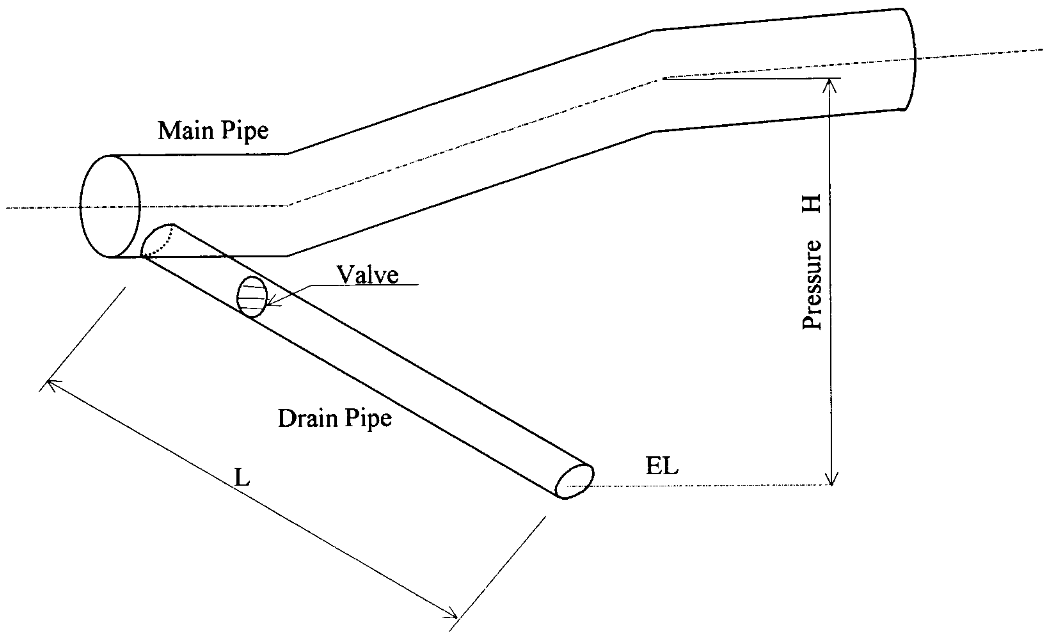
APPENDIX C.4.4-6 Dimensions and Structural Design of Blow Off

(1) Diameter of drain pipe and discharge time



Discharge of drain pipe will be estimated by the following equation;

$$q = a \cdot v = a \cdot \sqrt{\frac{2g \cdot H}{1 + f_1 + \Sigma fn + f\frac{L}{4R}}}$$

where

q	:	Discharge of drain pipe (m^3/s)
a	:	Flow area of drain pipe (m^2)
v	:	Velocity of drain pipe (m/s)
H	:	Water pressure of drain pipe (t/m)
f_1	:	Head loss coefficient of inflow of drain pipe
Σf_n	:	Head loss coefficient of bend, valve and others of drain pipe
f	:	Head loss coefficient of friction of drain pipe
L	:	Length of drain pipe (m)
		Beginning of pipeline L=110m (Assume)
		No.1～No.3 of blow off L=30m (Assume)
R	:	Hydraulic radius of drain pipe (m)
g	:	Acceleration of gravity (m/s^2) 9.8 m/s^2

Formula will be transformed by the practical figures

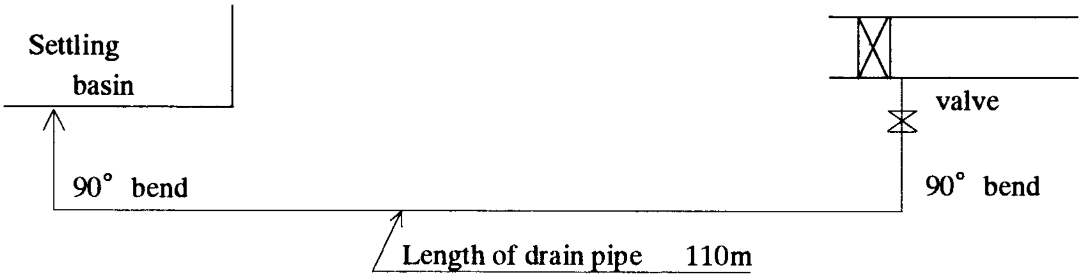
(a) Beginning of pipeline (No.1)

Diameter of blow off pipe will be specified 0.40m by Japanese Industrial Standard, and discharge time of main pipe will be calculated as follows.

$a = 0.126m^2$

$f_1 = 0.5$

Σf_n = bends (0.3×2)+valve (0.3×1)+others (0.3) = 1.2



$$f = \frac{2g}{C^2} = \frac{2 \times 9.8}{54.2^2} = 0.00714$$

$$C = \frac{1}{n} \cdot R^{1/6} = \frac{1}{0.013} \cdot (0.1)^{1/6} = 54.2$$

n : manning "n" 0.013 for steel pipe

$$R = \frac{D}{4} = \frac{0.4}{4} = 0.1$$

$$\therefore q = 0.126 \times \sqrt{\frac{2 \times 9.8 \times H}{1 + 0.5 + 1.2 + 0.0714 + \frac{110}{4 \times 0.1}}} = 0.126 \times 2.05\sqrt{H}$$

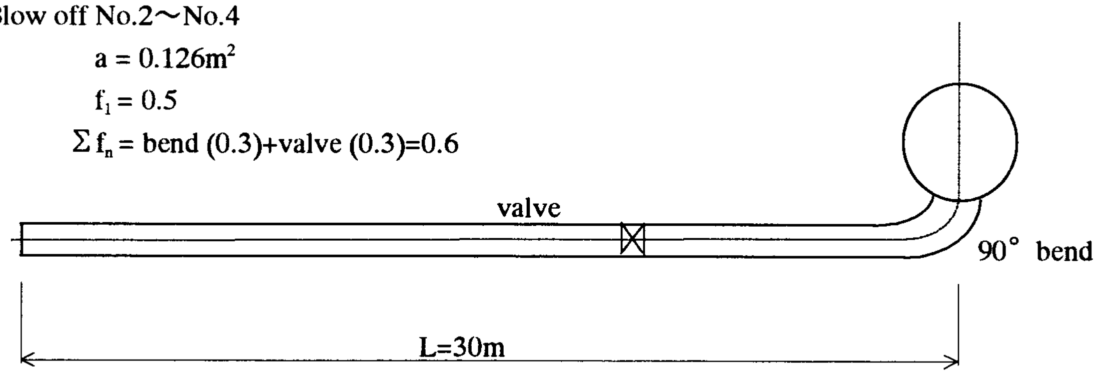
$$= 0.258\sqrt{H}$$

(b) Blow off No.2～No.4

$a = 0.126m^2$

$f_1 = 0.5$

Σf_n = bend (0.3)+valve (0.3)=0.6



f=0.00714 (same as beginning of pipeline No.1)

$$q = 0.126 \times \sqrt{\frac{2 \times 9.8 \times H}{1 + 0.5 + 0.6 + 0.00714 \times \frac{30}{4 \times 0.1}}} = 0.126 \times 2.73\sqrt{H}$$

$$= 0.343 \cdot \sqrt{H}$$

(c) Discharge Time (T) hours

$$T = \frac{V}{3600 \cdot q}$$

V : Water amount of main pipe to be drained

The following table is shown discharge time of each blow off and it's procedure, and the time will be estimated approx. 7 hours to empty main pipe.
The 7 hours is reasonable working time a day to consist with.

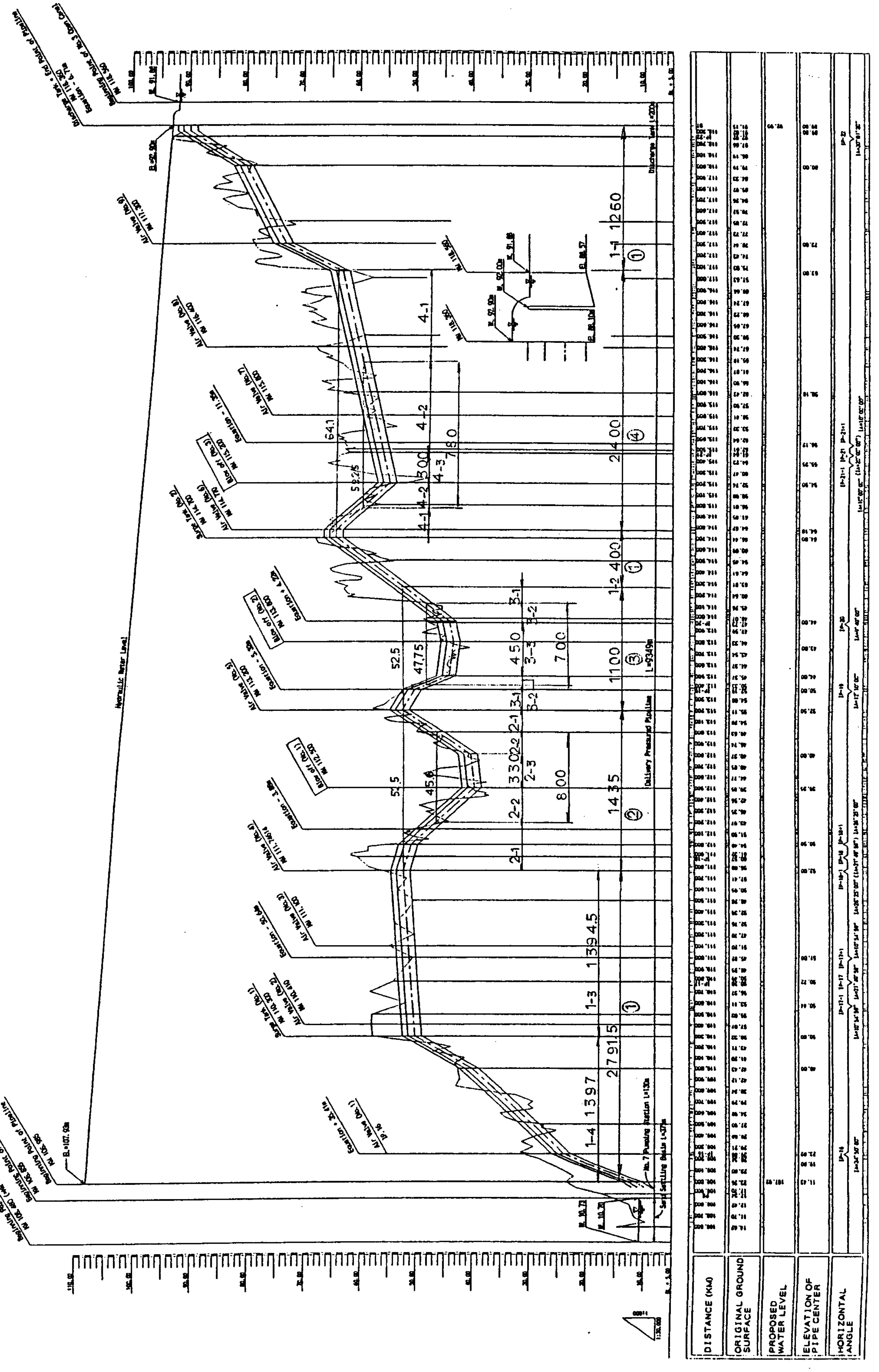
Discharge Time

No.	Part 1				Part 2				Part3				Part4				ΣT(hr)
	$\overline{H_1}$	q_1	V_1	T_1	$\overline{H_2}$	q_2	V_2	T_2	$\overline{H_3}$	q_3	V_3	T_3	$\overline{H_4}$	q_4	V_4	T_4	
Beginning of pipeline (KM108.93850)	69.0	2.14	5,700	0.74	50.0 ($q = 0.258\sqrt{H}$)	1.82	1,810	0.28	42.8	1.69	6,310	1.04	21.4	1.19	6,320	1.47	3.53
Blow off No.1 (KM 112.500)	11.3	1.15	2,870	0.69	5.3 ($q = 0.343\sqrt{H}$)	0.790	1,808	0.64	2.1	0.497	1,808	1.01	-	-	-	-	2.34
Blow off No.2 (KM 113.800)	8.8	1.02	1,808	0.49	4.6 ($q = 0.343\sqrt{H}$)	0.736	1,130	0.43	2.2	0.509	2,034	1.11	-	-	-	-	2.03
Blow off No.3 (KM115.200)	8.8	1.02	7,320	1.99	4.6 ($q = 0.343\sqrt{H}$)	0.736	2,170	0.82	2.2	0.509	1,360	0.74	-	-	-	-	3.55
					Total Discharge Time (max)				3.53 (No.1) + 3.55 (No.4) = 7.1 hr (max of No.2~No.4)								

(2) Pipe wall thickness of drain pipe

(a) Design condition (summarized)

Steel pipe dimension	Diameter	D = 400 mm, Dc= 406.4 mm, t = 6 mm
Design Inner pressure		P = 12 kgf/cm^2
Earth cover from the top of pipe to the surface of backfill or embankment		H = 7.5 m
Vertical load (Truck load)		T - 70
Unit weight of wet soil		γ = 1.8 tf/m^3
Angle of shear resistance		ϕ = 30°
Design support angle		θ = 90°
Reaction modulus of foundation material		E' = 48 kgf/cm^2
Excavation method		Non sheet pile method
Excavation width		B = 23.6/3 = 7.87 m
Material of steel pipe		STPY400
Allowable stress		σa = 1400 kgf/cm^2
Design deflection ratio (%)		3%


Hydraulic Water Level
Delivery Pressured Pipeline
DISTANCE (KM)
ORIGINAL GROUND SURFACE
PROPOSED WATER LEVEL
ELEVATION OF PIPE CENTER
HORIZONTAL ANGLE

(b) Tensile stress by Inner pressure of pipe

$\sigma t = PD/2t$

D = Dc–2t= 40.64 – 2 x 0.6 = 39.4 cm

∴ σt = 12 x 39.4 / (2 x 0.6) = 394 kgf/cm^2 < σa = 1400 kgf/cm^2 O.K.

(c) Vertical earth pressure

Vertical earth pressure shall be calculated by following equation;

$H > 2.0m \quad Wv = Cd \cdot \gamma \cdot B$

$Cd = (1 - e - 2K \cdot \mu' \cdot H / B) / 2K\mu'$

H (m)	K	μ'	B(cm)	-2K・μ・H/B	$e^{-2K\cdot\mu\cdot H/B}$	Cd	γ	**Wv(kgf/cm^2)**
7.5	0.33	0.58	787	-0.3633	0.695	0.799	0.0018	**1.132**

(d) Wheel Load

$$Wv = \frac{P \cdot \beta}{W} = \frac{P \cdot \beta}{155 + 2H}$$

$$P = \frac{2 \times ([FrontWheelLoad] + [BackWheelLoad])}{[VehicleOccupationWidth]} \times (1 + i)$$

Vertical Pressure by Wheel Load

H(m)	Back Wheel Loads (kgf)	Vehicle Occupation width (cm)	i	P (kgf/cm)	β	**Wt (kgf/cm^2)**
7.5	11700	350	0.2	160	0.9	**0.087**

(e) Calculation of Deflection

$$\Delta X = \frac{2Kx \cdot (Wv + Wt) \cdot R^4}{EI + 0.061E' R^3}$$

H(m)	Wv	Wt	ΔX	Design Deflection Ratio ΔX/D×100 (%)	Judge
7.5	1.132	0.087	0.613	**1.5%** < 3%	O.K.

(f) Flexural Stress

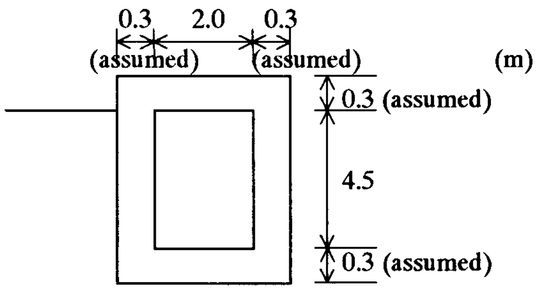
$$\sigma_b = \frac{2(Wv + Wt)}{f \cdot Z} \times \frac{Kb \cdot R^2 \cdot EI + (0.061Kb - 0.083Kx) \cdot E' R^5}{EI + 0.061E' R^3}$$

Calculation of Flexural Stress

H(m)	Wv	Wt	σ_b		σ_a	Judge
7.5	1.132	0.087	**1168**	<	1400	O.K.

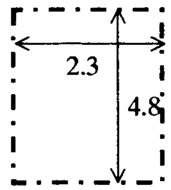
(3) Structural calculation of Blow Off

(a) Sectional Dimension for Calculation



Rigid Frame Dimension

(m)



(b) Calculation of Load

(i) Own Weight and Earth Weight Applied for Top Slab (W_1)

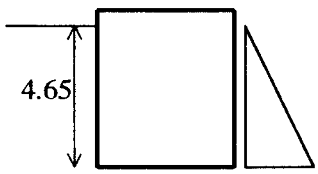
Concrete Weight of Top Slab 0.735 tf/m^2 (= 0.30 * 2.45)

(ii) Reaction Force of Bottom Slab (W_2)

	Concrete Weight of Top Slab	9.937 tf (= 0.30 *2.6*5.2* 2.45)
	Concrete Weight of Side Slab	47.628 tf (= (2.6 * 5.2 - 2.0 * 4.6) * 4.5 * 2.45)
	Pipe Weight (Inside Chamber)	0.355 tf (= (2.6 - 0.6) * 3 *0.0592 tf/m)
	Water Weight (Inside Pipe)	0.980 tf (= 2.6m * π * 0.4^2 / 4 * 3 * 1.0)
+)	Valve Weight	2.490 tf (= 0.83 * 3)
		61.390 tf / (2.3*4.9) = **5.561** tf/m^2

(iii) Side Earth Pressure (P_1)

Side earth pressure should be calculated by following equation; $P = K_0 \times \gamma_t \times H$

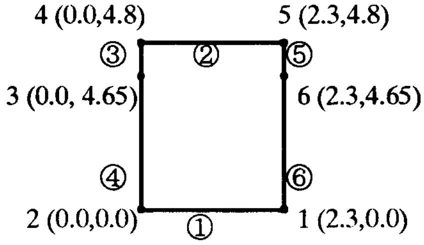


$P_1 = 0.5 \times 1.8 \times 4.65 = 4.185$ tf/m^2

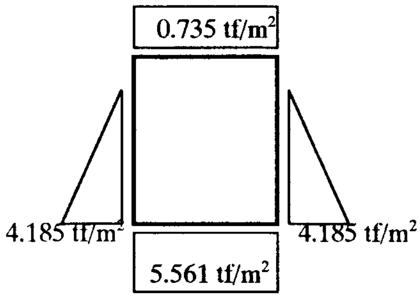
(iv) Load Distribution

Load Distribution, Element Number, Contact Point Number and Coordinates are figured as follows.

Element Number, Contact Number and Coordinates



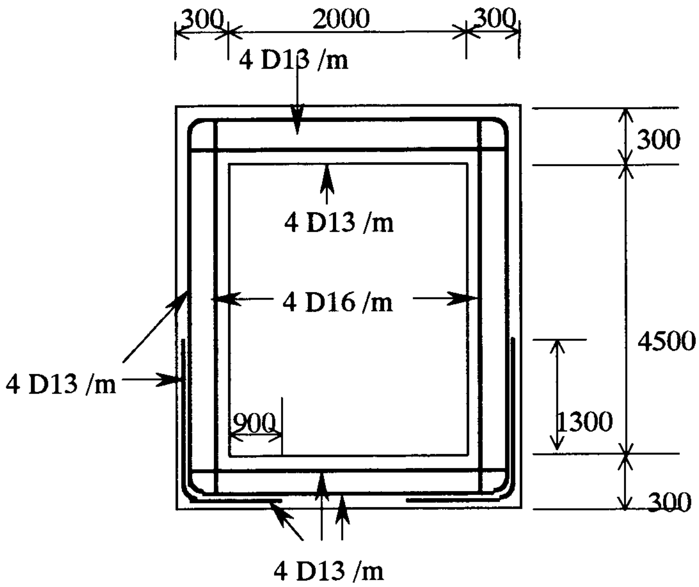
Load Distribution



(c) Result of Calculation

Part	Top Slab Outside	Side Slab Outside	Side Slab Inside	Bottom Slab Outside	Bottom Slab Inside
Bending Moment (kgf·cm)	21.090	40.490	28.040	40.490	3.710
Axial Force (kgf)	2.742	0.844	0.844	6.993	6.993
Shearing Force (kgf)	0.846	6.993	0.000	6.396	0.000

(d) Design of Reinforcement



(e) Stress Analysis

Stress analysis will be shown at next page.

Stress Analysis of North Sinai Blow Off

			Top Slab Outside	Side Slab Outside	Side Slab Inside	Bottom Slab Outside
Bending Moment		M (kgf·cm)	210,900	404,900	280,400	404,900
Axial Force		N (kgf)	2,742	844	844	6,993
Shearing Force		S (kgf)	846	6,993	-	6,396
Width		b (cm)	1,040	1,040	1,040	1,040
Thickness		h (cm)	30.0	30.0	30.0	30.0
Effective Depth		d (cm)	23.0	23.0	23.0	23.0
Cover (Compressive)		d_1 (cm)	7.0	7.0	7.0	7.0
Cover (Tensile)		d_2 (cm)	7.0	7.0	7.0	7.0
Required Effective Depth		d_0 (cm)	3.8	5.1	4.3	5.4
Judge	Axial Direction Force		Compressive	Compressive	Compressive	Compressive
			Case2-A	Case2-A	Case2-A	Case2-A
	Tensile Steel		Required	Required	Required	Required
	Compressive Steel		Not Required	Not Required	Not Required	Not Required
Max. Compressive Stress σ c1			-	-	-	-
Min. Compressive Stress σ c2			-	-	-	-
Area of Tensile Reinforcement *As*			5.00	11.07	7.58	9.03
Area of Compressive Reinforcement As'(Smaller Area of Tensile Reinforcement, in case Compressive one isn't required)			-	-	-	-
Min. Area of Reinforcement		(cm^2)	0.85	0.85	0.85	0.85
Required Area of Reinforcement		As (cm^2)	5.00	11.07	7.58	9.03
Required Perimeter		U (cm^2)	2.67	22.04	-	20.16

Design of Reinforcement

Main Reinforcement 1	Diameter	D_1 (㎜)	13	13	16	13
	Pitch	$c.to.c$ (㎜)	250	250	250	250
	Area	As_1 (cm^2)	5.32	5.32	8.04	5.32
	Perimeter	U_1 (cm)	16.00	16.00	20.00	16.00
Main Reinforcement 2	Diameter	D_2 (㎜)	-	13	-	10
	Pitch	$c.to.c$ (㎜)	-	250	-	250
	Area	As_2 (cm^2)	-	5.32	-	3.14
	Perimeter	U_2 (cm)	-	16.00	-	12.00
Area of Reinforcement As(cm2)			5.32	10.64	8.04	8.46
Perimeter of Reinforcement U(cm2)			16.00	32.00	20.00	28.00

Stress Check

Distance form Neutral axis to Compressive Edge x			2.086	2.563	2.268	2.728
$j = 1 - x/(3d)$			0.970	0.963	0.967	0.960
Reinforcement	Tensile Stress	σ_s	1,444	1,675	1,508	1,639
		Judge(σ_{sa}=1,800kgf/cm^2)	O.K.	O.K.	O.K.	O.K.
Concrete	Compressive Stress	σ_c	9.6	14.0	11.0	14.7
		Judge(σ_{ca}=85kgf/cm^2)	O.K.	O.K.	O.K.	O.K.
	Shear Stress	τ	-	0.3	-	0.3
		Judge(τ_a=8.0kgf/cm^2)	O.K.	O.K.		O.K.

APPENDIX C.4.4-7 Dimensions and Structural Design of Air Valve

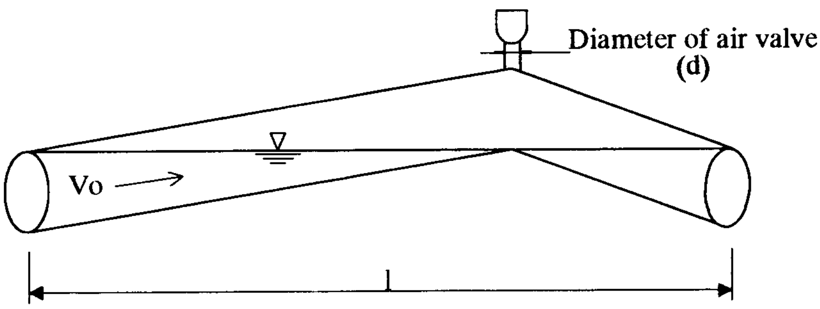
(1) Diameter of air valve

(a) Purpose and nominal diameter of air valve

The purpose of air valve is to exhaust air from pipeline, to keep flow capacity and to prevent air hammer phenomena. Another purpose is to breathe air when the pipeline will be drained water for maintenance works..

The diameter of air valve is determined to exhaust air as correspond to discharge when the pipeline is filled by water at beginning of pump operation.

Diameter will be determined 0.20m by the following conditions;



$$d = D \cdot \sqrt{\frac{V_0}{Ca \cdot Va}} = 2.40 \times \sqrt{\frac{0.24}{0.9 \times 45}} \doteqdot 0.20\text{m}$$

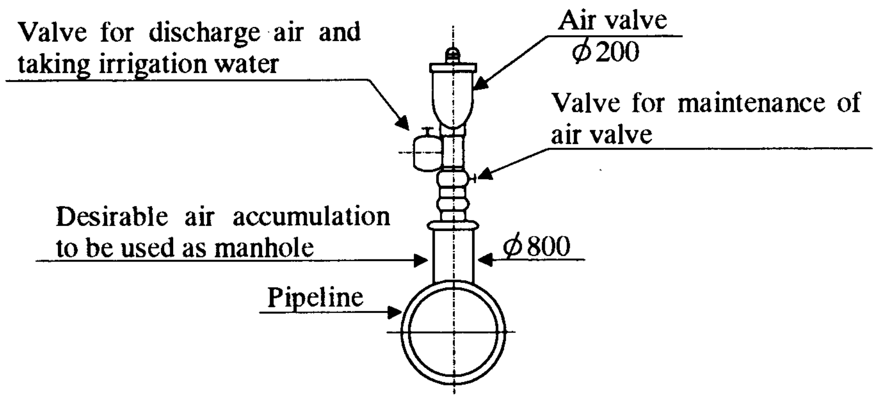
Where,

- d : Diameter of air valve (m)
- D : Diameter of main pipe (m)
- V_o : Velocity of main pipe before main pump operation
  V_o =0.1 Um=0.1×2.4=0.24m/s
- V_a : Velocity of air discharge from air valve
  $V_a \leqq 45$m/s
- C_a : Constant number 0.9

Further more, a certain suction volume of air valve is also requested at drain water of pipeline for maintenance.

Performance curve of air valve by a Japanese manufacture is shown in the Figure 3 and suction volume is about 80% of exhaust volume of 150m^3/min in case ϕ200 of air valve.

Then suction volume of 150×0.8/60=2.0m^3/s may be satisfied discharge q shown in the Table "Discharge Time", which is 1.82m^3/s q_2 of No.1 Blow off and in case q_1 (2.14m^3/s) of part 1 No1 is supplied air through the end of pipeline.



Composition of Air Valve

Relationship between main pipe diameter and air valve diameter

Pipe Diameter (mm)	Selection range of air valve size					Pipe Diameter (mm)
	High Speed			Double	Single	
1000						1000
1100	75				No,	1100
1200				150	application	1200
1350		100				1350
1500						1500
1650						1650
1800						1800
2000			200			2000
2100						2100
2200						2200
2400						2400
2600						2600

Source MOAFFJ's standard (Pipeline)

Figure 3 Performance Curve of an Air Valve

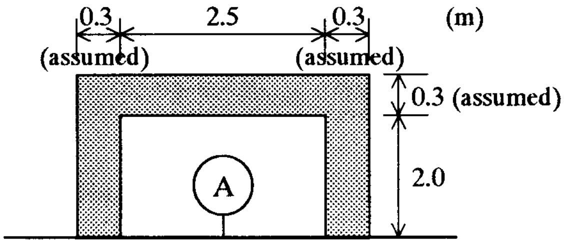
(b) Interval and location of air valve

The location of air valve shall be determined at adequate places which air will be left without transport such as place immediate downstream of an up-slope and place immediate upstream of a down-slope of pipeline. Even places at flat slope of pipeline, it is requested to provide air valve at each 600 to 700m intervals that will be recommended 1.5 times of standard distance (400m in general) because of both economical and adequate operation stated at 2.6.7 Study on beginning and end of pump operation.

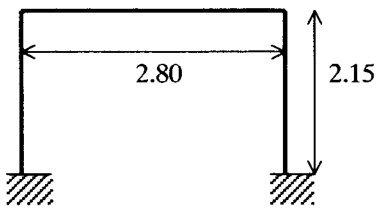
(2) Structural calculation of Air Valve Chamber

(a) Sectional Dimension for Calculation

Air Valve Chamber should be calculated by Gate Shaped Rigid Frame.



Rigid Frame Dimension (m)

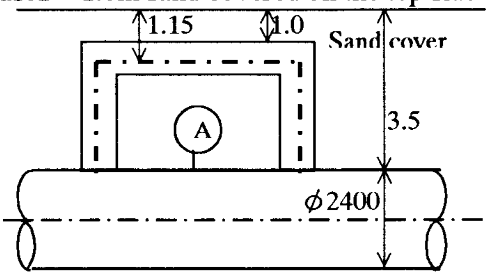


(b) Calculation of Load

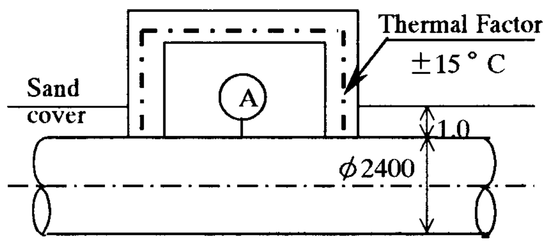
(i)Case of Calculation

Considering condition, following cases should be calculated.

Case1 1.0m sand covered on the top slab (m)



Case2 Consider Thermal Factor (m)



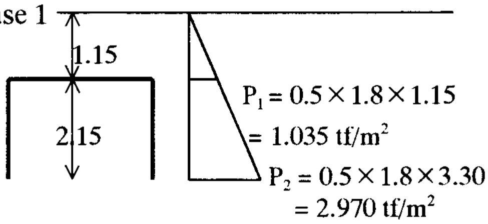
(ii) Own Weight and Earth Weight Applied for Top Slab (W_1)

- Vertical Earth Pressure Case 1 0.900 tf/m^2 (= 0.5 * 1.8 * 1.0)
  Case 2 0.000 tf/m^2
- Concrete Weight of Top Slab 0.735 tf/m^2 (= 0.30 * 2.45)
- Total Load Case 1 1.635 tf/m^2 (= 0.900 + 0.735)
  Case 2 0.735 tf/m^2

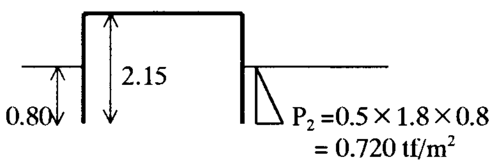
(iii) Side Earth Pressure (P_1 ~ P_2)

Side earth pressure should be calculated by following equation; $P = K_0 \times \gamma_t \times H$

Case 1



Case 2

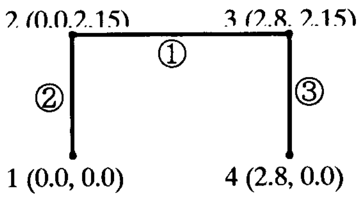


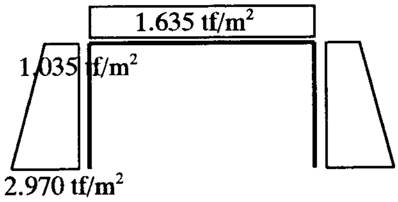
(iv) Load Distribution

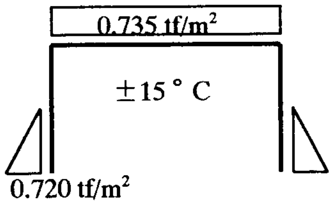
Load Distribution, Element Number, Contact Point Number and Coordinates are figured as follows.

Element Number, Contact Number Case1 Load Distribution Case2 Load Distribution

and Coordinates







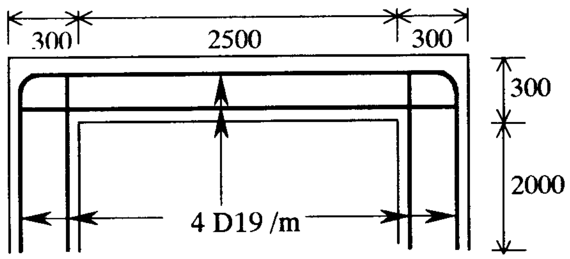
(c) Result of Calculation

	Top Slab		Side Slab	
	Outside	Inside	Outside	Inside
Case 1	① 0.958 2.289	① 0.644 0.000	②,③ 0.958 1.913	②,③ 0.333 0.000
Case 2	① 4.940 2.773	① 4.241 0.715	②,③ 4.940 1.746	②,③ 4.241 1.242

Upper : Element Number
Middle: Bending Moment
Lower : Shearing Force

(d) Design of Reinforcement

By using result of calculation reinforcement should be designed as following figure.



(e) Stress Analysis

Stress analysis will be shown at next page.

(f) Calculation of Soil Reaction of Air Valve Chamber

Load	Vertical Force (tf)
･Concrete Weight	265.0
･Air Valve φ200 ×3	0.5
･Pipe Weight φ2400	12.5
･Water Weight φ2400	43.0
･Soil Weight	70.0
･Total	391.0

Total of Vertical Force = 391.0 (tf)

Total of Horizontal Force = 0.0 (tf)

Width = 12.4 (m)

Length = 3.1 (m)

Soil Reaction = 391 / (12.4×3.1) = 10.50 (tf/m²)

Stress Analysis of North Sinai Air Valve

		Top Slab Outside	Top Slab Inside	Side Slab Outside	Side Slab Inside
Bending Moment	M (kgf·cm)	494,000	424,100	494,000	424,100
Axial Force	N (kgf)	1,746	1,242	2,773	715
Shearing Force	S (kgf)	2,773	715	1,746	1,242
Width	b (cm)	100	100	100	100
Thickness	h (cm)	30.0	30.0	30.0	30.0
Effective Depth	d (cm)	23.0	23.0	23.0	23.0
Cover (Compressive)	d_1 (cm)	7.0	7.0	7.0	7.0
Cover (Tensile)	d_2 (cm)	7.0	7.0	7.0	7.0
Required Effective Depth	d_0 (cm)	17.0	15.7	17.2	15.7
Judge	Axial Direction Force	Compressive	Compressive	Compressive	Compressive
		Case2-A	Case2-A	Case2-A	Case2-A
	Tensile Steel	Required	Required	Required	Required
	Compressive Steel	Not Required	Not Required	Not Required	Not Required
Max. Compressive Stress σ c1		-	-	-	-
Min. Compressive Stress σ c2		-	-	-	-
Area of Tensile Reinforcement *As*		11.53	9.98	11.24	10.13
Area of Compressive Reinforcement As'(Smaller Area of Tensile Reinforcement, in case Compressive one isn't required)		-	-	-	-
Min. Area of Reinforcement	(cm^2)	0.85	0.85	0.85	0.85
Required Area of Reinforcement	As (cm^2)	11.53	9.98	11.24	10.13
Required Perimeter	U (cm^2)	7.60	1.96	4.79	3.40

Design of Reinforcement

			Top Slab Outside	Top Slab Inside	Side Slab Outside	Side Slab Inside
Main Reinforcement 1	Diameter	D_1 (mm)	19	19	19	19
	Pitch	*c.to.c* (mm)	250	250	250	250
	Area	As_1 (cm^2)	11.34	11.34	11.34	11.34
	Perimeter	U_1 (cm)	24.00	24.00	24.00	24.00
Main Reinforcement 2	Diameter	D_2 (mm)	-	-	-	-
	Pitch	*c.to.c* (mm)	-	-	-	-
	Area	As_2 (cm^2)	-	-	-	-
	Perimeter	U_2 (cm)	-	-	-	-
Area of Reinforcement As(cm2)			11.34	11.34	11.34	11.34
Perimeter of Reinforcement U(cm2)			24.00	24.00	24.00	24.00

Stress Check

			Top Slab Outside	Top Slab Inside	Side Slab Outside	Side Slab Inside
Distance form Neutral axis to Compressive Edge x			7.525	7.488	7.657	7.410
$j = 1 - x/(3d)$			0.891	0.891	0.889	0.893
Reinforcement	Tensile Stress	σ_s	2,036	1,753	1,984	1,786
		Judge (σ_{sa}=2,070kgf/cm^2)	O.K.	O.K.	O.K.	O.K.
Concrete	Compressive Stress	σ_c	66.0	56.4	66.0	56.6
		Judge (σ_{ca}=98kgf/cm^2)	O.K.	O.K.	O.K.	O.K.
	Shear Stress	τ	1.2	0.3	0.8	0.5
		Judge (τ_a=9.2kgf/cm^2)	O.K.	O.K.	O.K.	O.K.

(3) Calculation of thrust block at Air valve chamber

Air valve chamber could be used as not only air valve chamber but also thrust block for bending point. At Air valve No.2, the thrust force should become the strictest. Then, the calculation should be done about Air valve No.2.

Whether pipeline moves or not by thrust force should be judged by following investigation;

$R_h \geqq S \cdot P_h$

where, S : Safety ratio (S = 1.5)

P_h : Thrust force

$P_h = 2H \cdot a_c \cdot \sin(\theta/2)$

where, H : Inner water pressure (80 tf/m^2)

a_c : Sectional area inner water pressure act (4.524 m^2)

θ : Bending angle (11.5 °)

$\therefore P_h = 74.858$ tf / 1 lane

R_h : Horizontal reaction force (tf)

$R_h = R_{h1} + R_{h2}$

where, R_{h1} : Frictional reaction force for thrust block (tf)

$R_{h1} = \mu \cdot W_s$

μ : Coefficient of friction between concrete and soil (0.6)

$W_s = W_1 + W_2 + W_3$

W_1 : Vertical soil pressure on the thrust block (tf)

W_2 : Bending pipe weight and inner pipe water weight (tf)

W_3 : Own weight of thrust block (tf)

$\{(2.3+3.1) \times 3.1 \times 12.4 - 2.0 \times 2.5 \times 11.8\} \times 2.45 = 364.011$

$(-)2.4^2 \times \pi/4 \times 3 \times 3.1 \times 2.45 = (-)103.077$

$364.011 - 103.077 = 260.934$

$W_s = \underbrace{0.0}_{W_1} + \underbrace{0.330 + 12.192 + 42.072}_{W_2} + \underbrace{260.934}_{W_3} = 315.528$ tf

$\therefore R_{h1} = 0.6 \times 315.528 = 189.317$ tf

R_{h2} : Passive soil pressure of thrust block (tf)

$R_{h2} = (1/2) \cdot w \cdot Bs \cdot (H_2^2 - H_1^2) \cdot \tan^2(45° + \phi/2)$

w : Unit weight of soil (1.8 tf/m^3)

B_s : Backside width of thrust block (3.1 m)

H_2 : Depth from surface to bottom of thrust block (3.9 m)

H_1 : Depth from surface to top of thrust block (0.0 m)

$\tan^2(45° + \phi/2)$: Coefficient of passive soil pressure

ϕ : Internal angle of soil (30 °)

$\therefore R_{h2} = 1/2 \times 1.8 \times 3.1 \times (3.9^2 - 0.0^2) \times 3.0 = 70.727$ tf

$R_h = 189.317 + 70.727 = 260.044$ tf

$R_h = 260.044$ tf

$S \cdot P' = 1.5 \times 74.858 \times 2 = 224.574$ tf

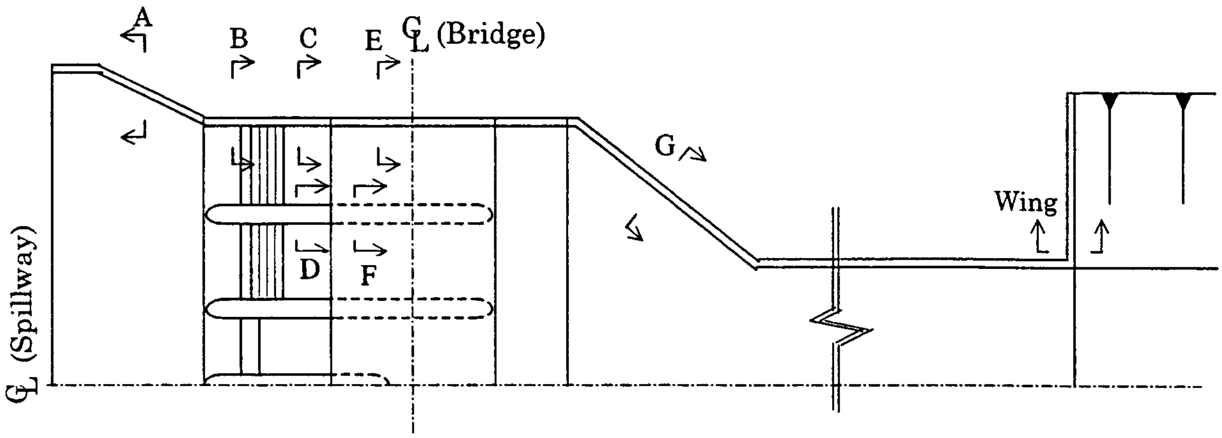
$\therefore R_h (= 260.044) \geqq S \cdot P' (= 224.574)$

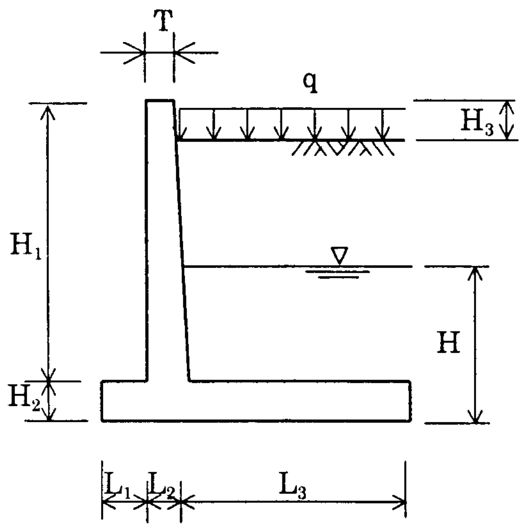
Then, air valve chamber should be enough heavy to resist thrust force.

APPENDIX C.4.5-1 Structural Computation of Spillway Structures

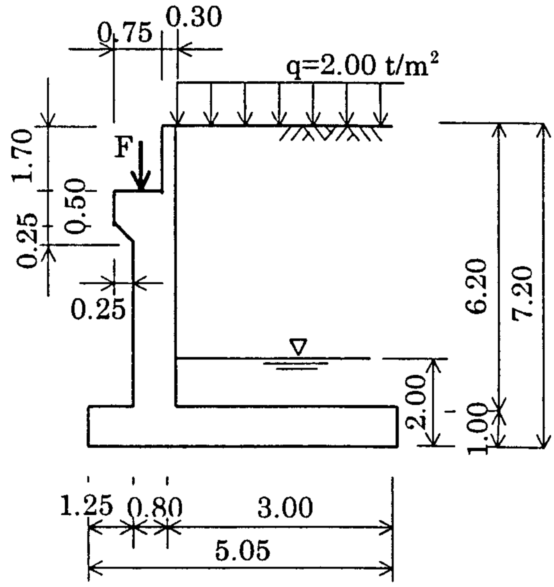
(1) Sections for Computation

Type of Structures	Section for Computation
Retaining Wall	Sections A, B, C, D and G
Abutment	Section E
Pier	Section F

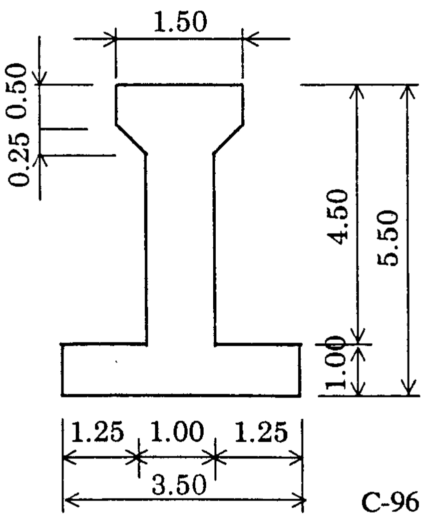




Sections A, B, C, D and G



Section E



Section F

Table 1 Dimensions of Retaining Wall

Section	A	B	C	D	G
T(m)	0.60	0.80	0.80	1.00	0.30
H_1(m)	4.50	5.40	6.20	4.50	4.00
H_2(m)	0.80	1.00	1.00	1.00	0.60
H_3(m)	0.00	0.90	0.00	0.00	0.00
H(m)	0.00	0.00	2.00	0.00	0.00
L_1(m)	1.25	1.25	1.25	1.25	0.70
L_2(m)	0.60	0.80	0.80	1.00	0.50
L_3(m)	1.60	3.00	3.00	1.25	1.60

(b) Coefficient of Earth Pressure ; Ka=0.333

(c) Live Load ; q=1.00 tf/m^2 (Section A B, C, F, G)
q=2.00 tf/m^2 (Section E)

Load of bridge for the Section E

f_1 = 16.777 tf (Dead Load Only)※

f_2 = 12.242 tf (Live Load Only) ※

Case A; F = $f_1 + f_2$ = 29.019 tf

Case B; F = f_1 = 16.777 tf

Load of bridge for the Section F

F = ($f_1 + f_2$)×2 = 58.038 tf

※ Calculation of load of bridge

Dead Load ; f_1 = 29.08×6 / 10.4 = 16.777 tf

Live Load ; f_2 = 21.22×6 / 10.4 = 12.242 tf

(d) Cases of Stability analysis

Case 1 : After Construction

Case 2 : Under Construction

(2) Result of Calculation

The result of computations are shown in the following tables.

Section for Computation		Stability Analysis	Structural Analysis
A		Table 2	Table 3
B		Table 4	Table 5
C		Table 6	Table 7
D		-	Table 8
E	Case A	Table 9	Table 10
	Case B	Table 11	Table 12
F		-	Table 13
G		Table 14	Table 15

Table 2　　Stability Analysis of Retaining Wall (Section A)

Load	Vertical Force (tf)	Arm Length (m)	Stabilizing Moment (tf·m)	Horizontal Force (tf)	Arm Length (m)	Overturning Moment (tf·m)
Wall	13.377	1.638	21.912			
Weight of Earth	14.400	2.650	38.160			
Earth Pressure				-1.765	2.650	-4.677
Earth Pressure				-9.354	1.767	-16.529
Total	27.777		60.072	-11.119		-21.206

Total of Moment　$\Sigma M =$ 38.866 (tf·m)
Total of Vertical Force　$\Sigma V =$ 27.777 (tf)
Total of Horizontal Force　$\Sigma H =$ -11.119 (tf)

Stability Against Overturning and Soil Reaction
Case-1 : After Construction
$\chi = (\Sigma M / \Sigma V) =$ 1.399 (m)
Width of Invert　$L =$ 3.45 (m)
Eccentric Length　$e =$ 0.326 (m)　<　L/6=　0.575 (m)
Soil Reaction　$Q_1 =$ 12.613 (tf/m^2)
$Q_2 =$ 3.489 (tf/m^2)
Case-2 : Under Construction
$\chi' = M / V =$ 1.638
Eccentric Length　$e' =$ 0.087　<　L/6=　0.575 (m)
Soil Reaction　$Q_1' =$ 4.464 (tf/m^2)
$Q_2' =$ 3.291 (tf/m^2)

Factor of Safety Against Sliding
Coefficient of friction　$f =$ 0.600
Cohesion　$C =$ 0.000 (tf/m^2)
Total of Vertical Force　$\Sigma V =$ 27.777 (tf)
Width of Invert　$L =$ 3.450 (m)
Total of Horizontal Force　$\Sigma H =$ 11.119 (tf)

Factor of Safety　Fs= 1.50 = 1.50　OK

Table 3 Structural Analysis of Retaining Wall (Section A)

1. Calculation of stem — Effective Depth = 0.53(m)

Height (m)	Bending Moment (tf・m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.055	0.250	0.038	0.000
1.00	0.277	0.666	0.064	0.000
1.50	0.749	1.249	0.091	0.303
2.00	1.554	1.998	0.121	1.079
2.50	2.775	2.914	0.155	2.362
3.00	4.495	3.996	0.191	4.252
3.50	6.799	5.245	0.230	6.851
4.00	9.768	6.660	0.271	10.259
4.50	13.486	8.242	0.315	14.580

2. Calculation of Toe — Effective Depth = 0.73(m)

Length (m)	Bending Moment (tf・m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	1.250	4.907	0.091	1.104
1.00	4.815	9.261	0.178	4.252
1.25	7.379	11.232	0.221	6.517

3. Calculation of Heel — Effective Depth = 0.73(m)

Length (m)	Bending Moment (tf・m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.861	-3.352	0.075	0.760
1.00	3.260	-6.151	0.147	2.879
1.50	6.920	-8.398	0.214	6.111
1.60	7.779	-8.782	0.227	6.870

Table 4 Stability Analysis of Retaining Wall (Section B)

Load	Vertical Force (tf)	Arm Length (m)	Stabilizing Moment (tf·m)	Horizontal Force (tf)	Arm Length (m)	Overturning Moment (tf·m)
Wall	22.956	2.122	48.713			
Weight of Earth	27.000	3.550	95.850			
Earth Pressure				-1.831	2.750	-5.035
Earth Pressure				-10.073	1.833	-18.464
Total	49.956		144.563	-11.904		-23.499

Total of Moment $\Sigma M=$ 121.064 (tf·m)
Total of Vertical Force $\Sigma V=$ 49.956 (tf)
Total of Horizontal Force $\Sigma H=$ -11.904 (tf)

Stability Against Overturning and Soil Reaction
Case-1 : After Construction
$\chi = (\Sigma M / \Sigma V) =$ 2.423 (m)
Width of Invert $L =$ 5.05 (m)
Eccentric Length $e =$ 0.102 (m) < L/6= 0.842 (m)
Soil Reaction $Q_1 =$ 11.086 (tf/m^2)
$Q_2 =$ 8.698 (tf/m^2)
Case-2 : Under Construction
$\chi' = M / V =$ 2.122
Eccentric Length $e' =$ 0.403 < L/6= 0.842 (m)
Soil Reaction $Q_1' =$ 6.722 (tf/m^2)
$Q_2' =$ 2.369 (tf/m^2)

Factor of Safety Against Sliding
Coefficient of friction $f=$ 0.600
Cohesion $C=$ 0.000 (tf/m^2)
Total of Vertical Force $\Sigma V=$ 49.956 (tf)
Width of Invert $L=$ 5.050 (m)
Total of Horizontal Force $\Sigma H=$ 11.904 (tf)

Factor of Safety $Fs=$ 2.52 > 1.50 OK

Table 5 Structural Analysis of Retaining Wall (Section B)

1. Calculation of stem — Effective Depth = 0.73(m)

Height (m)	Bending Moment (tf·m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.000	0.000	0.046	0.000
1.00	0.002	0.037	0.065	0.000
1.50	0.084	0.320	0.083	0.000
2.00	0.349	0.769	0.104	0.000
2.50	0.881	1.385	0.128	0.000
3.00	1.762	2.168	0.156	0.003
3.50	3.076	3.117	0.188	0.905
4.00	4.907	4.232	0.222	2.262
4.50	7.337	5.514	0.260	4.149
5.00	10.449	6.963	0.301	6.639
5.40	13.486	8.242	0.335	9.114

2. Calculation of Toe — Effective Depth = 0.93(m)

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	1.060	4.232	0.084	0.735
1.00	4.224	8.417	0.167	4.928
1.25	6.588	10.492	0.209	4.566

3. Calculation of Heel — Effective Depth = 0.93(m)

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.301	-1.195	0.045	0.209
1.00	1.188	-2.344	0.089	0.823
1.50	2.637	-3.445	0.132	1.828
2.00	4.625	-4.500	0.175	3.206
2.50	7.129	-5.507	0.217	4.942
3.00	10.125	-6.468	0.259	7.018

Table 6 Stability Analysis of Retaining Wall (Section C)

Load	Vertical Force (tf)	Arm Length (m)	Stabilizing Moment (tf·m)	Horizontal Force (tf)	Arm Length (m)	Overturning Moment (tf·m)
Wall	24.524	2.091	51.280			
Weight of Wet Earth	28.080	3.550	99.684			
Weight of Saturated Earth	6.000	3.550	21.300			
Up Lift	-10.100	2.525	-25.503			
Water Pressure				-2.000	0.667	-1.334
Earth Pressure				-2.398	3.600	-8.633
Earth Pressure				-8.104	3.733	-30.252
Earth Pressure				-6.234	1.000	-6.234
Earth Pressure				-0.666	0.667	-0.444
Total	48.504		146.761	-19.402		-46.897

Total of Moment $\Sigma M=$ 99.864 (tf·m)
Total of Vertical Force $\Sigma V=$ 48.504 (tf)
Total of Horizontal Force $\Sigma H=$ -19.402 (tf)

Stability Against Overturning and Soil Reaction
Case-1 : After Construction
$\chi = (\Sigma M/\Sigma V) =$ 2.059 (m)
Width of Invert $L =$ 5.05 (m)
Eccentric Length $e =$ 0.466 (m) $<$ L/6= 0.842 (m)
Soil Reaction $Q_1 =$ 14.924 (tf/m^2)
$Q_2 =$ 4.286 (tf/m^2)
Case-2 : Under Construction
$\chi' = M / V =$ 2.091
Eccentric Length $e' =$ 0.434 $<$ L/6= 0.842 (m)
Soil Reaction $Q_1' =$ 7.360 (tf/m^2)
$Q_2' =$ 2.352 (tf/m^2)

Factor of Safety Against Sliding
Coefficient of friction $f=$ 0.600
Cohesion $C=$ 0.000 (tf/m^2)
Total of Vertical Force $\Sigma V=$ 48.504 (tf)
Width of Invert $L=$ 5.050 (m)
Total of Horizontal Force $\Sigma H=$ 19.402 (tf)
Factor of Safety $Fs=$ 1.50 = 1.50 OK

Table 7 Structural Analysis of Retaining Wall (Section C)

1. Calculation of stem — Effective Depth = 0.73(m)

Height (m)	Bending Moment (tf·m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.054	0.241	0.050	0.000
1.00	0.266	0.633	0.078	0.000
1.50	0.712	1.174	0.105	0.000
2.00	1.465	1.865	0.135	0.258
2.50	2.602	2.706	0.167	1.003
3.00	4.196	3.696	0.201	2.152
3.50	6.323	4.837	0.238	3.772
4.00	9.058	6.127	0.277	5.928
4.50	12.475	7.567	0.319	8.687
5.00	16.650	9.157	0.362	12.115
5.50	21.661	10.930	0.408	16.281
6.00	27.635	13.022	0.456	21.298
6.20	30.331	13.952	0.476	23.576

2. Calculation of Toe — Effective Depth = 0.93(m)

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	1.755	6.944	0.108	1.216
1.00	6.868	13.433	0.213	4.761
1.25	10.613	16.506	0.265	7.356

3. Calculation of Heel — Effective Depth = 0.93(m)

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.863	-3.375	0.075	0.598
1.00	3.299	-6.295	0.148	2.287
1.50	7.082	-8.760	0.216	4.909
2.00	11.983	-10.770	0.281	8.306
2.50	17.776	-12.326	0.343	12.322
3.00	24.233	-13.427	0.400	16.798

Table 8 Structural Analysis of Retaining Wall (Section D)

1. Calculation of stem — Effective Depth = 0.93(m)

Height (m)	Bending Moment (tf·m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.000	0.000	0.059	0.000
1.00	0.000	0.000	0.083	0.000
1.50	0.000	0.000	0.102	0.000
2.00	0.000	0.000	0.118	0.000
2.50	0.000	0.000	0.132	0.000
3.00	0.000	0.000	0.144	0.000
3.50	0.000	0.000	0.156	0.000
4.00	0.000	0.000	0.167	0.000
4.50	0.000	0.000	0.177	0.000

2. Calculation of Toe — Effective Depth = 0.93(m)

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.394	1.575	0.051	0.273
1.00	1.575	3.150	0.102	1.092
1.25	2.461	3.937	0.127	1.706

3. Calculation of Heel — Effective Depth = 0.93(m)

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.394	1.575	0.051	0.273
1.00	1.575	3.150	0.102	1.092
1.25	2.461	3.937	0.127	1.706

Table 9 Stability Analysis of Abutment (Section E : Case A)

Load	Vertical Force (tf)	Arm Length (m)	Stabilizing Moment (tf·m)	Horizontal Force (tf)	Arm Length (m)	Overturning Moment (tf·m)
Wall	22.825	2.129	48.594			
Weight of Wet Earth	28.080	3.550	99.684			
Weight of Saturated Earth	6.000	3.550	21.300			
Up Lift	-10.100	2.525	-25.503			
Water Pressure				-2.000	0.667	-1.334
Earth Pressure				-4.795	3.600	-17.262
Earth Pressure				-8.104	3.733	-30.252
Earth Pressure				-6.234	1.000	-6.234
Earth Pressure				-0.666	0.667	-0.444
Bridge	29.019	1.350	39.176			
Total	75.824		183.252	-21.799		-55.526

Total of Moment $\Sigma M=$ 127.725 (tf·m)
Total of Vertical Force $\Sigma V=$ 75.824 (tf)
Total of Horizontal Force $\Sigma H=$ -21.799 (tf)

Stability Against Overturning and Soil Reaction

Case-1 : After Construction

$\chi = (\Sigma M/\Sigma V) =$ 1.684 (m)
Width of Invert L = 5.05 (m)
Eccentric Length e = 0.841 (m) < L/6= 0.842 (m)
Soil Reaction Q_1 = 30.009 (tf/m^2)
Q_2 = 0.021 (tf/m^2)

Case-2 : Under Construction

$\chi' = M / V =$ 2.129
Eccentric Length e' = 0.396 < L/6= 0.842 (m)

Soil Reaction Q_1' = 6.646 (tf/m^2)
Q_2' = 2.393 (tf/m^2)

Factor of Safety Against Sliding
Coefficient of friction f= 0.600
Cohesion C= 0.000 (tf/m^2)
Total of Vertical Force $\Sigma V=$ 75.824 (tf)
Width of Invert L= 5.050 (m)
Total of Horizontal Force $\Sigma H=$ 21.799 (tf)
Factor of Safety Fs= 2.09 > 1.50 OK

Table 10 Structural Analysis of Abutment (Section E : Case A)

1. Calculation of stem

Height (m)	Bending Moment (tf•m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
1.00	0.433	0.966	0.230	0.136	0.000
1.70	1.453	1.998	0.230	0.160	0.000
2.00	2.131	2.531	0.980	0.328	0.000
3.00	5.694	4.695	0.730	0.332	0.000
4.00	11.722	7.459	0.730	0.392	1.064
5.00	20.812	10.822	0.730	0.467	8.575
6.00	33.629	15.020	0.730	0.554	19.375
6.20	36.732	16.016	0.730	0.573	22.012

2. Calculation of Toe

Length (m)	Bending Moment (tf•m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	3.551	13.979	0.930	0.153	2.461
1.00	13.755	26.616	0.930	0.301	9.535
1.25	17.940	24.776	0.930	0.344	12.433

3. Calculation of Heel

Length (m)	Bending Moment (tf•m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	1.282	-4.906	0.930	0.092	0.889
1.00	4.682	-8.471	0.930	0.176	3.246
1.50	9.529	-10.694	0.930	0.251	6.606
2.00	15.153	-11.577	0.930	0.316	10.504
2.50	20.883	-11.118	0.930	0.371	14.475
3.00	26.047	-9.318	0.930	0.415	18.055

Table 11 Stability Analysis of Abutment (Section E : Case B)

Load	Vertical Force (tf)	Arm Length (m)	Stabilizing Moment (tf·m)	Horizontal Force (tf)	Arm Length (m)	Overturning Moment (tf·m)
Wall	22.825	2.129	48.594			
Weight of Wet Earth	28.080	3.550	99.684			
Weight of Saturated Earth	6.000	3.550	21.300			
Up Lift	-10.100	2.525	-25.503			
Water Pressure				-2.000	0.667	-1.334
Earth Pressure				-4.795	3.600	-17.262
Earth Pressure				-8.104	3.733	-30.252
Earth Pressure				-6.234	1.000	-6.234
Earth Pressure				-0.666	0.667	-0.444
Bridge	16.777	1.350	22.649			
Total	63.582		166.725	-21.799		-55.526

Total of Moment $\Sigma M=$ 111.198 (tf·m)
Total of Vertical Force $\Sigma V=$ 63.582 (tf)
Total of Horizontal Force $\Sigma H=$ -21.799 (tf)

Stability Against Overturning and Soil Reaction
Case-1 : After Construction
$\chi = (\Sigma M / \Sigma V) =$ 1.749 (m)
Width of Invert $L =$ 5.05 (m)
Eccentric Length $e =$ 0.776 (m) < L/6= 0.842 (m)
Soil Reaction $Q_1 =$ 24.200 (tf/m^2)
$Q_2 =$ 0.981 (tf/m^2)

Case-2 : Under Construction
$\chi' = M / V =$ 2.129
Eccentric Length $e' =$ 0.396 < L/6= 0.842 (m)
Soil Reaction $Q_1' =$ 6.646 (tf/m^2)
$Q_2' =$ 2.393 (tf/m^2)

Factor of Safety Against Sliding
Coefficient of friction f= 0.600
Cohesion C= 0.000 (tf/m^2)
Total of Vertical Force $\Sigma V=$ 63.582 (tf)
Width of Invert L= 5.050 (m)
Total of Horizontal Force $\Sigma H=$ 21.799 (tf)
Factor of Safety Fs= 1.75 > 1.50 OK

Table 12 Structural Analysis of Abutment (Section E : Case B)

1. Calculation of stem

Height (m)	Bending Moment (tf•m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm2)
1.00	0.433	0.966	0.230	0.110	0.000
1.70	1.453	1.998	0.230	0.138	0.000
2.00	2.131	2.531	0.980	0.266	0.000
3.00	5.694	4.695	0.730	0.289	0.000
4.00	11.722	7.459	0.730	0.357	4.298
5.00	20.812	10.822	0.730	0.438	11.808
6.00	33.629	15.020	0.730	0.530	22.609
6.20	36.732	16.016	0.730	0.550	25.245

2. Calculation of Toe

Length (m)	Bending Moment (tf•m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	2.852	11.242	0.930	0.137	1.977
1.00	11.074	21.478	0.930	0.270	7.676
1.25	13.839	18.562	0.930	0.302	1.643

3. Calculation of Heel

Length (m)	Bending Moment (tf•m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	1.190	-4.593	0.930	0.089	0.825
1.00	4.426	-8.181	0.930	0.171	3.068
1.50	9.203	-10.762	0.930	0.247	6.380
2.00	15.020	-12.337	0.930	0.315	10.412
2.50	21.373	-12.906	0.930	0.376	14.815
3.00	27.758	-12.469	0.930	0.428	19.242

Table 13 Structural Analysis of Pier (Section F)

1. Calculation of Toe

Soil Reaction Q = [(58.038+{(0.5+0.75) × 0.25+1.0 × 4.5} × 2.45] / 3.50=19.951 tf/m^2

Up Lift = 2.00 tf/m^2

Maximum moment

$$M_{max} = \frac{1}{2} \times (19.951+2.00) \times 1.25^2 = 17.149 \ tf \cdot m$$

Required area of tension reinforcement

$$As = \frac{17.149 \times 10^5}{1{,}800 \times 0.862 \times 93} = 11.884 \ cm^2$$

Required effective depth

$$D = 0.275\sqrt{\frac{17.149 \times 10^5}{100}} = 33.7 \ cm$$

Table 14 Stability Analysis of Retaining Wall (Section G)

Load	Virtical Force (tf)	Arm Length (m)	Stabilizing Moment (tf·m)	Horizontal Force (tf)	Arm Length (m)	Overturning Moment (tf·m)
Wall	7.901	1.540	12.168			
Weight of Earth	11.520	2.449	28.212			
Earth Pressure				-1.498	2.250	-3.371
Earth Pressure				-6.069	1.500	-9.104
Total	19.421		40.380	-7.567		-12.474

Total of Moment $\Sigma M =$ 27.906 (tf·m)
Total of Virtical Force $\Sigma V =$ 19.421 (tf)
Total of Horizontal Force $\Sigma H =$ -7.567 (tf)

Stability Against Overturning
Case-1 : After Construction
$\chi = (\Sigma M / \Sigma V) =$ 1.437 (m)
Width of Invert $L =$ 3.25 (m)
Eccentric Length $e =$ 0.188 (m) < $L/6 =$ 0.542 (m)
Soil Reaction $Q_1 =$ 8.051 (tf/m^2)
$Q_2 =$ 3.901 (tf/m^2)
Case-2 : Under Construction
$\chi' = M / V =$ 1.540
Eccentric Length $e' =$ 0.085 < $L/6 =$ 0.542 (m)
Soil Reaction $Q_1' =$ 2.813 (tf/m^2)
$Q_2' =$ 2.050 (tf/m^2)

Factor of Safety Against Sliding
Coefficient of friction $f =$ 0.600
Cohesion $C =$ 0.000 (tf/m^2)
Total of Vertical Force $\Sigma V =$ 19.421 (tf)
Width of Invert $L =$ 3.250 (m)
Total of Horizontal Force $\Sigma H =$ 7.567 (tf)

Factor of Safety $Fs =$ 1.54 > 1.50 OK

Table 15 Structural Analysis of Retaining Wall (Section G)

1. Calculation of stem

Height (m)	Bending Moment (tf•m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.054	0.241	0.255	0.024	0.014
1.00	0.266	0.633	0.280	0.048	0.363
1.50	0.712	1.174	0.305	0.075	1.123
2.00	1.465	1.865	0.330	0.106	2.345
2.50	2.602	2.706	0.355	0.139	4.065
3.00	4.196	3.696	0.380	0.175	6.312
3.50	6.323	4.837	0.405	0.213	9.104
4.00	9.058	6.127	0.430	0.254	12.459

2. Calculation of Toe

Length (m)	Bending Moment (tf•m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.801	3.169	0.430	0.073	1.200
1.00	3.134	6.133	0.430	0.144	4.699
1.25	4.844	7.538	0.430	0.179	7.263

3. Calculation of Heel

Length (m)	Bending Moment (tf•m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.523	-2.056	0.430	0.059	0.783
1.00	2.022	-3.908	0.430	0.116	3.032
1.50	4.396	-5.555	0.430	0.170	6.591

APPENDIX C.4.5-2 Structural Computation of Spillway Outlet Channel Structure

APPENDIX C.4.5-2 (1) Flume

(1) Design Criteria

(a) Sectional Dimension for Analysis

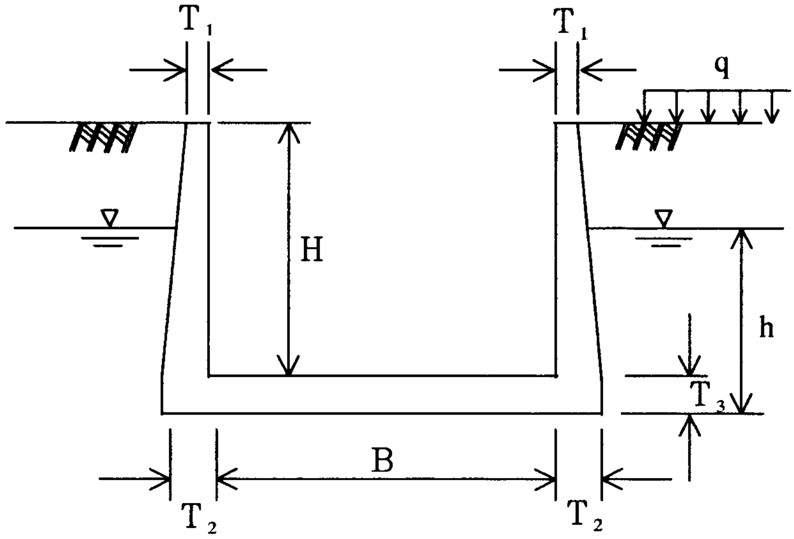


Table 1 Dimensions of flume

Section	Discharge Canal			Stilling Basin	
	Type - 1	Type - 2	Type - 3	Type - 1	Type - 2
T_1(m)	0.30	0.30	0.30	0.30	0.30
T_2(m)	0.50	0.50	0.50	0.50	0.50
T_3(m)	0.50	0.50	0.50	0.50	0.50
H (m)	3.30	3.00	2.70	4.70	4.00
h (m)	0.00	0.00	0.00	1.60	0.90
B (m)	10.00	10.00	10.00	10.00	10.00

(b) Coefficient of Earth Pressure ; Ka=0.333

(c) Live Load ; q=1.00 tf/m^2

(d) Up Lift ; Stilling Basin Type – 1 =1.60 tf/m^2
Stilling Basin Type – 2 =0.90 tf/m^2

(2) Result of Analysis

Result of calculation of flume been made to show the results in Table 2 to 6.

Table 2 Structural Analysis of Flume (Discharge Canal Type-1)

1. Calculation of wall

Height (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.054	0.241	0.260	0.024	0.011
1.00	0.266	0.633	0.291	0.048	0.339
1.50	0.712	1.174	0.321	0.076	1.045
2.00	1.465	1.865	0.351	0.106	2.164
2.50	2.602	2.706	0.382	0.140	3.723
3.00	4.196	3.696	0.412	0.176	5.741
3.30	5.403	4.363	0.430	0.199	7.177

2. Calculation of Invert

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.00	-5.403	3.234	0.430	0.202	6.854
0.50	-3.863	2.926	0.430	0.175	4.545
1.00	-2.477	2.618	0.430	0.147	2.468
1.50	-1.245	2.310	0.430	0.116	0.621
2.00	-0.167	2.002	0.430	0.079	0.000
2.50	0.757	1.694	0.430	0.101	0.000
3.00	1.527	1.386	0.430	0.124	1.042
3.50	2.143	1.078	0.430	0.139	1.966
4.00	2.605	0.770	0.430	0.150	2.659
4.50	2.913	0.462	0.430	0.156	3.120
5.00	3.067	0.154	0.430	0.160	3.351
5.25	3.086	0.000	0.430	0.160	3.380

Table 3 Structural Analysis of Flume (Discharge Canal Type-2)

1. Calculation of wall

Height (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.054	0.241	0.263	0.025	0.009
1.00	0.266	0.633	0.297	0.049	0.326
1.50	0.712	1.174	0.330	0.076	1.003
2.00	1.465	1.865	0.363	0.107	2.069
2.50	2.602	2.706	0.397	0.140	3.547
3.00	4.196	3.696	0.430	0.177	5.450

2. Calculation of Invert

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.00	-4.196	2.940	0.430	0.179	5.234
0.50	-2.796	2.660	0.430	0.151	3.135
1.00	-1.536	2.380	0.430	0.121	1.246
1.50	-0.416	2.100	0.430	0.085	0.000
2.00	0.564	1.820	0.430	0.090	0.000
2.50	1.404	1.540	0.430	0.117	1.049
3.00	2.104	1.260	0.430	0.135	2.099
3.50	2.664	0.980	0.430	0.148	2.938
4.00	3.084	0.700	0.430	0.157	3.568
4.50	3.364	0.420	0.430	0.163	3.988
5.00	3.504	0.140	0.430	0.166	4.197
5.25	3.522	0.000	0.430	0.166	4.224

Table 4 Structural Analysis of Flume (Discharge Canal Type-3)

1. Calculation of wall

Height (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.054	0.241	0.267	0.025	0.007
1.00	0.266	0.633	0.304	0.049	0.311
1.50	0.712	1.174	0.341	0.077	0.954
2.00	1.465	1.865	0.378	0.107	1.961
2.50	2.602	2.706	0.415	0.141	3.348
2.70	3.180	3.084	0.430	0.155	4.012

2. Calculation of Invert

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.00	-3.180	2.646	0.430	0.157	3.887
0.50	-1.920	2.394	0.430	0.128	1.998
1.00	-0.786	2.142	0.430	0.094	0.297
1.50	0.222	1.890	0.430	0.072	0.000
2.00	1.104	1.638	0.430	0.105	0.774
2.50	1.860	1.386	0.430	0.126	1.907
3.00	2.490	1.134	0.430	0.142	2.852
3.50	2.994	0.882	0.430	0.153	3.607
4.00	3.372	0.630	0.430	0.161	4.174
4.50	3.624	0.378	0.430	0.166	4.552
5.00	3.750	0.126	0.430	0.169	4.741
5.25	3.766	0.000	0.430	0.169	4.764

Table 5 Structural Analysis of Flume (Stilling Basin Type-1)

1. Calculation of wall

Height (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.054	0.241	0.262	0.025	0.010
1.00	0.266	0.633	0.294	0.049	0.332
1.50	0.712	1.174	0.326	0.076	1.022
2.00	1.465	1.865	0.358	0.107	2.113
2.50	2.602	2.706	0.390	0.140	3.628
3.00	4.196	3.696	0.421	0.176	5.583
3.50	6.323	4.837	0.453	0.215	7.991
4.00	9.061	6.160	0.485	0.256	10.863
4.50	12.538	7.802	0.517	0.300	14.272
4.70	14.172	8.552	0.530	0.319	15.809

2. Calculation of Invert

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.00	-14.172	13.662	0.530	0.326	14.879
0.50	-7.663	12.373	0.530	0.252	6.962
1.00	-1.799	11.084	0.530	0.158	0.000
1.50	3.421	9.795	0.530	0.189	1.802
2.00	7.996	8.506	0.530	0.257	7.367
2.50	11.927	7.218	0.530	0.303	12.149
3.00	15.214	5.929	0.530	0.337	16.146
3.50	17.856	4.640	0.530	0.362	19.360
4.00	19.853	3.351	0.530	0.380	21.790
4.50	21.207	2.062	0.530	0.391	23.436
5.00	21.916	0.773	0.530	0.397	24.298
5.30	22.032	0.000	0.530	0.398	24.439

Table 6 Structural Analysis of Flume (Stilling Basin Type-2)

1. Calculation of wall

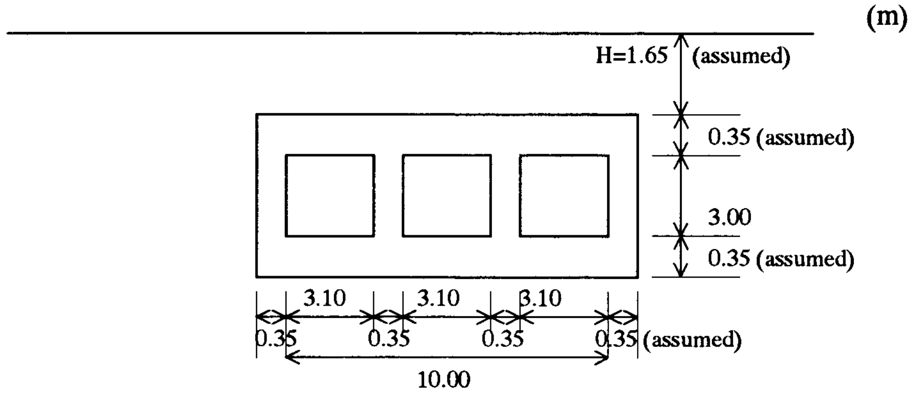
Height (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.054	0.241	0.267	0.025	0.006
1.00	0.266	0.633	0.305	0.049	0.309
1.50	0.712	1.174	0.342	0.077	0.948
2.00	1.465	1.865	0.380	0.108	1.948
2.50	2.602	2.706	0.418	0.141	3.324
3.00	4.196	3.696	0.455	0.178	5.087
3.50	6.323	4.837	0.492	0.217	7.244
4.00	9.061	6.160	0.530	0.258	9.805

2. Calculation of Invert

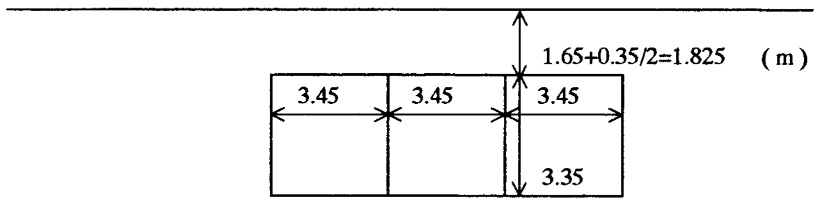
Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.00	-9.061	9.180	0.530	0.263	9.322
0.50	-4.688	8.314	0.530	0.201	4.003
1.00	-0.747	7.448	0.530	0.120	0.000
1.50	2.760	6.582	0.530	0.166	1.659
2.00	5.835	5.716	0.530	0.219	5.398
2.50	8.476	4.850	0.530	0.256	8.611
3.00	10.685	3.984	0.530	0.283	11.297
3.50	12.460	3.118	0.530	0.303	13.457
4.00	13.802	2.252	0.530	0.317	15.089
4.50	14.712	1.386	0.530	0.326	16.195
5.00	15.188	0.520	0.530	0.331	16.775
5.30	15.266	0.000	0.530	0.332	16.870

APPENDIX C.4.5-2 (2) 3- Cell Box Culvert

(1) Sectional Dimension for Calculation



Rigid Frame Dimension



(2) Calculation of Load

(a) Case of Calculation

Considering condition, next cases should be calculated.

Case 1 Maximum wheel load works at middle of the middle box.
- Case 1-1 Empty
- Case 1-2 Full water (All Box)

Case 2 Maximum wheel load works middle of the side box.
- Case 2-1 Empty
- Case 2-2 Full water (All Box)

(b) Own Weight and Earth Weight Applied for Top Slab (W_1)

- Vertical Earth Pressure 1.643 tf/m² (= 0.5 * 1.8 * 1.825)
- Concrete Weight of Top Slab 0.858 tf/m² (= 0.35 * 2.45)
- Wheel Load (T-70) at H = 1.65m

	23.3t	23.4t	7.5t	5.0t
q (tf/m²)	2.225	2.235	0.836	0.478

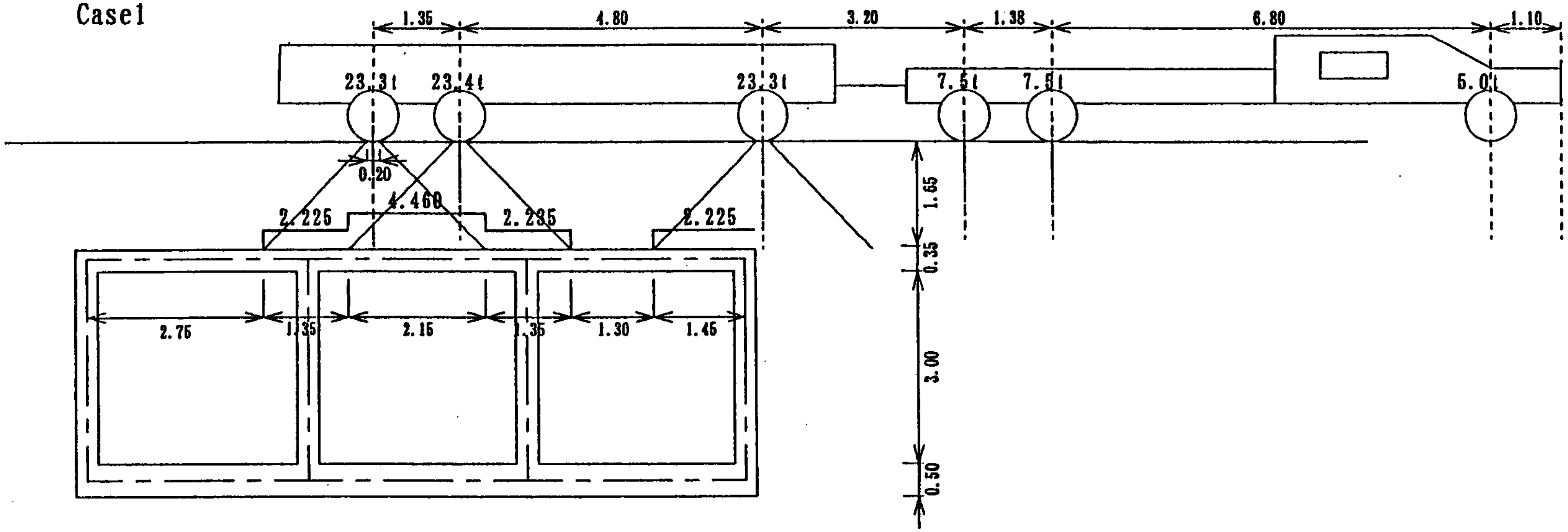
(c) Reaction Force of Bottom Slab (W_2)

Reaction Force of Bottom Slab is calculated by round moment as follows;

Case 1 5.796 ~ 7.303 tf/m²

Case 2 8.139 ~ 5.837 tf/m²

Case1



< Case2 >

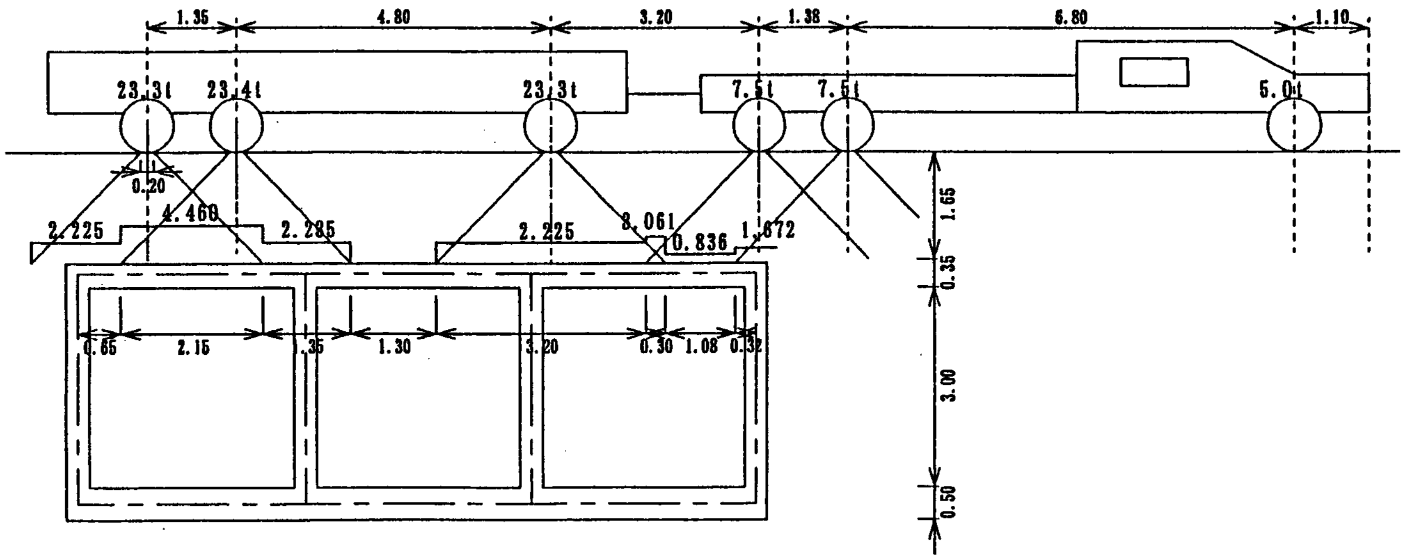
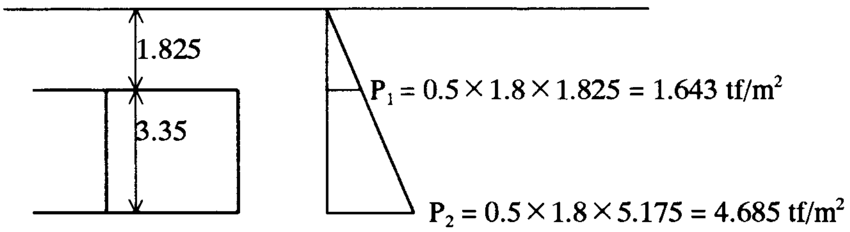


Figure 1 Wheel Load Distribution

(d) Side Earth Pressure (P_1 ~ P_2)

Side earth pressure should be calculated by following equation;

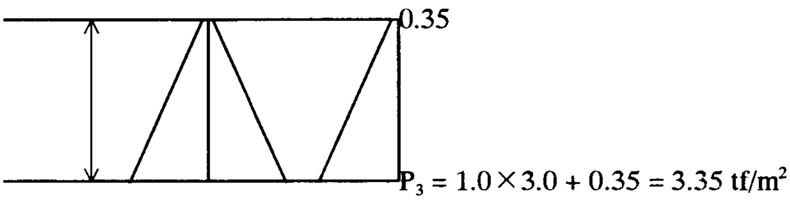
$$P = K_0 \times \gamma_t \times H$$



(e) Inner Water Pressure (P_3)

Inner water pressure should be calculated by following equation ;

$$P = \gamma_w \times H_w$$



(f) Load Distribution

Load Distribution, Element Number, Contact Point Number and Coordinates are figured as Figure 2 and Figure 5.

(g) Result of calculation

Upper : Element Number
Middle: Required Reinforcement
Lower : Required Perimeter

	Top Slab		Side Slab	Bottom Slab	
	Outside	Inside	Outside	Outside	Inside
Case 1-1	⑧ 15.726 33.598	⑦ 9.267 0.000	⑫ 8.627 17.233	① 17.513 33.282	① 9.406 0.000
Case 1-2	⑧ 16.728 33.598	⑦ 9.608 0.000	⑫ 5.947 6.913	① 18.353 34.465	① 10.549 0.000
Case 2-1	⑥ 16.192 35.316	⑤ 11.521 0.000	⑰ 7.569 11.539	③ 16.856 36.548	③ 9.833 0.000
Case 2-2	⑥ 17.455 36.218	⑤ 13.095 0.000	⑰ 5.495 5.924	② 17.942 32.702	③ 12.233 0.000

Stress Analysis of North Sinai Box Culvert (3 Cell)

		Top Slab Outside	Top Slab Inside	Side Slab Outside	Bottom Slab Outside	Bottom Slab Inside
Bending Moment	M (kgf·cm)	789, 300	599, 900	489, 000	811, 500	560, 100
Axial Force	N (kgf)	2, 287	2, 287	8, 385	617	2, 115
Shearing Force	S (kgf)	13, 983	-	6, 653	13, 306	-
Width	b (cm)	100	100	100	100	100
Thickness	h (cm)	35. 0	35. 0	35. 0	35. 0	35. 0
Effective Depth	d (cm)	28. 0	28. 0	28. 0	28. 0	28. 0
Cover (Compressive)	d_1 (cm)	7. 0	7. 0	7. 0	7. 0	7. 0
Cover (Tensile)	d_2 (cm)	7. 0	7. 0	7. 0	7. 0	7. 0
Required Effective Depth	d_0 (cm)	23. 1	20. 3	19. 5	23. 2	19. 6
Judge	Axial Direction Force	Compressive	Compressive	Compressive	Compressive	Compressive
		Case2-2	Case2-2	Case1-1	Case1-2	Case2-2
	Tensile Steel	Required	Required	Required	Required	Required
	Compressive Steel	Not Required	Not Required	Not Required	Not Required	Not Required
Max. Compressive Stress $\sigma c1$		-	-	-	-	-
Min. Compressive Stress $\sigma c2$		-	-	-	-	-
Area of Tensile Reinforcement *As*		17. 45	13. 09	8. 62	18. 49	12. 23
Area of Compressive Reinforcement As'(Smaller Area of Tensile Reinforcement, in case Compressive one isn't required)		-	-	-	-	-
Min. Area of Reinforcement	(cm^2)	0. 85	0. 85	0. 85	0. 85	0. 85
Required Area of Reinforcement	As (cm^2)	17. 45	13. 09	8. 62	18. 49	12. 23
Required Perimeter	U (cm^2)	36. 21	-	17. 23	34. 46	-

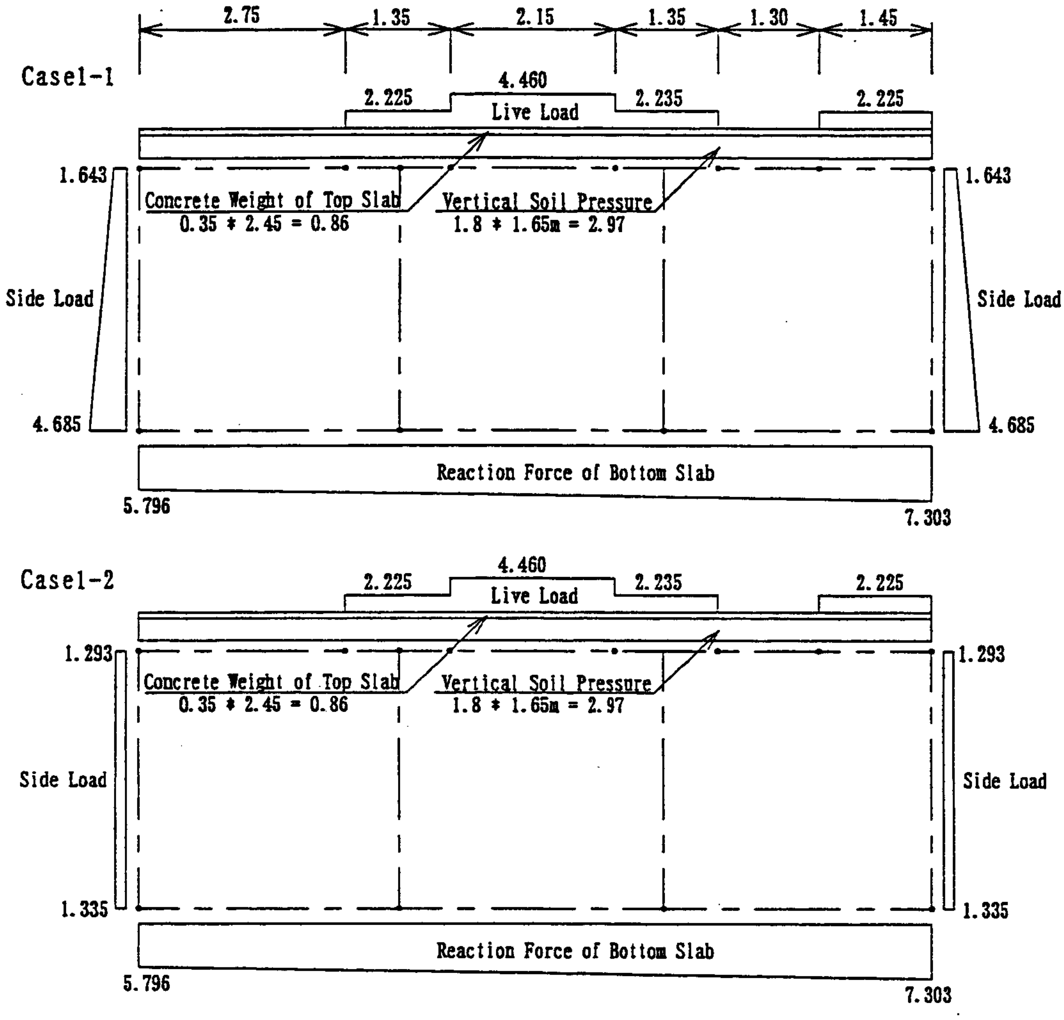
Design of Reinforcement

Main Reinforcement 1	Diameter	D_1 (㎜)	19	22	19	19	22
	Pitch	c.to.c (㎜)	250	250	250	250	250
	Area	As_1 (cm^2)	11. 34	15. 20	11. 34	11. 34	15. 20
	Perimeter	U_1 (cm)	24. 00	28. 00	24. 00	24. 00	28. 00
Main Reinforcement 2	Diameter	D_2 (㎜)	16	-	-	16	-
	Pitch	c.to.c (㎜)	250	-	-	250	-
	Area	As_2 (cm^2)	8. 04	-	-	8. 04	-
	Perimeter	U_2 (cm)	20. 00	-	-	20. 00	-
Area of Reinforcement As(cm2)			19. 38	15. 20	11. 34	19. 38	15. 20
Perimeter of Reinforcement U(cm2)			44. 00	28. 00	24. 00	44. 00	28. 00

Stress Check

Distance form Neutral axis to Compressive Edge x			10. 464	9. 606	9. 824	10. 253	9. 602
$j=1-x/(3d)$			0. 875	0. 886	0. 883	0. 878	0. 886
Reinforcement	Tensile Stress	σ_s	1, 596	1, 502	1, 318	1, 690	1, 405
		Judge(σ_{sa}=1,800kgf/cm^2)	O. K	O. K	O. K	O. K	O. K
Concrete	Compressive Stress	σ_c	63. 5	52. 3	47. 5	65. 1	48. 9
		Judge(σ_{ca}=85kgf/cm^2)	O. K	O. K	O. K	O. K	O. K
	Shear Stress	τ	5. 0	-	2. 4	4. 8	-
		Judge(τ_a=8.0kgf/cm^2)	O. K		O. K	O. K	

Load Distribution



Element Number and Contact Point Number (Case1)

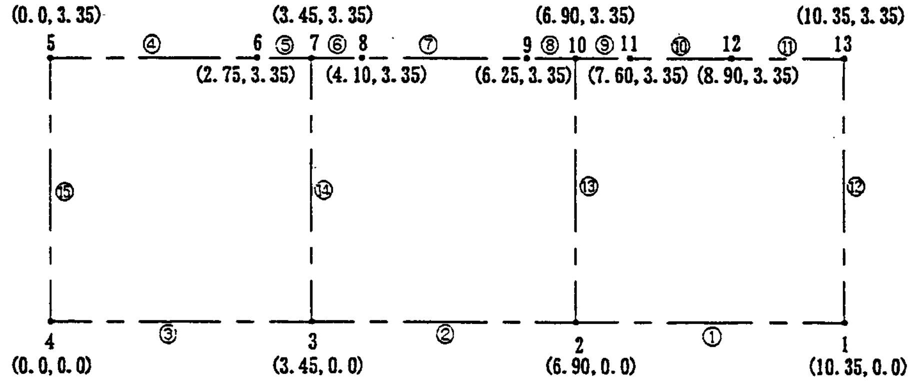
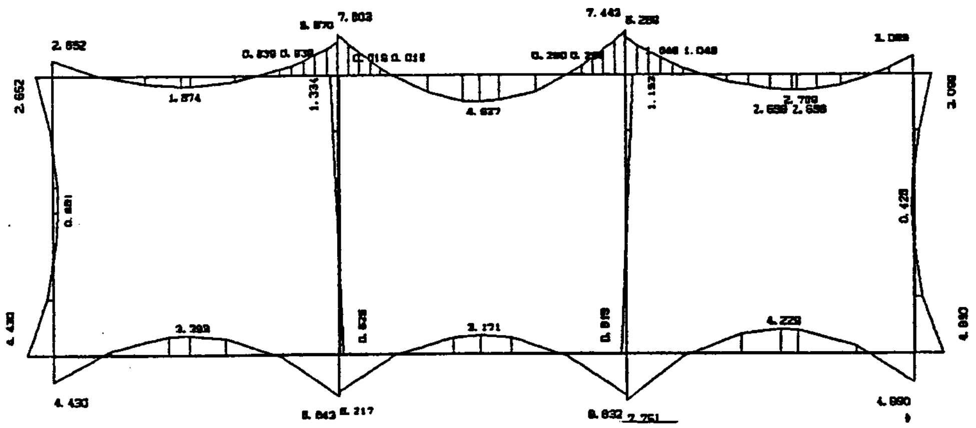
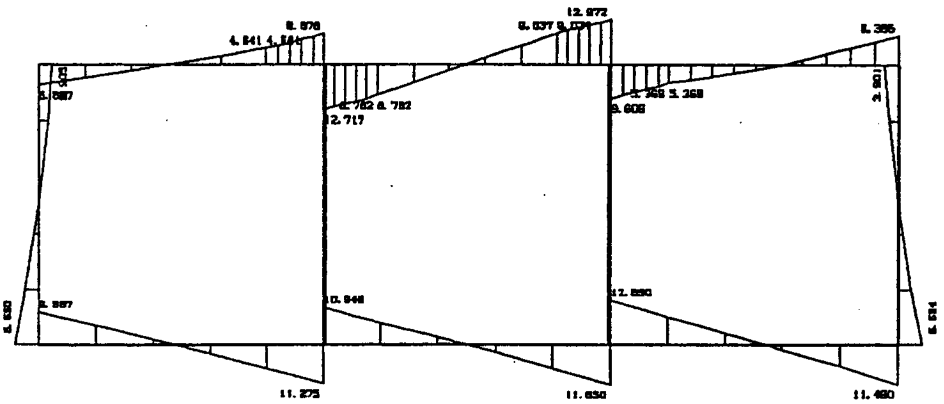


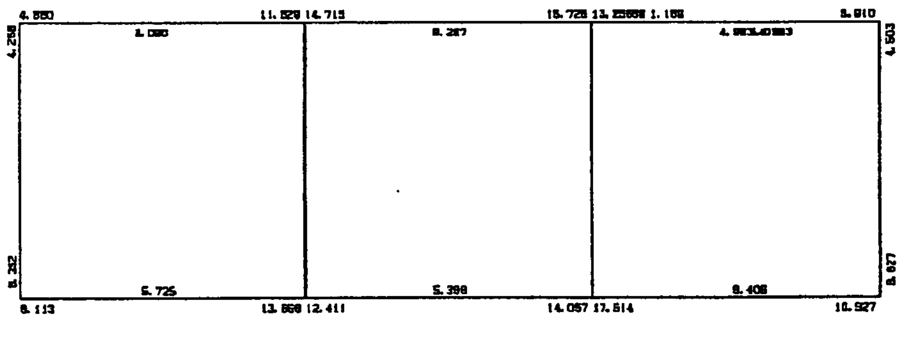
Figure 2 Load Distribution and Numbers of Elements and Contact Points (Case 1)



Moment in t-m

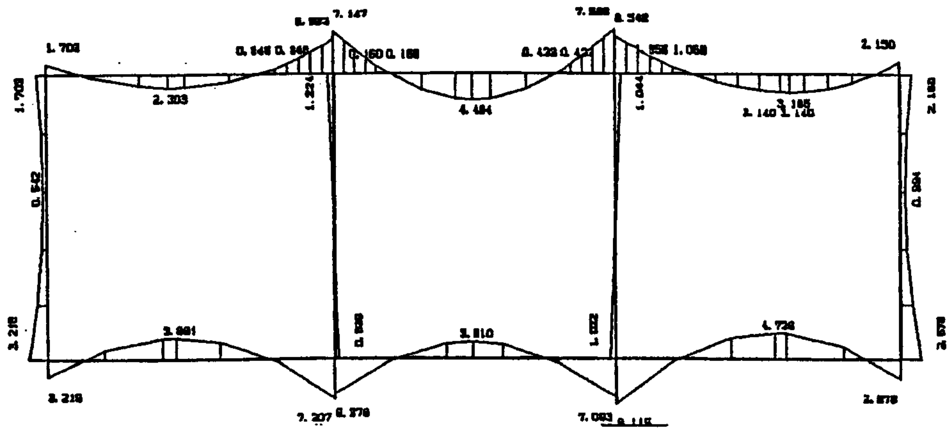


Shearing Force in ton

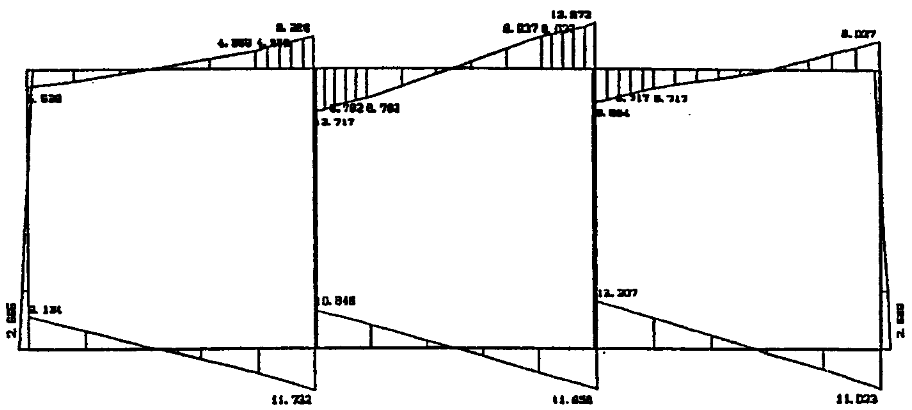


Necessary Reinforcement in cm²

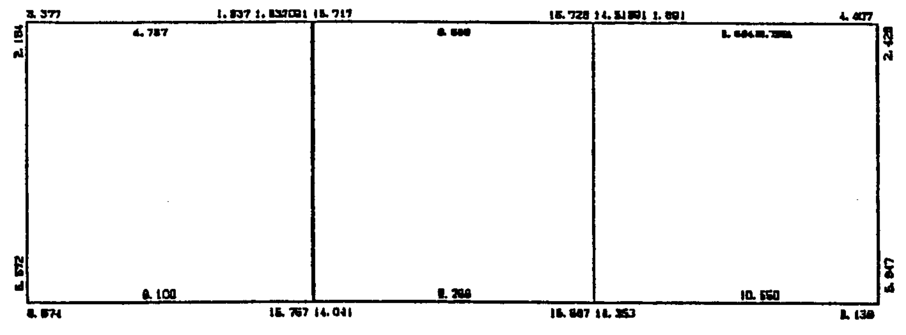
Figure 3 Results of Structural Computation (Case 1-1)



Moment in t-m



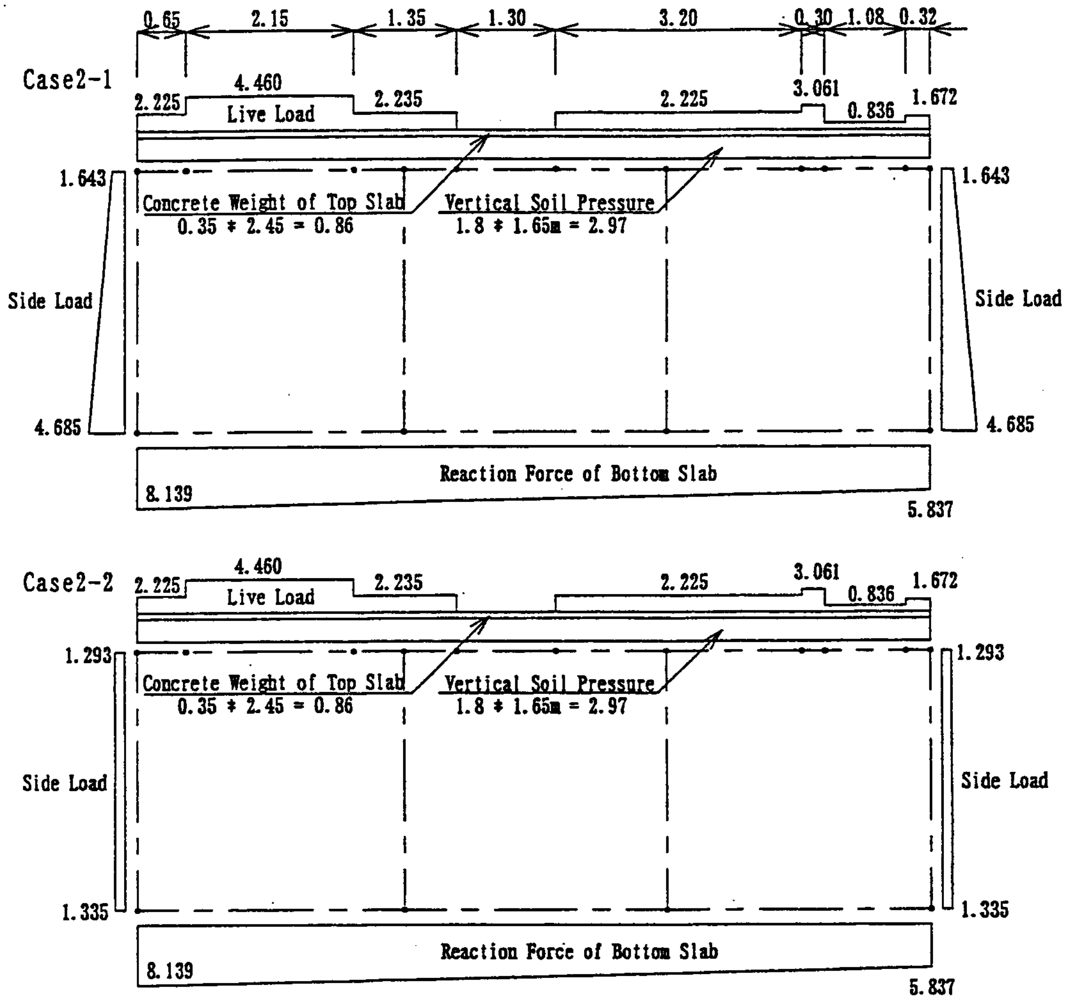
Shearing Force in ton



Necessary Reinforcement in cm²

Figure 4 Results of Structural Computation (Case 1-2)

Load Distribution



Element Number and Contact Point Number (Case2)

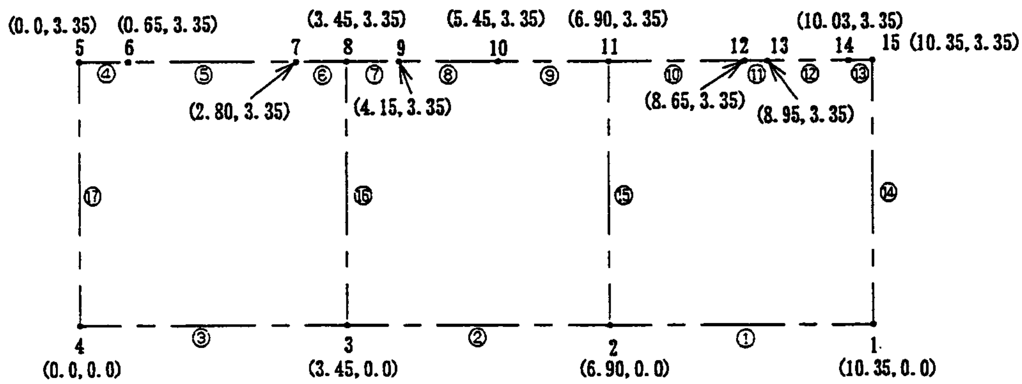
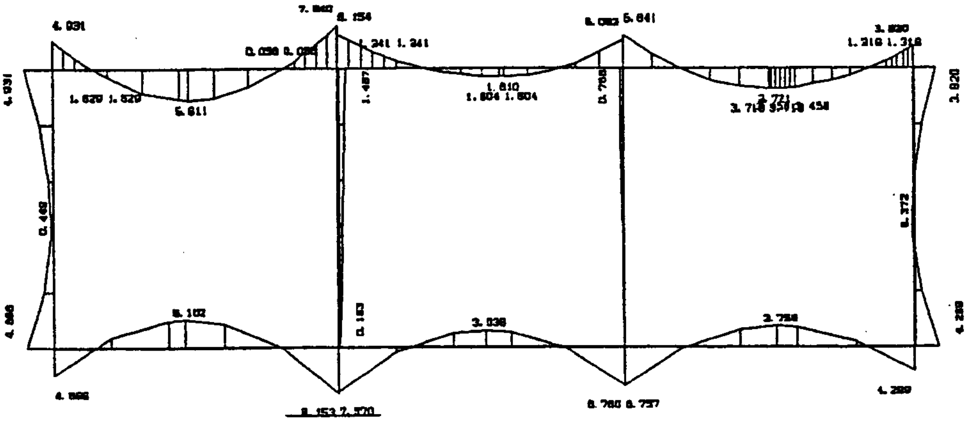
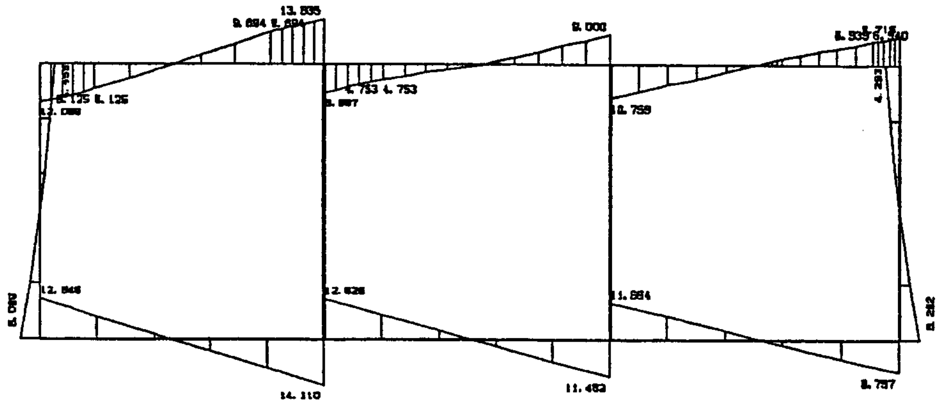


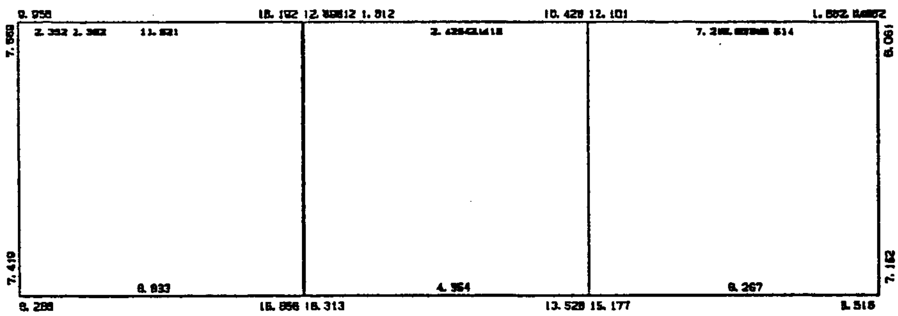
Figure 5 Load Distribution and Numbers of Elements and Contact Points (Case 2)



Moment in t-m

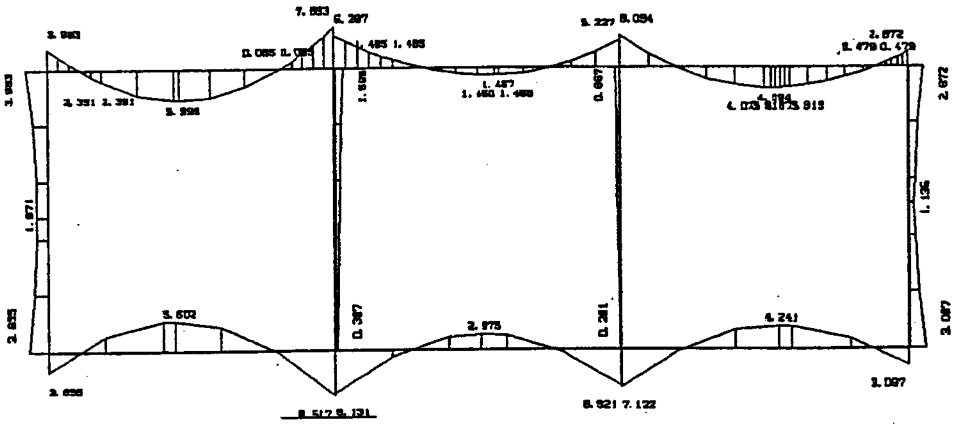


Shearing Force in ton

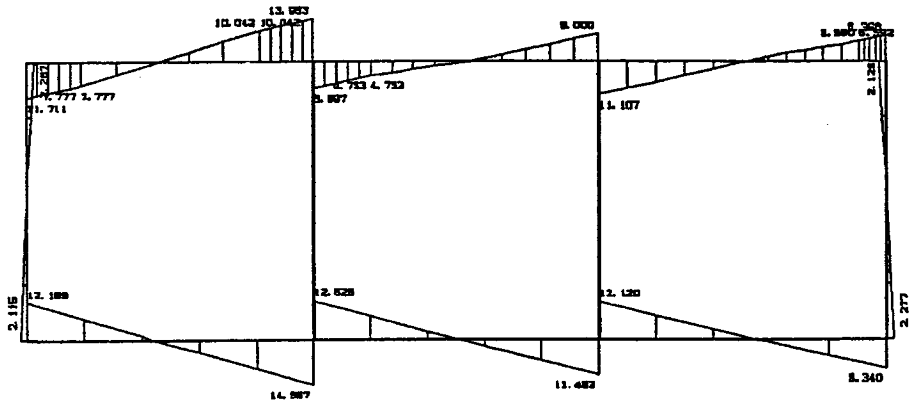


Necessary Reinforcement in cm²

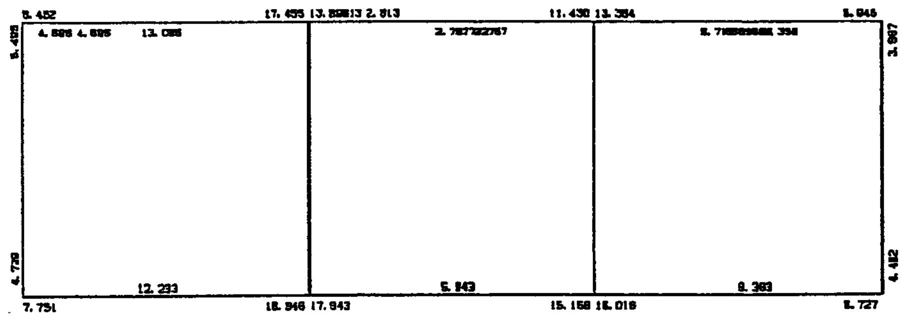
Figure 6 Results of Structural Computation (Case 2-1)



Moment in t-m



Shearing Force in ton

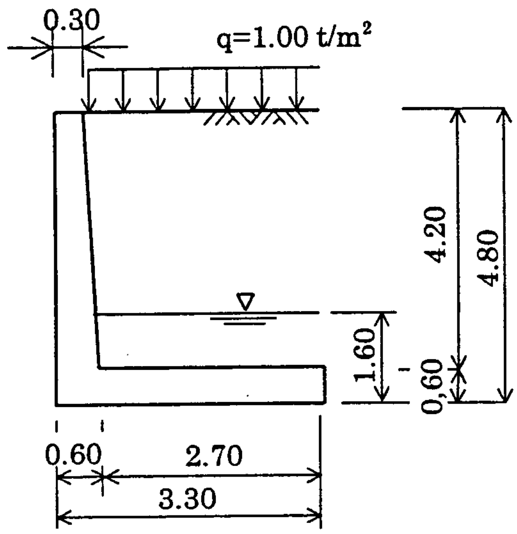


Necessary Reinforcement in cm²

Figure 7 Results of Structural Computation (Case 2-2)

APPENDIX C.4.5-2 (3) Retaining Wall (Wing Wall at BP+1,161m)

(1) Section for Computation



(2) Results of Computation

The results of computation are shown in Tables 1 and 2.

Table 1 Stability Analysis of Retaining Wall (Wing Wall at BP+1,161m)

Load	Vertical Force (tf)	Arm Length (m)	Stabilizing Moment (tf·m)	Horizontal Force (tf)	Arm Length (m)	Overturning Moment (tf·m)
Wall	8.820	1.012	8.926			
Weight of Wet Earth	13.532	1.854	25.088			
Weight of Saturated Earth	5.483	1.929	10.577			
Up Lift	-5.280	1.650	-8.712			
Water Pressure				-1.280	0.533	-0.682
Earth Pressure				-1.399	2.100	-2.938
Earth Pressure				-2.026	2.467	-4.998
Earth Pressure				-2.494	0.800	-1.995
Earth Pressure				-0.426	0.553	-0.236
Total	22.555		35.879	-7.625		-10.849

Total of Moment $\Sigma M=$ 25.030 (tf·m)
Total of Vertical Force $\Sigma V=$ 22.555 (tf)
Total of Horizontal Force $\Sigma H=$ -7.625 (tf)

Stability Against Overturning and Soil Reaction
Case-1 : After Construction
$\chi = (\Sigma M/\Sigma V) =$ 1.110 (m)
Width of Invert L = 3.30 (m)
Eccentric Length e = 0.540 (m) < L/6= 0.550 (m)
Soil Reaction $Q_1 =$ 13.549 (tf/m^2)
$Q_2 =$ 0.121 (tf/m^2)
Case-2 : Under Construction
$\chi' = M / V =$ 1.012
Eccentric Length e' = 0.638 > L/6= 0.550 (m)
Soil Reaction $Q_1' =$ 5.773 (tf/m^2)
$Q_2' =$ -0.428 (tf/m^2)

Factor of Safety Against Sliding
Coefficient of friction f= 0.600
Cohesion C= 0.000 (tf/m^2)
Total of Vertical Force $\Sigma V=$ 22.555 (tf)
Width of Invert L= 3.300 (m)
Total of Horizontal Force $\Sigma H=$ 7.625 (tf)
Factor of Safety Fs= 1.77 = 1.50 OK

Table 2 Structural Analysis of Retaining Wall (Wing Wall at BP+1,161m)

1. Calculation of stem

Height (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.054	0.241	0.272	0.025	0.004
1.00	0.266	0.633	0.313	0.049	0.293
1.50	0.712	1.174	0.355	0.077	0.897
2.00	1.465	1.865	0.397	0.108	1.836
2.50	2.602	2.706	0.438	0.142	3.121
3.00	4.204	3.755	0.480	0.179	4.770
3.50	6.412	5.134	0.522	0.219	6.867
3.60	6.941	5.450	0.530	0.228	7.348

2. Calculation of Heel

Length (m)	Bending Moment (tf·m)	Shearing Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)
0.50	0.702	-2.644	0.530	0.068	0.854
1.00	2.481	-4.309	0.530	0.128	3.018
1.50	4.848	-4.995	0.530	0.179	5.896
2.00	7.313	-4.702	0.530	0.220	8.895
2.50	9.387	-3.431	0.530	0.249	11.418
2.70	9.998	-2.648	0.530	0.257	12.160