	Internal	mm^2	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4	D16 @ 250 D—@—— 794.4
Neutral Axis	X	m	0.062	0.065	0.062
Stress Intensity	σc	N/mm^2	1.65	1.40	1.65
	σs	N/mm^2	64.88	57.20	64.88
	σs'	N/mm^2	0.00	0.00	0.00
Allowable Stress	σca	N/mm^2	8.20	8.20	8.20
	σsa	N/mm^2	140.00	140.00	140.00
	σsa'	N/mm^2	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min	mm^2			
	req	mm^2	481.1	423.4	481.1
	inp	mm^2	794.4	794.4	794.4
Case	——	——	Dead-1+Live-1	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

■Shear Stress Intensity

$$\tau m = \frac{S}{b \times d} \leqq \tau a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm^2)	τa (N/mm^2)	Cases	L (m)
Top Slap	Left τ Point	21.690	360.0	0.060	0.457	Dead-1+Live-1	0.525
	Right τ Point	-21.690	360.0	0.060	0.457	Dead-1+Live-1	0.525
Left Side Wall	Upper τ Point	-12.174	360.0	0.034	0.457	Dead-1+Live-1	0.525
	Lower τ Point	17.285	360.0	0.048	0.495	Dead-1+Live-1	0.450
Right Side Wall	Upper τ Point	12.174	360.0	0.034	0.457	Dead-1+Live-1	0.525
	Lower τ Point	-17.285	360.0	0.048	0.495	Dead-1+Live-1	0.450
Bottom Slab	Left τ Point	-33.028	360.0	0.092	0.478	Dead-1+Live-1	0.450
	Right τ Point	33.028	360.0	0.092	0.478	Dead-1+Live-1	0.450

Note) τ Point: Check point for shear stress intensity
L: Distance from grid point of corner

2.2.2.7 SLUICEWAY TYPE J

(3) BREAST WALL - LAND SIDE

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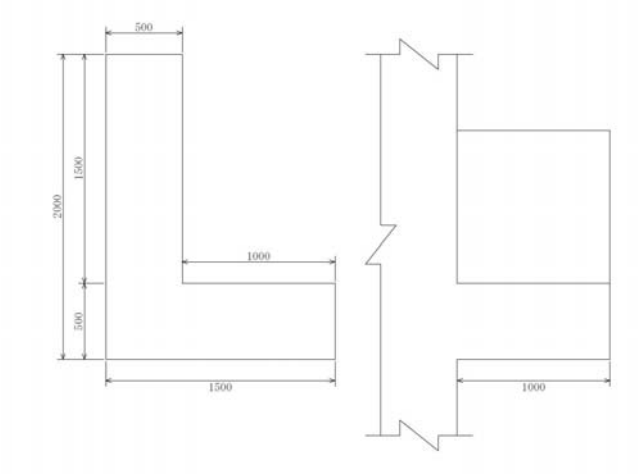
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1.3.3 Stress Intensity Calculation 19

1 Calculation of Land Side Breast Wall

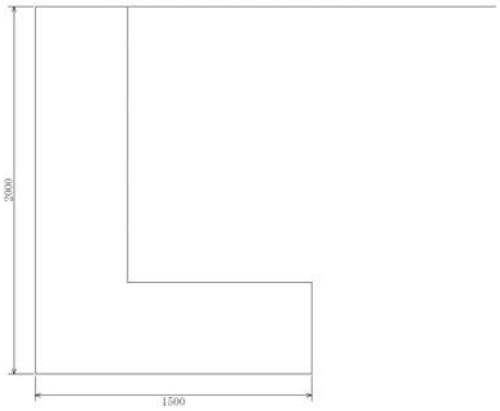
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material		SD295		
Normal		Sidewall	Harsh Environment	
		Bottom Slab	Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φres	○	30
Peak Angle of Internal Friction	φpeak	○	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm²/m)
Wall	Front Face	90.0	D13	247	506.8
	Back Face	90.0	D19	250	1146.0
Bottom Slab	Top Face	90.0	D16	247	794.4
	Bottom Face	115.0	D13	247	506.8

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Loads

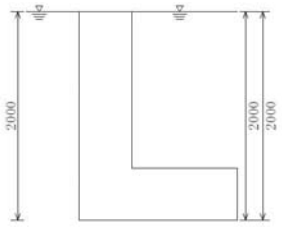
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

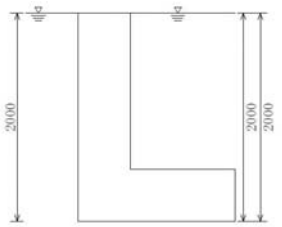
	(m)
Toe	2.000
Heel	2.000



1-2) Seismic Condition Number of Cases [1]

<Case 1>

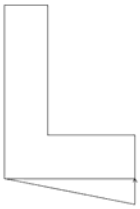
	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front



2) Subgrade Reaction

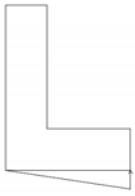
2-1) Normal <Case 1>

	(kN/m²), (m)
Toe	0.00
Heel	51.54
Load Width	1.500



2-2) Seismic <Case 1>

	(kN/m²), (m)
Toe	0.00
Heel	38.99
Load Width	1.500



3) Surcharge Load

Normal	kN/m²	10.00
Seismic	kN/m²	5.00

4) Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W =0.000 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (0.000+ 10.00× 1.500) / 1.500

= 10.000 (kN/m²)

Earth Pressure at the Top

p1 = q0'・Ko = 10.000× 0.500 = 5.000 (kN/m²)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.000+ 5.000

= 5.000 (kN/m²)

Earth Pressure at Junction

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500×(20.00- 9.80)× 1.500+ 5.000

= 12.650 (kN/m²)

Design Earth Pressure

P = p3

=12.650 (kN/m²)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

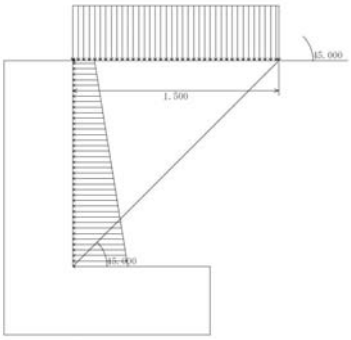
q_0 : Surcharge (kN/m²)

w_{q0} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 1.500× 9.80 = 14.700 (kN/m^2)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

(2) Seismic Condition-1

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.500 × 24.00 × 0.20 = 2.400

Thus、

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	0.000	(m)
Embankment Height under the water level surface	H2	=	1.500	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γt	=	19.00	(kN/m^3)
Unit Weight of Soil (Saturated)	γ_{sat}	=	20.00	(kN/m^3)
Unit Weight of Water	γ_w	=	9.80	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	1.863	(m)
Width of Converted Load	B	=	1.863	(m)
Internal Friction Angle of Soil	ϕ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Apparent Horizontal Seismic Coefficient underwater	kh	=	0.345	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}$ (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}$ (kh')	=	19.026	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ + 0.00^\circ + 11.310^\circ\ )\times\sin(\ 30.00^\circ + 0.00^\circ\ )}{\cos(\ 0.00^\circ - 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}}$$

$$\cot(\xi_{EA}-\alpha) = 0.85094$$

Thus,

$$\cot(\xi_{EA}-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604(^\circ)$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{EA}'-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o')\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o')}}$$

$$= -\tan(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$+\sec(\ 30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ\ )$$
$$\times\sqrt{\frac{\cos(\ 0.00^\circ + 0.00^\circ + 19.026^\circ\ )\times\sin(\ 30.00^\circ + 0.00^\circ\ )}{\cos(\ 0.00^\circ - 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 19.026^\circ\ )}}$$

$$\cot(\xi_{EA}'-\alpha) = 1.24217$$

Thus,

$$\cot(\xi_{EA}'-\ 0.00^\circ\ ) = \frac{1}{\tan(\xi_{EA}')} = 1.24217$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{1.24217}\right) = 38.836(^\circ)$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ - 11.310^\circ - 0.00^\circ\ )}{\cos(\ 11.310^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )}$$
$$\times\frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ + 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 11.310^\circ\ )}{\cos(\ 0.00^\circ + 11.310^\circ + 0.00^\circ\ )\times\cos(\ 0.00^\circ - 0.00^\circ\ )}}\right]^2}$$

= 0.4733

In case φ-α-θ_o< 0, sin(φ-α-θ_o) = 0.

$$K_{EA}' = \frac{\cos^2(\phi-\theta_o'-\theta)}{\cos\theta_o'\cdot\cos^2\theta\cdot\cos(\theta+\theta_o'+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o')}{\cos(\theta+\theta_o'+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(\ 30.00^\circ - 19.026^\circ - 0.00^\circ\ )}{\cos(\ 19.026^\circ\ )\times\cos^2(\ 0.00^\circ\ )\times\cos(\ 0.00^\circ + 19.026^\circ + 0.00^\circ\ )}$$
$$\times\frac{1}{\left[1+\sqrt{\frac{\sin(\ 30.00^\circ + 0.00^\circ\ )\times\sin(\ 30.00^\circ - 0.00^\circ - 19.026^\circ\ )}{\cos(\ 0.00^\circ + 19.026^\circ + 0.00^\circ\ )\times\cos(\ 0.00^\circ - 0.00^\circ\ )}}\right]^2}$$

= 0.6214

In case φ-α-θ'$_o$< 0, sin(φ-α-θ'$_o$) = 0.

Weight of Embankment W

$$W = 0.000\ (kN/m)$$

Converted Load q0'

$$q0' = (W + q0\cdot wq0)\ /\ B$$
$$= (\ 0.000 + 5.00\times 1.863)\ /\ 1.863$$
$$= 5.000\ (kN/m^2)$$

Earth Pressure at the Top

P1 = q0'・K_{EA} = 5.000× 0.4733 = 2.366 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 0.000+ 2.366

= 2.366 (kN/m^2)

Earth Pressure at Junction

P3 = K_{EA}・ (γ_{sat} – γ_w)・h2 + p2

= 0.6214×(20.00- 9.80)× 1.500+ 2.366

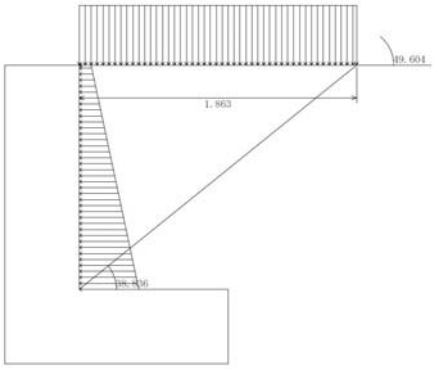
= 11.874 (kN/m^2)

Design Earth Pressure

P_{HE} = P3 ・cosδ= 11.874× cos(0.00°)

= 11.874 (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

Ph = hh・γ_w= 1.500× 9.80 = 14.700 (kN/m^2)

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Water Pressure	14.70	1.000	7.35
Earth Pressure	12.65	1.000	6.32
Σ	27.35	----	13.68
Bending Moment	M (kN.m/m)	Σ(P･l²/2) = 13.68	
Shear Force	S (kN/m)	Σ(P･l) = 27.35	

2) Seismic Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Inertia force	2.40	1.000	1.20
Water Pressure	14.70	1.000	7.35
Earth Pressure	11.87	1.000	5.94
Σ	28.97	----	14.49
Bending Moment	M (kN.m/m)	Σ(P･l²/2) = 14.49	
Shear Force	S (kN/m)	Σ(P･l) = 28.97	

1.2.3 Stress Calculation

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Front	mm²	D16 - 4.00 = 794.4
	Back	mm²	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	13.68
Re-bar	d1 As1	mm mm²	410.0 794.4
Required Area of Re-bar	Back	mm²	246.4
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm²	1.01
	σs	N/mm²	44.51
Allowable Value	σca	N/mm²	8.20
	σsa	N/mm²	140.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	328.5
	inp	mm²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	14.49
Re-bar	d1 As1	mm mm²	410.0 794.4
Required Area of Re-bar	Back	mm²	195.7
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm²	1.07
	σs	N/mm²	47.15
Allowable Value	σca	N/mm²	12.30
	σsa	N/mm²	186.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	261.0
	inp	mm²	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	27.35
Re-bar	d1 As1	mm mm²	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.067
Allowable Value	τa	N/mm²	0.360
	τa2	N/mm²	1.600

■Seismic Condition-1

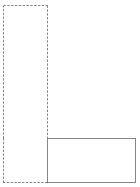
	Symbol	Unit	Junction
Shear Force	S	kN	28.97
Re-bar	d1 As1	mm mm²	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.071
Allowable Value	τa	N/mm²	0.540
	τa2	N/mm²	2.400

1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall

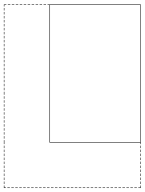


Sw = h・γc= 0.500 × 24.00 = 12.000

Thus,

Sw : Weight of Body (kN/m²)
h : Height of Bottom Slab (m)
γc : Unit Weight of Concrete (kN/m³)

1-2) Weight of the Embankment



Pw1 = (h1・γt+ h2・γsat) = 0.000× 19.00 + 1.500× 20.00 = 30.000
Pw2 = (h1・γt+ h2・γsat) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Thus、

Pw1 : Wight of Embankment at basis (kN/m²)
Pw2 : Weight of Embankment at edge (kN/m²)
H1 : Height of Embankment above water (m)
H2 : Height of Embankment underwater (m)
γt : Wet Unit Weight of Soil (kN/m³)
γsat : Unit Weight of Soil underwater (kN/m³)

1-3) Subgrade Reaction Force

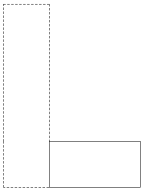
	Intensity of subgrade reaction (kN/m²)
Base	17.18
Edge	51.54

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

(2)) Seismic Condition-1

2-1) Self-weight of Wall



Sw = h・γ_c= 0.500 × 24.00 = 12.000

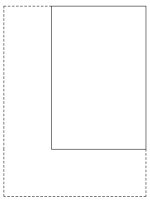
Thus、

Sw : Weight of Wall (kN/m^2)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m^3)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 0.000× 19.00 + 1.500× 20.00 = 30.000

Thus、

Pw1 : Wight of Embankment at basis (kN/m^2)

Pw2 : Weight of Embankment at edge (kN/m^2)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m^3)

γ_{sat} : Unit Weight of Soil underwater (kN/m^3)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	13.00
Edge	38.99

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m^2)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

1.3.2 Summary of Cross-Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	17.18	1.000	8.59
Surcharge	-10.00	1.000	-5.00
Σ	-15.22	----	-7.61
Bending Moment M (kN.m/m) Σ(P・l^2/2) = -7.61			
Shear Force S (kN/m) Σ(P・l) = -15.22			

1-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	51.54	1.000	25.77
Surcharge	-10.00	1.000	-5.00
Σ	19.14	----	9.57
Bending Moment M (kN.m/m) Σ(P・l^2/2) = 9.57			
Shear Force S (kN/m) Σ(P・l) = 19.14			

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	13.00	1.000	6.50
Surcharge	-5.00	1.000	-2.50
Σ	-14.40	----	-7.20
Bending Moment M (kN.m/m) Σ(P・l^2/2) = -7.20			
Shear Force S (kN/m) Σ(P・l) = -14.40			

2-2) Edge

	P (kN/m^2)	L (m)	P・l^2/2 (kN.m/m)
Body Weight	-12.00	1.000	-6.00
Embankment Weight	-30.00	1.000	-15.00
Uplift Force	19.60	1.000	9.80
Intensity of Subgrade Reaction	38.99	1.000	19.50
Surcharge	-5.00	1.000	-2.50
Σ	11.59	----	5.80
Bending Moment M (kN.m/m) Σ(P・l^2/2) = 5.80			
Shear Force S (kN/m) Σ(P・l) = 11.59			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.500
Re-bar	Upper	mm^2	D16 - 4.00 = 794.4
	Lower	mm^2	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	-7.61	9.57
Re-bar	d1 As1	mm mm^2	90.0 794.4	385.0 794.4
Required Area of Re-bar	Upper	mm^2	135.9	
	Lower	mm^2		182.9
Neutral Axis	X	m	0.070	0.067
Stress Intensity	σc	N/mm^2	0.56	0.78
	σs	N/mm^2	24.77	33.23
Allowable Value	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	181.3	243.9
	inp	mm^2	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	-7.20	5.80
Re-bar	d1 As1	mm mm^2	90.0 794.4	385.0 794.4
Required Area of Re-bar	Upper	mm^2	96.5	
	Lower	mm^2		82.6
Neutral Axis	X	m	0.070	0.067
Stress Intensity	σc	N/mm^2	0.53	0.47
	σs	N/mm^2	23.44	20.12
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	128.6	110.1
	inp	mm^2	794.4	794.4

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	-15.22	19.14
Re-bar	d1 As1	mm mm^2	90.0 794.4	385.0 794.4
Effective Height	d	mm	410.0	385.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.037	0.050
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	-14.40	11.59
Re-bar	d1 As1	mm mm^2	90.0 794.4	385.0 794.4
Effective Height	d	mm	410.0	385.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.035	0.030
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400

2.2.2.7 SLUICEWAY TYPE J

(4) BREAST WALL - RIVER SIDE

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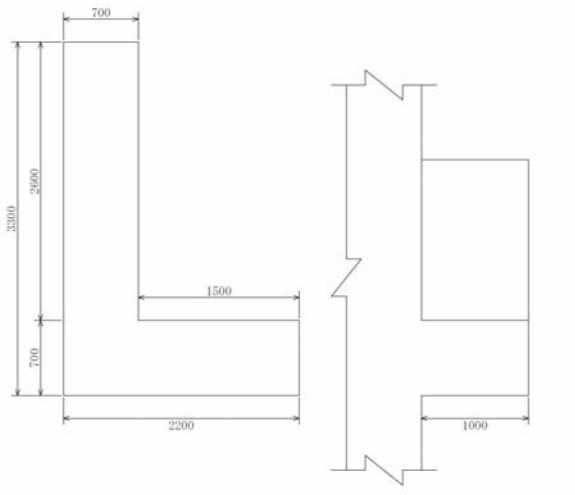
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1 Calculation of River Side Breast Wall

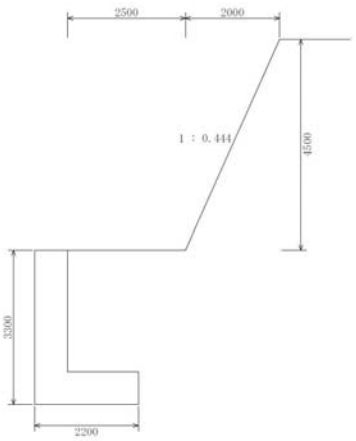
1.1 Design Condition

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 **Material and Design Parameters**

■Unit Weights

Reinforced Concrete	γc	kN/m³	24.00
Water	γw	kN/m³	9.80
Soil (Wet)	γt	kN/m³	19.00
Soil (Saturated)	γsat	kN/m³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σck	N/mm²	20.70	20.70
Modulus of Young's *10⁴	Ec	N/mm²	2.31	2.31
Allow Flexural Strength	σca	N/mm²	8.20	8.20
Allow Axial Strength	σca	N/mm²	8.20	8.20
Allow Shear Strength	τa1	N/mm²	0.360	0.360
Allow Shear Strength	τa2	N/mm²	1.600	1.600
Young's modulus ratio	Es/Ec		9.0	9.0
Expansion Coefficient *10⁻⁶	α	/℃	9.00	9.00

■Steel Reinforcement

Material				SD295
Normal	Sidewall		Harsh Environment	
	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σsa	N/mm²	Normal (General)	140.00
		N/mm²	Normal (Harsh)	140.00
		N/mm²	Seimic	186.00
Allow Compressive Strength	σsa'	N/mm²	Normal	140.00
		N/mm²	Seimic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φres	○	30
Peak Angle of Internal Friction	φpeak	○	30
Coefficient of Lateral Earth Pressure at-rest	Ko		0.500

1.1.3 **Reinforcement Arrangement**

■Main Tensile Reinforcement

Location		Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm²/m)
Wall	Front Face	90.0	D16	250	794.4
	Back Face	90.0	D16	250	794.4
Bottom Slab	Top Face	90.0	D16	250	794.4
	Bottom Face	115.0	D16	250	794.4

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 **Loads**

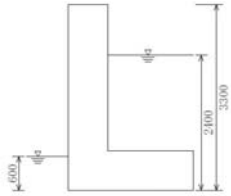
■Basic Load

1)Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

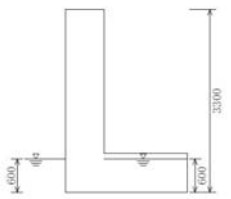
	(m)
Toe	0.600
Heel	2.400



1-2) Seismic Condition Number of Cases [1]

<Case 1>

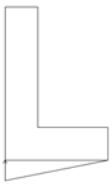
	(m)
Toe	0.600
Heel	0.600
Direction	Back → Front



2)Subgrade Reaction

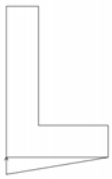
2-1) Normal <Case 1>

	(kN/m²), (m)
Toe	151.82
Heel	0.00
Load Width	2.200



2-2) Seismic <Case 1>

	(kN/m²), (m)
Toe	129.02
Heel	0.00
Load Width	2.200



3)Surcharge Load

Normal	kN/m²	10.00
Seismic	kN/m²	5.00

4)Seismic Condition (Design Horizontal Seismic Coefficient)

Structure Calculation	0.20
Earth Pressure Calculation	0.20

1.2 Calculation of Vertical Wall

1.2.1 Load

(1) Normal Condition-1

1-1) Earth Pressure (Earth Pressure at Rest)

Weight of Embankment W =115.425 (kN/m)

※ξ_A(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W+q0・wq0)/B

= (115.425+ 10.00× 2.600)/ 2.600

= 54.394 (kN/m^2)

Earth Pressure at the Top

p1 = q0'・Ko = 54.394× 0.500 = 27.197 (kN/m^2)

Earth Pressure at Water Level

p2 = Ko・γ_t・h1+p1

= 0.500× 19.00× 0.900+ 27.197

= 35.747 (kN/m^2)

Earth Pressure at Bottom Surface of Base

p3 = Ko・(γ_{sat}-γ_w)・h2+p2

= 0.500×(20.00- 9.80)× 1.700+ 35.747

= 44.417 (kN/m^2)

Design Earth Pressure

P = p3

= 44.417 (kN/m^2)

Thus、

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γt : Unit Weight of Soil (Wet) (kN/m^3)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m^3)

γ_w : Unit Weight of Water (kN/m^3)

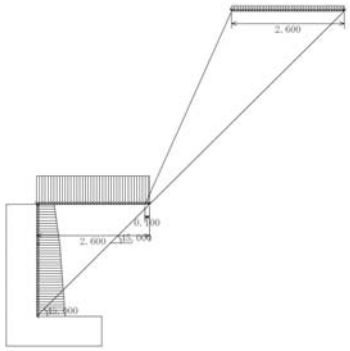
q_0 : Surcharge (kN/m^2)

w_{qo} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

■Converted Loads Acting on Breast Wall



1-2) Water Pressure

Ph = hh・γ_w= 1.700× 9.80 = 16.660 (kN/m^2)

Thus、

hh : Height from the Junction of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

(2) Seismic Condition-1

2-1) Seismic Inertia Force

H = B・γ_c・kh= 0.700 × 24.00 × 0.20 = 3.360

Thus、

H : Inertia Force (kN/m^2)

B : Thickness of Vertical Wall (m)

γ_s : Unit Weight of Concrete (kN/m^3)

Kh : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h1	=	2.600	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_t	=	19.00	(kN/m^3)
Surcharge	q0	=	5.00	(kN/m^2)
Load width of Surcharge	wq0	=	0.00	(m)
Width of Converted Load	B	=	2.212	(m)
Internal Friction Angle of Soil	ϕ	=	30.00	(degree)
Angle between Ground Surface and Horizontal Plane	α	=	0.00	(degree)
Friction Angle (Soil and Concrete)	δ_E	=	0.00	(degree)
Design Horizontal Seismic Coefficient	kh	=	0.20	(degree)
Compound Angle in Seismic Condition	$\theta_0 = \tan^{-1}(kh)$	=	11.310	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{EA}-\alpha) = -\tan(\phi+\delta_E+\theta-\alpha)+\sec(\phi+\delta_E+\theta-\alpha)\sqrt{\frac{\cos(\theta+\delta_E+\theta_o)\cdot\sin(\phi+\delta_E)}{\cos(\theta-\alpha)\cdot\sin(\phi-\alpha-\theta_o)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ)\times\sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$\cot(\xi_{EA}-\alpha) = 0.85094$

Thus,

$$\cot(\xi_{EA} - 0.00^\circ) = \frac{1}{\tan(\xi_{EA})} = 0.85094$$

$$\xi_{EA} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o\cdot\cos^2\theta\cdot\cos(\theta+\theta_o+\delta_E)\left[1+\sqrt{\frac{\sin(\phi+\delta_E)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta_E)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ)\times\cos^2(0.00^\circ)\times\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \times \frac{1}{\left[1+\sqrt{\frac{\sin(30.00^\circ + 0.00^\circ)\times\sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ)\times\cos(0.00^\circ - 0.00^\circ)}}\right]^2}$$

$= 0.4733$

In case $\varphi-\alpha-\theta_o < 0$, $\sin(\varphi-\alpha-\theta_o) = 0$.

Earth Pressure at the Top

P1 = q0'・K_{EA} = 0.000× 0.4733 = 0.000 (kN/m^2)

Earth Pressure at Water Level

P2 = K_{EA}・γ_t・h1 + p1

= 0.4733× 19.00× 2.600+ 0.000

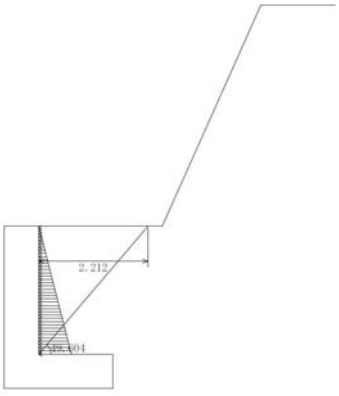
= 23.379 (kN/m^2)

Design Earth Pressure

P_{HE} = P3 ・cosδ= 23.379× cos(0.00°)

= 23.379 (kN/m^2)

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

Ph = hh・γ_w= 0.000× 9.80 = 0.000 (kN/m^2)

Thus、

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m^3)

Weight of Embankment	W	W = 0.000 (kN/m)
Converted Load	q0'	q0' = (W + q0・wq0) / B = (0.000+ 5.00× 0.000) / 2.212 = 0.000 (kN/m^2)

1.2.2 **Summary of Cross-sectional Internal Forces**

1) Normal Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Water Pressure	16.66	1.000	8.33
Earth Pressure	44.42	1.000	22.21
Σ	61.08	----	30.54
Bending Moment M (kN.m/m) Σ(P･l²/2) = 30.53			
Shear Force S (kN/m) Σ(P･l) = 61.08			

2) Seismic Condition-1

	P (kN/m²)	L (m)	P･l²/2 (kN.m/m)
Inertia force	3.36	1.000	1.68
Water Pressure	0.00	1.000	0.00
Earth Pressure	23.38	1.000	11.69
Σ	26.74	----	13.37
Bending Moment M (kN.m/m) Σ(P･l²/2) = 13.37			
Shear Force S (kN/m) Σ(P･l) = 26.74			

1.2.3 **Stress Calculation**

1) Bending Stress Intensity

■Cross-sectional Properties

	Symbol	Unit	Vertical Wall
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Front	mm²	D16 - 4.00 = 794.4
	Back	mm²	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	30.54
Re-bar	d1 As1	mm mm²	610.0 794.4
Required Area of Re-bar	Back	mm²	369.8
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm²	1.21
	σs	N/mm²	66.15
Allowable Value	σca	N/mm²	8.20
	σsa	N/mm²	140.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	493.1
	inp	mm²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	13.37
Re-bar	d1 As1	mm mm²	610.0 794.4
Required Area of Re-bar	Back	mm²	120.2
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm²	0.53
	σs	N/mm²	28.96
Allowable Value	σca	N/mm²	12.30
	σsa	N/mm²	186.00
Minimum Area of Re-Bar	min	mm²	
	req	mm²	160.2
	inp	mm²	794.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	61.08
Re-bar	d1 As1	mm mm²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.100
Allowable Value	τa	N/mm²	0.360
	τa2	N/mm²	1.600

■Seismic Condition-1

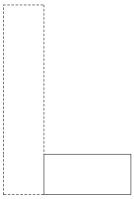
	Symbol	Unit	Junction
Shear Force	S	kN	26.74
Re-bar	d1 As1	mm mm²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm²	0.044
Allowable Value	τa	N/mm²	0.540
	τa2	N/mm²	2.400

1.3 Calculation of Bottom Slab

1.3.1 **Load**

(1) **Normal Condition-1**

1-1) Self-weight of Wall



Sw = h・γc= 0.700 × 24.00 = 16.800

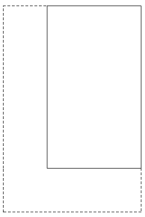
Thus,

Sw : Weight of Body (kN/m2)

h :Height of Bottom Slab (m)

γc : Unit Weight of Concrete (kN/m³)

1-2) Weight of the Embankment



Pw1 = (h1・γt+ h2・γsat) = 0.900× 19.00 + 1.700× 20.00 = 51.100

Pw2 = (h1・γt+ h2・γsat) = 0.900× 19.00 + 1.700× 20.00 = 51.100

Thus、

Pw1 : Wight of Embankment at basis (kN/m²)

Pw2 : Weight of Embankment at edge (kN/m²)

H1 :Height of Embankment above water (m)

H2 :Height of Embankment underwater (m)

γt : Wet Unit Weight of Soil (kN/m³)

γsat : Unit Weight of Soil underwater (kN/m³)

1-3) Subgrade Reaction Force

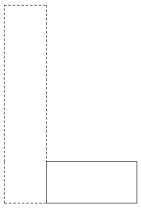
	Intensity of subgrade reaction (kN/m²)
Base	103.51
Edge	0.00

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m²)
Base	1.173× 9.80	11.493
Edge	2.400× 9.80	23.520

(2) **) Seismic Condition-1**

2-1) Self-weight of Wall



Sw = h・γ_c= 0.700 × 24.00 = 16.800

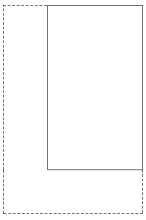
Thus、

Sw : Weight of Body (kN/m²)

H :Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



Pw1 = (h1・γ_t+ h2・γ_{sat}) = 2.600× 19.00 + 0.000× 20.00 = 49.400

Pw2 = (h1・γ_t+ h2・γ_{sat}) = 2.600× 19.00 + 0.000× 20.00 = 49.400

Thus、

Pw1 : Wight of Embankment at basis (kN/m²)

Pw2 : Weight of Embankment at edge (kN/m²)

H1 : Height of Embankment above water (m)

H2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

2-3) Subgrade Reaction Force

	Intensity of Subgrade Reaction
Base	87.97
Edge	0.00

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unite (kN/m²)
Base	0.600× 9.80	5.880
Edge	0.600× 9.80	5.880

1.3.2 **Summary of Cross Sectional Force**

1) Normal Condition-1

1-1) Junction Section

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.10	1.000	-25.55
Uplift Force	11.49	1.000	5.75
Intensity of Subgrade Reaction	103.51	1.000	51.76
Σ	47.11	----	23.55
Bending Moment M (kN.m/m) Σ(P・l²/2) = 23.55			
Shear Force S (kN/m) Σ(P・l) = 47.11			

1-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-51.10	1.000	-25.55
Uplift Force	23.52	1.000	11.76
Intensity of Subgrade Reaction	0.00	1.000	0.00
Σ	-44.38	----	-22.19
Bending Moment M (kN.m/m) Σ(P・l²/2) = -22.19			
Shear Force S (kN/m) Σ(P・l) = -44.38			

2) Seismic Condition-1

2-1) Base

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-49.40	1.000	-24.70
Uplift Force	5.88	1.000	2.94
Intensity of Subgrade Reaction	87.97	1.000	43.98
Σ	27.65	----	13.82
Bending Moment M (kN.m/m) Σ(P・l²/2) = 13.82			
Shear Force S (kN/m) Σ(P・l) = 27.65			

2-2) Edge

	P (kN/m²)	L (m)	P・l²/2 (kN.m/m)
Body Weight	-16.80	1.000	-8.40
Embankment Weight	-49.40	1.000	-24.70
Uplift Force	5.88	1.000	2.94
Intensity of Subgrade Reaction	0.00	1.000	0.00
Σ	-60.32	----	-30.16
Bending Moment M (kN.m/m) Σ(P・l²/2) = -30.16			
Shear Force S (kN/m) Σ(P・l) = -60.32			

1.3.3 **Stress Intensity Calculation**

(1) **Flexural Stress Intensity**

■Cross Section Characteristics

	Symbol	Unit	Toe Slab
Cross Section Width	B	m	1.000
Height of Section	H	m	0.700
Re-bar	Upper	mm^2	D16 - 4.00 = 794.4
	Lower	mm^2	D16 - 4.00 = 794.4

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	23.55	-22.19
Re-bar	d1	mm	585.0	90.0
	As1	mm^2	794.4	794.4
Required Area of Re-bar	Upper	mm^2		267.4
	Lower	mm^2	296.6	
Neutral Axis	X	m	0.085	0.087
Stress Intensity	σc	N/mm^2	1.00	0.88
	σs	N/mm^2	53.25	48.06
Allowable Value	σca	N/mm^2	8.20	8.20
	σsa	N/mm^2	140.00	140.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	395.5	356.6
	inp	mm^2	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	13.82	-30.16
Re-bar	d1	mm	585.0	90.0
	As1	mm^2	794.4	794.4
Required Area of Re-bar	Upper	mm^2		273.6
	Lower	mm^2	129.7	
Neutral Axis	X	m	0.085	0.087
Stress Intensity	σc	N/mm^2	0.59	1.20
	σs	N/mm^2	31.25	65.33
Allowable Value	σca	N/mm^2	12.30	12.30
	σsa	N/mm^2	186.00	186.00
Minimum of Re-bar Area	min	mm^2		
	req	mm^2	172.9	364.9
	inp	mm^2	794.4	794.4

(2) **Shear Stress Intensity**

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	47.11	-44.38
Re-bar	d1	mm	585.0	90.0
	As1	mm^2	794.4	794.4
Effective Height	d	mm	585.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.081	0.073
Allowable Value	τa	N/mm^2	0.360	0.360
	τa2	N/mm^2	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	27.65	-60.32
Re-bar	d1	mm	585.0	90.0
	As1	mm^2	794.4	794.4
Effective Height	d	mm	585.0	610.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	τm	N/mm^2	0.047	0.099
Allowable Value	τa	N/mm^2	0.540	0.540
	τa2	N/mm^2	2.400	2.400