

REPUBLIC OF THE PHILIPPINES

**DEPARTMENT OF
PUBLIC WORKS AND HIGHWAYS**

**THE DETAILED DESIGN STUDY
FOR
THE PASIG-MARIKINA RIVER
CHANNEL
IMPROVEMENT PROJECT
(PHASE IV)**

FINAL REPORT

**VOLUME-4C
STRUCTURAL CALCULATION FOR
CONTRACT PACKAGE-3 (2/2)**

AUGUST 2020

JAPAN INTERNATIONAL COOPERATION AGENCY

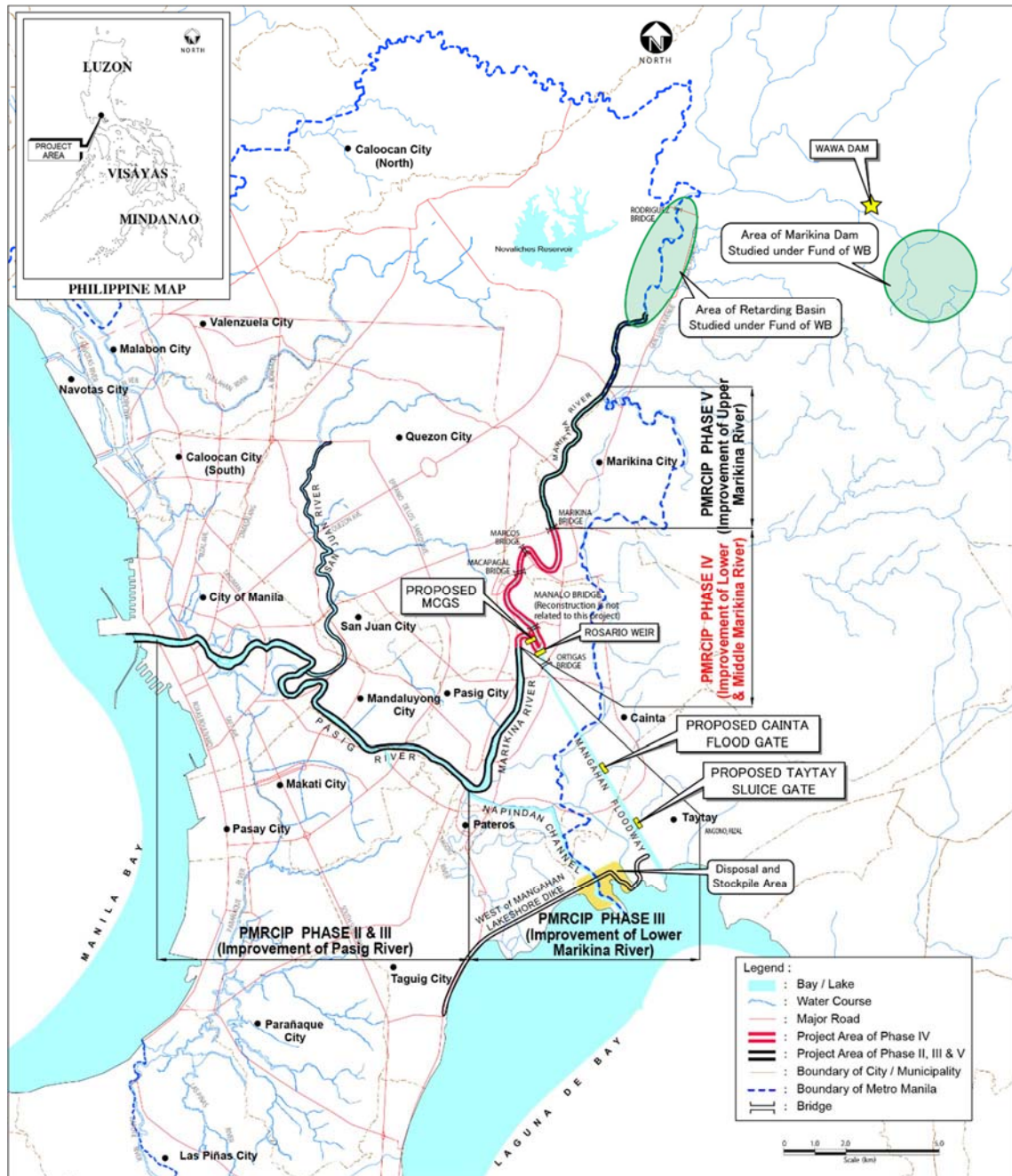
**CTI ENGINEERING INTERNATIONAL CO., LTD.
JAPAN WATER AGENCY
NIPPON KOEI CO., LTD.
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COMPOSITION OF FINAL REPORT

VOLUME-1A	:	MAIN REPORT (CHAPTER 1 to 6)
VOLUME-1B	:	MAIN REPORT (CHAPTER 7 / 7.1 to 7.3)
VOLUME-1C	:	MAIN REPORT (CHAPTER 7 / 7.4 to 7.6)
VOLUME-1D	:	MAIN REPORT (CHAPTER 8 to 14)
VOLUME-2	:	APPENDIX
VOLUME-3	:	APPENDIX FOR GEOTECHNICAL INVESTIGATION
VOLUME-4A	:	STRUCTURAL CALCULATION FOR CONTRACT PACKAGE-1
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VOLUME-5A	:	QUANTITY CALCULATION FOR CONTRACT PACKAGE-1
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VOLUME-5C	:	QUANTITY CALCULATION FOR CONTRACT PACKAGE-3
VOLUME-6	:	COST ESTIMATE

EXCHANGE RATES USED IN THE REPORT:

PHP 1.0 = JPY 2.15
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(November 2019)



PROJECT LOCATION MAP

**THE DETAILED DESIGN STUDY
FOR
THE PASIG-MARIKINA RIVER CHANNEL
IMPROVEMENT PROJECT (PHASE IV)**

**FINAL REPORT
VOLUME-4C
STRUCTURAL CALCULATION
FOR CONTRACT PACKAGE-3
(2/2)**

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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) $\gamma_c = 24.50$ (kN/m³)

Unit weight (Reinforced concrete (submerged)) $\gamma_{c'} = 14.50$ (kN/m³)

(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/m³)

(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/m²)

(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	Vd2	H	Opening	Vd1	Vd2	H	w	
	(mm)	(mm)	(mm)	w (mm)	(mm)	(mm)	(mm)	(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)	w (mm)
	Vd1 (mm)	Vd2 (mm)	H (mm)	Opening 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	

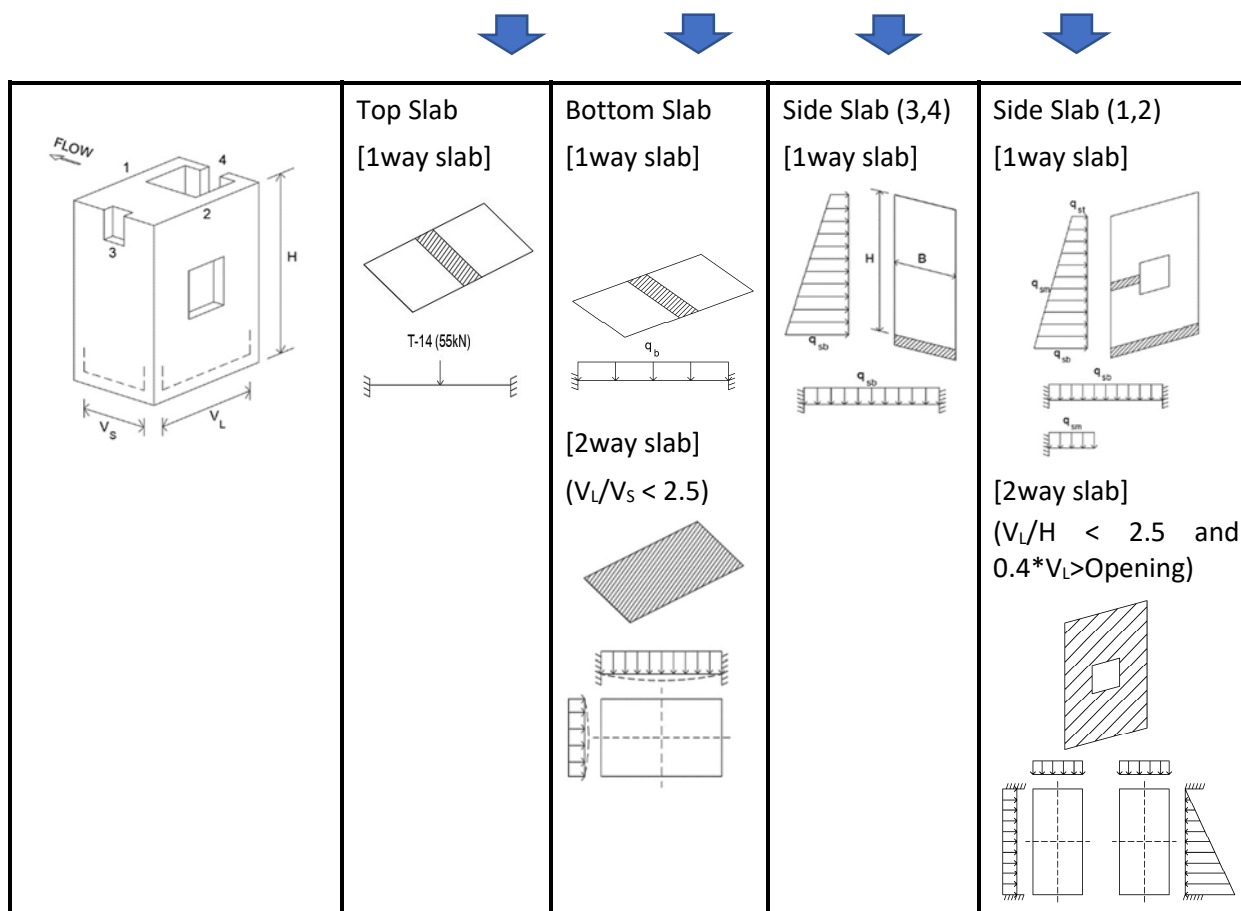
Source: JICA Study Team

(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) (mm)	Vd(2) (mm)	H (mm)	Opening		GL-WL (mm)	Top Slab			Bottom Slab			Side Slab (Short Side)			Side Slab (Long Side)		
				width (mm)	height (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



Source: JICA Study Team

(4) Summary of Load Calculation

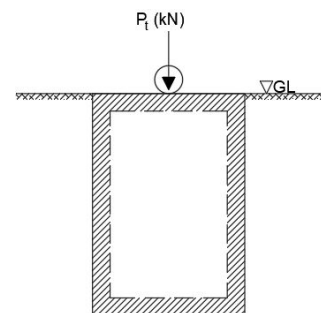
1) Top Slab

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 :

$$P = \frac{(2 \times \text{Rear wheel (kN)})}{\text{Width of vehicle} \times (1 + \text{Impact factor})}$$

$$= (2 \times 55) / 2.75 \times (1 + 0.30) = 52.0 \text{ kN}$$



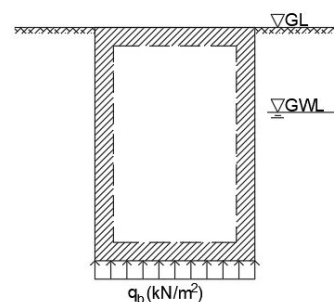
2) Bottom Slab

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.

$$W_b = (W + W_s) / A + P_v1$$

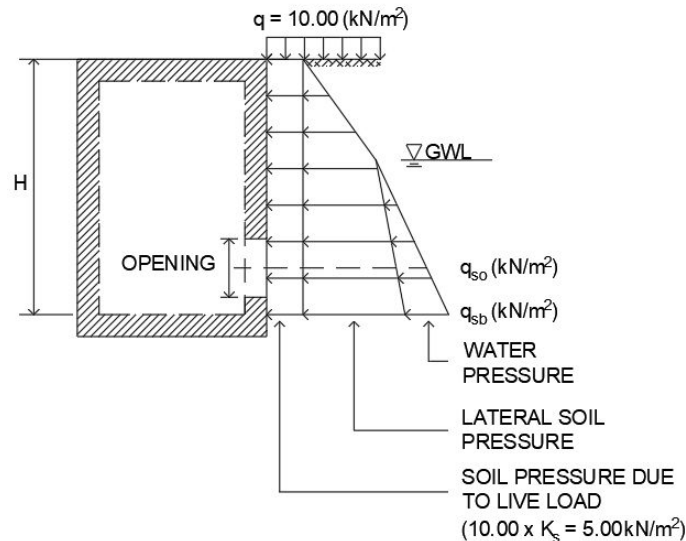
Where,

- W : Self-Weight
- W_s : Weight of Soil Coverage (=0.0(kN/m²))
- A : Area of Bottom Slab (m)
- P_{v1} : Live Load at Ground Surface(=10.0(kN/m²))



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/m² shall be considered for middle slab.

(5) Summary of Calculation Results and Bar Arrangement

Summary 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 ts (mm)	Bottom Slab tb (mm)	Side Wall tw (mm)	Top Slab		Bottom Slab		Side Wall				Shear Reinforcing Bar	
				Top Bar	Bottom Bar	Top Bar	Bottom Bar	Horizontal		Vertical			
								Outer Bar	Inner Bar	Outer Bar	Inner Bar		
a	250	300	300	D16 @250	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	D12 @250	-
c	250	300	300	D12 @250	D12 @250	D20 @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	D16 @250	-
e	250	300	300	D12 @250	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	D16 @250	-
g	250	350	350	D16 @250	D16 @250	D20 @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	D16 @250	-
i	250	350	350	D12 @250	D12 @250	D20 @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	D20 @250	-
k	250	300	300	D12 @250	D12 @250	D16 @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	D16 @250	-
m	250	450	450	D16 @250	D16 @250	D20 @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	D20 @250	-
o	250	450	400	D16 @250	D16 @250	D20 @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	D25 @250	-
q	250	400	400	D16 @250	D16 @250	D20 @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	D25 @250	-
s	250	300	300	D12 @250	D12 @250	D16 @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	D20 @250	-
u	250	550	550	D16 @250	D16 @250	D20 @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

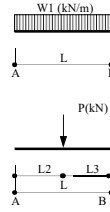
The calculation sheets of each manhole type are shown from next page by following order.

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

$$L = 1.500 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

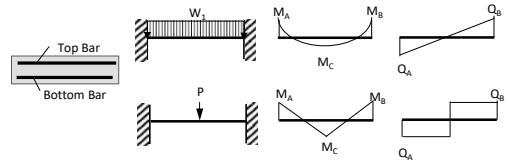
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.750 \text{ m} \quad L3 = 0.750 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 Calculator】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	3.136	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	87.756	N/mm ²	○
Shearing Stress of Concrete	τ =	0.200	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k / 3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 313.59854$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 8775.60927$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 20.00078$$

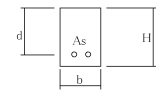
$$x = k \cdot d = 4.502$$

【Stress Intensity Calculator】

FOR BOTTOM BARS

Position of Reinforcing 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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	2.843	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	79.566	N/mm ²	○
Shearing Stress of Concrete	τ =	0.200	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k / 3) = 0.91888$$

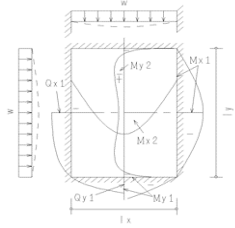
$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 284.32934$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 7956.55240$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 20.00078$$

$$x = k \cdot d = 4.502$$

Type a
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 1.500 \text{ m}$$

$$l_y = 2.400 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$w = 41.200 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 41.20 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	0.019	0.5	0.46
1.4	0.072	0.031	0.059	0.019	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.6$$

$$\alpha \text{ for } M_{x2} = 0.036$$

$$\alpha \text{ for } M_{x1} = 0.078$$

$$\alpha \text{ for } Q_{x1} = 0.520$$

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 Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 3.34 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 32.14 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.770 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 22.528 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.174 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} \cdot n \cdot p$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 77.01635$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2252.76683$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 17.43764$$

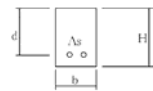
5

【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 7.24 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 32.14 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.669 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 48.832 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.174 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} \cdot n \cdot p$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 166.94562$$

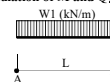
$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 4883.24307$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 17.43764$$

Type a
Analysis of Side Slab Slab (VdI)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.500 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$W1 = 28.609 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 28.61 \text{ kN/m}$$

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



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7

Type a

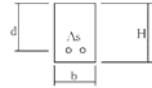
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.238	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	36.220	N/mm ²	○
Shearing Stress of Concrete	τ =	0.098	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 123.82569 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 3621.96344 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 9.76595
 \end{aligned}$$

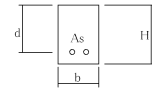
8

【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	0.620	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	18.144	N/mm ²	○
Shearing Stress of Concrete	τ =	0.098	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 62.02814 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 1814.35412 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 9.76595
 \end{aligned}$$

9

Type a

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q by Uniform Load】

①Dimensional Conditions

l _x	=	1.750	m
l _y	=	2.400	m
B × D	=	100 × 30	cm

②Load Conditions

w = 6.250 kN/m : Uniform Load

$$\Sigma W = 6.25 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

l _y /l _x	M _{x1}	M _{x2}	M _{y1}	M _{y2max}	Q _{x1}	Q _{y1}
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

l _y /l _x	=	1.4
α for M _{x1}	=	0.072
α for M _{y1}	=	0.056
α for Q _{y1}	=	0.460

Load	M _{x1} (kN · m)	M _{y1} (kN · m)	Q (kN)
Uniform	1.38	1.08	5.04

Type a

Analysis of Bottom Slab

【Calculation of M and Q】

①Dimensional Conditions

l _x	=	1.750	m
l _y	=	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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

l _y /l _x	M _{x1}	M _{x1max}	M _{y1}	Q _{x1}	Q _{y1}
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		

l _y /l _x	=	1.4
α for M _{x1max}	=	0.045
α for M _{y1}	=	0.000
α for Q _{y1}	=	0.350

Load	M _{x1max} (kN · m)	M _{y1} (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

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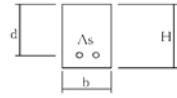
Type a

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】

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 =	4.47	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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	$\sigma_c =$	1.031	N/mm ² ○
Tensile Stress of Reinforcing Bar	$\sigma_s =$	30.149	N/mm ² ○
Shearing Stress of Concrete	$\tau =$	0.102	N/mm ² ○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	$\sigma_{ca} =$	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	$\sigma_{sa} =$	140.0	N/mm ²
Allowable Shear Stress of Concrete	$\tau_a =$	0.36	N/mm ²

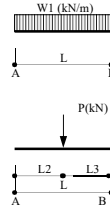
Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00402 & &= 4.706 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.23529 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 103.07278 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3014.93046 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 10.16744
 \end{aligned}$$

2.1.2.2 MANHOLE TYPE B

Type b

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

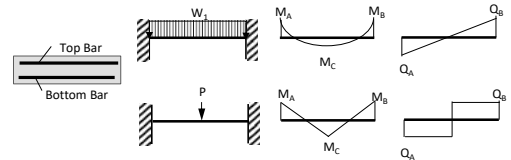
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.600 \text{ m} \quad L3 = 0.600 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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

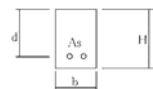
Analysis of Top Slab

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.050	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	117.823	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 304.98173$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 18.45994$$

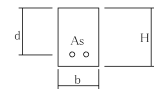
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

【Stress Intensity Calculation】

FOR BOTTOM BARS

Position of Reinforcing 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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	2.812	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	108.642	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

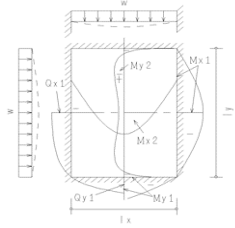
$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 281.21692$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 18.45994$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

Type b
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 1.200 \text{ m}$$

$$l_y = 1.400 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$w = 58.400 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 58.40 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	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

$$l_y/l_x = 1.2$$

$$\alpha \text{ for } M_{x2} = 0.025$$

$$\alpha \text{ for } M_{x1} = 0.064$$

$$\alpha \text{ for } Q_{x1} = 0.490$$

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 Calculation】

FOR TOP BARS

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 2.11 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 34.34 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 4.524 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.616 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 24.830 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.183 \text{ N/mm}^2$$

→ Only concrete does't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00226 \quad = 3.649$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.18245$$

$$j = 1 - (k/3)$$

$$= 0.93918$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 61.56894$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2483.01444$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

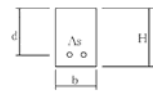
$$= 18.28183$$

【Stress Intensity Calculation】

FOR BOTTOM BARS

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 5.39 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 34.34 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 4.524 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.573 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 63.429 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.183 \text{ N/mm}^2$$

→ Only concrete does't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00226 \quad = 3.649$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.18245$$

$$j = 1 - (k/3)$$

$$= 0.93918$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 157.27802$$

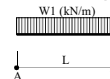
$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 6342.86626$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 18.28183$$

Type b
Analysis of Side Slab Slab (VdI)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

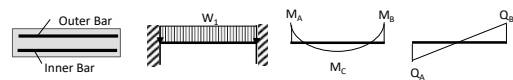
②Load Conditions

$$W1 = 52.520 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 52.52 \text{ kN/m}$$

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

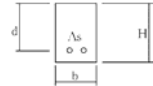
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

For Outer Bars



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	1.841	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	74.255	N/mm ²	○
Shearing Stress of Concrete	τ =	0.128	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00226 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.1824484 \\
 j &= 1 - (k/3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 184.12324 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 7425.50762 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 12.77705
 \end{aligned}$$

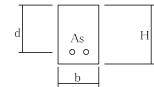
8

【Stress Intensity Calculator】

For Inner Bars

Position of Reinforcing 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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	0.922	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	37.186	N/mm ²	○
Shearing Stress of Concrete	τ =	0.128	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

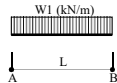
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00226 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.18245 \\
 j &= 1 - (k/3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 92.20752 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3718.63773 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 12.77705
 \end{aligned}$$

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Type b

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



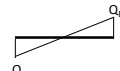
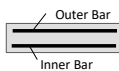
① Dimensional Conditions

$$\begin{aligned}
 L &= 1.400 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 52.520 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 52.52 \text{ kN/m}
 \end{aligned}$$

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



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Type b

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

For Outer Bars



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	2.504	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	100.968	N/mm ²	○
Shearing Stress of Concrete	τ =	0.154	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00226 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.1824484 \\
 j &= 1 - (k/3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 250.36092 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 10096.8075 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 15.43894
 \end{aligned}$$

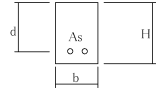
11

【Stress Intensity Calculation】

For Inner Bars

Position of Reinforcing 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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	1.252	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	50.484	N/mm ²	○
Shearing Stress of Concrete	τ =	0.154	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00226 & &= 3.649 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2)} - n \cdot p \\
 &= 0.18245 \\
 j &= 1 - (k/3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 125.18046 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 5048.40376 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 15.43894
 \end{aligned}$$

【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	

$$A_w = \frac{1.15 \cdot S_h \cdot S_s}{\sigma_{sa} \cdot d}$$

$$S_h = Q - S_{ca}$$

$$S_{ca} = b \cdot d \cdot \tau_a$$

where,

Sca : Shear force beared by concrete

Sh : Shear force beared by stirrup reinforcement bars

Sca =	67.62	kN
Sh =	-38.62	kN

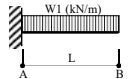
12

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Type b

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



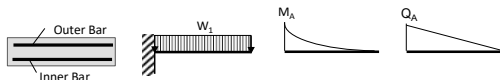
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.250 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 23.920 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 23.92 \text{ kN/m}
 \end{aligned}$$

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 Reinforcing 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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	0.219	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	8.826	N/mm ²	○
Shearing Stress of Concrete	τ =	0.016	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00226 & &= 3.649 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2)} - n \cdot p \\
 &= 0.1824484 \\
 j &= 1 - (k/3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 21.88470 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 882.588069 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 1.59713
 \end{aligned}$$

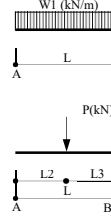
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15

2.1.2.3 MANHOLE TYPE C

Type c

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

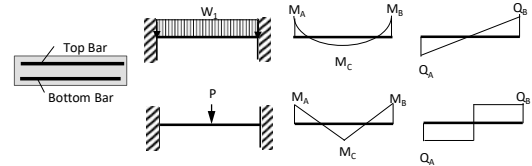
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.600 \text{ m} \quad L3 = 0.600 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 c

Analysis of Top Slab

【Stress Intensity Calculation】

Position of Reinforcing Bar

FOR TOP BARS

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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.050	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	117.823	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 304.98173$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 11782.28829$$

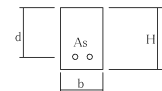
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

FOR BOTTOM BARS

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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.812	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	108.642	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

$$j = 1 - (k / 3) = 0.93702$$

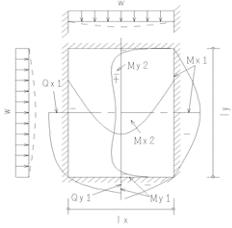
$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 281.21692$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 10864.18790$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

Type c

Analysis of Bottom Slab [Calculation of M and Q]



①Dimensional Conditions

$$l_x = 1.200 \text{ m}$$

$$l_y = 2.600 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$w = 53.450 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 53.45 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	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

$$l_y/l_x = 2.2$$

$$\alpha \text{ for } M_{x2} = 0.040$$

$$\alpha \text{ for } M_{x1} = 0.083$$

$$\alpha \text{ for } Q_{x1} = 0.520$$

Load	Mx2 (kN·m) for top bars	Mx1 (kN·m) for bottom bars	Q(kN)
w	3.08	6.39	33.36

4

Type c

Analysis of Bottom Slab [Stress Intensity Calculation]

FOR TOP 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



$$\text{Bending Moment } M = 3.08 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 33.36 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.598 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 13.537 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.184 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00628 \quad = 5.690$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.28449$$

$$j = 1 - (k/3)$$

$$= 0.90517$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 59.80358$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 1353.70482$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 18.42746$$

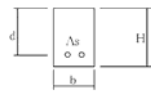
5

[Stress Intensity Calculation]

FOR BOTTOM 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



$$\text{Bending Moment } M = 6.39 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 33.36 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.241 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 28.085 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.184 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00628 \quad = 5.690$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.28449$$

$$j = 1 - (k/3)$$

$$= 0.90517$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 124.07300$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2808.49800$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

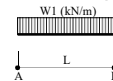
$$= 18.42746$$

6

Type c

Analysis of Side Slab Slab (Vd1)

[Calculation of M and Q]



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

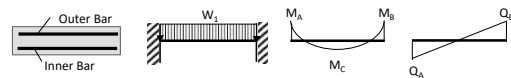
②Load Conditions

$$W1 = 46.612 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 46.61 \text{ kN/m}$$

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



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Type c

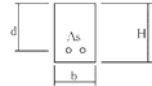
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	1.087	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	24.613	N/mm ²	○
Shearing Stress of Concrete	τ =	0.116	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00628 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2844874 \\
 j &= 1 - (k/3) \\
 &= 0.90517 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 108.73378 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 2461.2815 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 11.60002
 \end{aligned}$$

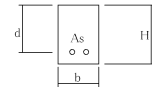
8

【Stress Intensity Calculator】

For Inner 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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	0.544	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	12.306	N/mm ²	○
Shearing Stress of Concrete	τ =	0.116	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

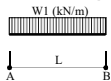
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00628 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.28449 \\
 j &= 1 - (k/3) \\
 &= 0.90517 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 54.36689 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 1230.64075 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 11.60002
 \end{aligned}$$

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Type c

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 2.600 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 46.612 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ : Self Weight} \\
 \Sigma W &= 46.61 \text{ kN/m}
 \end{aligned}$$

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



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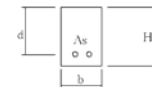
Type c

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	5.099	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	115.417	N/mm ²	○
Shearing Stress of Concrete	τ =	0.298	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00628 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2844874 \\
 j &= 1 - (k/3) \\
 &= 0.90517 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 509.88374 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 11541.6522 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 29.82862
 \end{aligned}$$

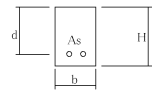
11

【Stress Intensity Calculation】

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

For Inner Bars



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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.549	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	57.708	N/mm ² ○
Shearing Stress of Concrete	τ =	0.298	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00628 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.28449 \\
 j &= 1 - (k/3) \\
 &= 0.90517 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 254.94187 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5770.82609 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 29.82862
 \end{aligned}$$

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【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

$$A_w = \frac{1.15 \cdot S_h \cdot s}{\sigma_{sa} \cdot d}$$

$$S_h = Q - S_{ca}$$

$$S_{ca} = b \cdot d \cdot \tau_a$$

where,

Sca : Shear force borne by concrete

Sh : Shear force borne by stirrup reinforcement bars

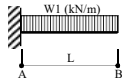
Sca =	65.17	kN
Sh =	-11.17	kN

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Type c

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



① Dimensional Conditions

$$L = 0.800 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

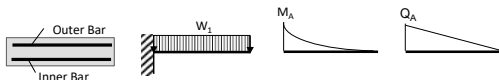
② Load Conditions

$$W1 = 35.737 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 35.74 \text{ kN/m}$$

Load	M(kN·m) for outer bars	Q(kN)
W1+w	11.44	24.00
Total	11.44	24.00



14

Type c

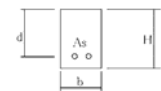
Analysis of Side Slab (Vd2 Opening)

【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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.221	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	50.280	N/mm ² ○
Shearing Stress of Concrete	τ =	0.133	N/mm ² ○

→ Only concrete doesn'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

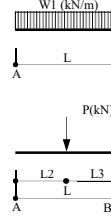
Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00628 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2844874 \\
 j &= 1 - (k/3) \\
 &= 0.90517 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 222.12757 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5028.04649 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 13.25717
 \end{aligned}$$

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2.1.2.4 MANHOLE TYPE D

Type d Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.500 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

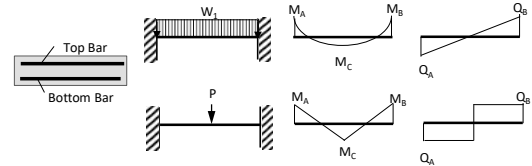
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.750 \text{ m} \quad L3 = 0.750 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 d

Analysis of Top Slab 【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.136	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	87.756	N/mm ² ○
Shearing Stress of Concrete	τ =	0.200	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k / 3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 313.59854$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 8775.60927$$

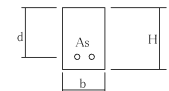
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 20.00078$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.843	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	79.566	N/mm ² ○
Shearing Stress of Concrete	τ =	0.200	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

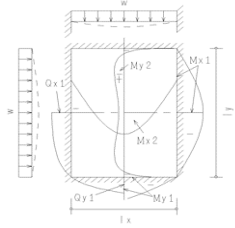
$$j = 1 - (k / 3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 284.32934$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 7956.55240$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 20.00078$$

Type d
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 1.500 \text{ m}$$

$$l_y = 2.100 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$w = 52.540 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 52.54 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.4$$

$$\alpha \text{ for } M_{x2} = 0.031$$

$$\alpha \text{ for } M_{x1} = 0.072$$

$$\alpha \text{ for } Q_{x1} = 0.510$$

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 Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 3.67 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 40.20 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.846 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 24.753 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.218 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 84.62575$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2475.34559$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

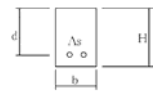
$$= 21.81061$$

【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 8.52 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 40.20 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.965 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 57.466 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.218 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 196.46087$$

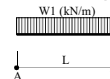
$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 5746.57886$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 21.81061$$

Type d
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.500 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

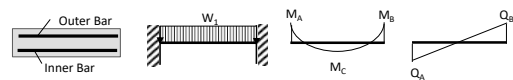
②Load Conditions

$$W1 = 44.869 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 44.87 \text{ kN/m}$$

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

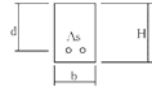
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.942	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 194.15499 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5679.13075 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.64892
 \end{aligned}$$

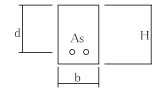
8

【Stress Intensity Calculator】

For Inner 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 =	4.21	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	0.971	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

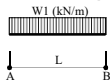
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 97.07749 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 2839.56538 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.64892
 \end{aligned}$$

9

Type d

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

$$\begin{aligned}
 L &= 2.100 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

②Load Conditions

$$\begin{aligned}
 W1 &= 44.869 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 44.87 \text{ kN/m}
 \end{aligned}$$

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

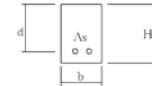
Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	3.802	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 380.23940 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 11122.1931 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 22.24466
 \end{aligned}$$

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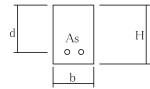
10

【Stress Intensity Calculation】

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

For Inner Bars



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	1.902	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	55.645	N/mm ² ○
Shearing Stress of Concrete	τ =	0.222	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.23529 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 190.23499 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5564.46897 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 22.24466
 \end{aligned}$$

12

【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

$$A_w = \frac{1.15 \cdot S_h \cdot s}{\sigma_{sa} \cdot d}$$

$$S_h = Q - S_{ca}$$

$$S_{ca} = b \cdot d \cdot \tau_a$$

where,

Sca : Shear force borne by concrete

Sh : Shear force borne by stirrup reinforcement bars

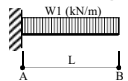
Sca =	66.35	kN
Sh =	-25.35	kN

13

Type d

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



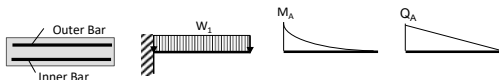
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.525 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 33.994 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 33.99 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars	Q(kN)
W1+w	4.69	13.00
Total	4.69	13.00



14

Type d

Analysis of Side Slab (Vd2 Opening)

【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 =	4.69	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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	1.081	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	31.633	N/mm ² ○
Shearing Stress of Concrete	τ =	0.071	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

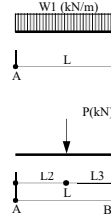
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 108.14571 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3163.3163 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 7.05318
 \end{aligned}$$

15

2.1.2.5 MANHOLE TYPE E

Type e

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

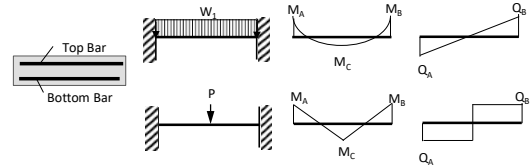
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.600 \text{ m} \quad L3 = 0.600 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 e

Analysis of Top Slab

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.050	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	117.823	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.18895$$

$$j = 1 - (k/3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) = 304.98173$$

$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) = 11782.28829$$

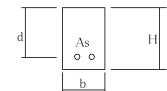
$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d) = 18.45994$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.812	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	108.642	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.18895$$

$$j = 1 - (k/3) = 0.93702$$

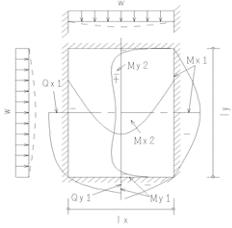
$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) = 281.21692$$

$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) = 10864.18790$$

$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d) = 18.45994$$

Type e

Analysis of Bottom Slab [Calculation of M and Q]



①Dimensional Conditions

$$l_x = 1.200 \text{ m}$$

$$l_y = 1.400 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$w = 71.200 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 71.20 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.2$$

$$\alpha \text{ for } M_{x2} = 0.025$$

$$\alpha \text{ for } M_{x1} = 0.064$$

$$\alpha \text{ for } Q_{x1} = 0.490$$

Load	Mx2 (kN·m) for top bars	Mx1 (kN·m) for bottom bars	Q(kN)
w	2.57	6.57	41.87

4

Type e

Analysis of Bottom Slab [Stress Intensity Calculation]

FOR TOP BARS

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 2.57 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 41.87 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 4.524 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.750 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 30.243 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.223 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00226 \quad x = k \cdot d = 3.649$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18245$$

$$j = 1 - (k/3) = 0.93918$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 74.99156$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 3024.33512$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 22.29063$$

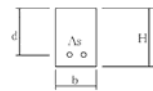
5

[Stress Intensity Calculation]

FOR BOTTOM BARS

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 6.57 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 41.87 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 4.524 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.917 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 77.315 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.223 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00226 \quad x = k \cdot d = 3.649$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18245$$

$$j = 1 - (k/3) = 0.93918$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 191.70994$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 7731.47149$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 22.29063$$

$$\tau = 22.29063$$

6

Type e

Analysis of Side Slab Slab (Vd1) [Calculation of M and Q]

①Dimensional Conditions

$$L = 1.200 \text{ m}$$

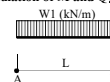
$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$W1 = 58.725 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 58.73 \text{ kN/m}$$



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



7

Type e

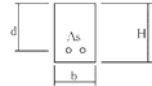
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.057	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	82.963	N/mm ²	○
Shearing Stress of Concrete	τ =	0.144	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00226 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.1824484 \\
 j &= 1 - (k / 3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 205.71614 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 8296.32785 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.37418
 \end{aligned}$$

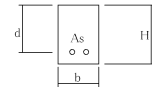
8

【Stress Intensity Calculator】

For Inner Bars

Position of Reinforcing 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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.030	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	41.540	N/mm ²	○
Shearing Stress of Concrete	τ =	0.144	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

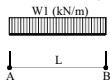
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00226 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.18245 \\
 j &= 1 - (k / 3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 103.00397 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 4154.04785 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.37418
 \end{aligned}$$

9

Type e

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 1.400 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 58.725 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 58.73 \text{ kN/m}
 \end{aligned}$$

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



10

Type e

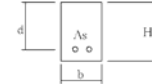
Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

For Outer Bars

Position of Reinforcing 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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.801	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	112.971	N/mm ²	○
Shearing Stress of Concrete	τ =	0.176	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00226 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.1824484 \\
 j &= 1 - (k / 3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 280.12411 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 11297.1273 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 17.56845
 \end{aligned}$$

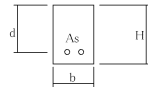
11

【Stress Intensity Calculation】

For Inner Bars

Position of Reinforcing 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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	1.401	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	56.486	N/mm ²	○
Shearing Stress of Concrete	τ =	0.176	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00226 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.18245 \\
 j &= 1 - (k/3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 140.06205 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5648.56364 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 17.56845
 \end{aligned}$$

12

【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	

$$A_w = \frac{1.15 \cdot S_h \cdot s}{\sigma_{sa} \cdot d}$$

$$S_h = Q - S_{ca}$$

$$S_{ca} = b \cdot d \cdot \tau_a$$

where,

Sca : Shear force borne by concrete

Sh : Shear force borne by stirrup reinforcement bars

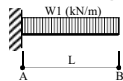
Sca =	67.62	kN
Sh =	-34.62	kN

13

Type e

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



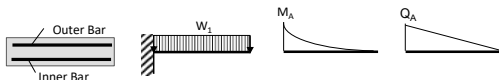
① Dimensional Conditions

L	=	0.250	m
B × D	=	100 × 30	cm

② Load 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



14

Type e

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】

For Outer Bars

Position of Reinforcing 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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	0.449	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	18.122	N/mm ²	○
Shearing Stress of Concrete	τ =	0.027	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

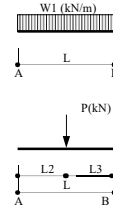
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00226 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.1824484 \\
 j &= 1 - (k/3) \\
 &= 0.93918 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 44.93658 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 1812.2475 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 2.66189
 \end{aligned}$$

15

2.1.2.6 MANHOLE TYPE F

Type f

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

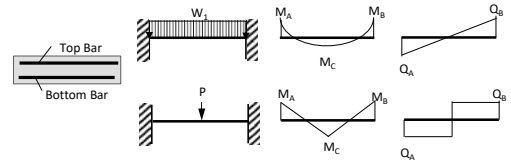
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.600 \text{ m} \quad L3 = 0.600 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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

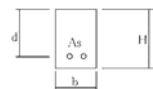
Analysis of Top Slab

【Stress Intensity Calculator】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	3.050	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	117.823	N/mm ²	○
Shearing Stress of Concrete	τ =	0.185	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 304.98173$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 11782.28829$$

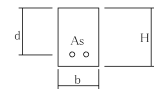
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

【Stress Intensity Calculator】

FOR BOTTOM BARS

Position of Reinforcing 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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	2.812	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	108.642	N/mm ²	○
Shearing Stress of Concrete	τ =	0.185	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

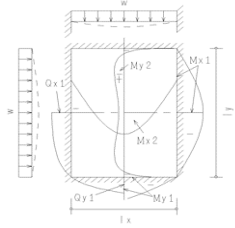
$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 281.21692$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 10864.18790$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

Type f
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 1.200 \text{ m}$$

$$l_y = 2.000 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$w = 67.050 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 67.05 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.7$$

$$\alpha \text{ for } M_{x2} = 0.037$$

$$\alpha \text{ for } M_{x1} = 0.079$$

$$\alpha \text{ for } Q_{x1} = 0.520$$

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

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 3.58 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 41.84 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.826 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 24.146 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.227 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 82.55046$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2414.64229$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 22.70040$$

4

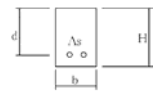
5

【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 7.63 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 41.84 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.759 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 51.463 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.227 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 175.93855$$

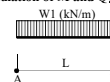
$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 5146.29069$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 22.70040$$

Type f
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$W1 = 58.323 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 58.32 \text{ kN/m}$$

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



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7

Type f

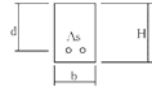
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.614	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	47.214	N/mm ²	○
Shearing Stress of Concrete	τ =	0.146	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 161.41151 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 4721.36761 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.64892
 \end{aligned}$$

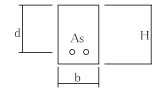
8

【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	0.807	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	23.607	N/mm ²	○
Shearing Stress of Concrete	τ =	0.146	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

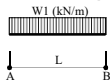
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 80.70576 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 2360.68380 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.64892
 \end{aligned}$$

9

Type f

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 2.000 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 58.323 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 58.32 \text{ kN/m}
 \end{aligned}$$

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



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Type f

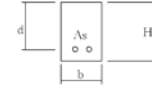
Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	4.485	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	131.187	N/mm ²	○
Shearing Stress of Concrete	τ =	0.271	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 448.49341 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 13118.6571 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 27.12763
 \end{aligned}$$

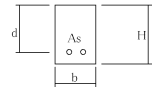
11

【Stress Intensity Calculation】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.244	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	65.627	N/mm ²	○
Shearing Stress of Concrete	τ =	0.271	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

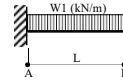
Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00402 & &= 4.706 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.23529 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 224.36200 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 6562.70097 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 27.12763
 \end{aligned}$$

Type f

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



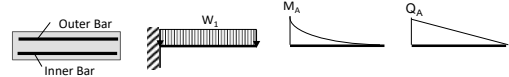
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.475 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 46.323 \text{ kN/m} & : \text{Uniform Load} \\
 w &= \text{ } & : \text{Self Weight} \\
 \Sigma W &= 46.32 \text{ kN/m}
 \end{aligned}$$

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 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 =	5.23	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.015	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	22.987	N/mm ²	○
Shearing Stress of Concrete	τ =	0.088	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

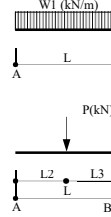
Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00628 & &= 5.690 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.284874 \\
 j &= 1 - (k/3) \\
 &= 0.90517 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 101.54958 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 2298.66111 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 8.83811
 \end{aligned}$$

2.1.2.7 MANHOLE TYPE G

Type g Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.000 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad \text{Uniform Load}$$

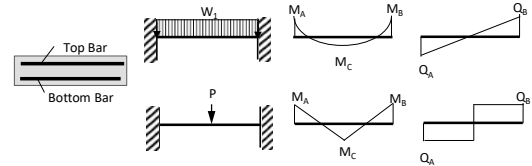
$$P = 52.000 \text{ kN} \quad \text{Point Load}$$

$$L2 = 1.000 \text{ m} \quad L3 = 1.000 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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



1

Type g

Analysis of Top Slab

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



$$\text{Bending Moment } M = 17.00 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 37.00 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 25.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 18.500 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 4.443 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 124.321 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.218 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00435$$

$$x = k \cdot d = 4.502$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) = 444.26459$$

$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) = 12432.11313$$

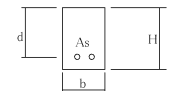
$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d) = 21.76556$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



$$\text{Bending Moment } M = 15.00 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 37.00 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 25.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 18.500 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 3.920 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 109.695 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.218 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00435$$

$$x = k \cdot d = 4.502$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

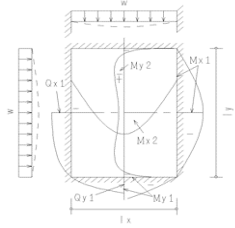
$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) = 391.99817$$

$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) = 10969.51158$$

$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d) = 21.76556$$

Type g
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 2.000 \text{ m}$$

$$l_y = 2.500 \text{ m}$$

$$B \times D = 100 \times 35 \text{ cm}$$

②Load Conditions

$$w = 74.070 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 74.07 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.3$$

$$\alpha \text{ for } M_{x2} = 0.029$$

$$\alpha \text{ for } M_{x1} = 0.068$$

$$\alpha \text{ for } Q_{x1} = 0.500$$

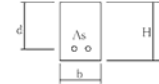
Load	Mx2 (kN·m) for top bars	Mx1 (kN·m) for bottom bars	Q(kN)
w	8.60	20.15	74.07

Type g
Analysis of Bottom Slab
【Stress Intensity Calculation】

FOR TOP BARS

Position of Reinforcing Bar

Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 8.60 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 74.07 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 35.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 25.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.163 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 29.957 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.324 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00503 \quad = 6.474$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.25895$$

$$j = 1 - (k/3)$$

$$= 0.91368$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 116.31381$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2995.69190$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 32.42703$$

【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 20.15 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 74.07 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 35.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 25.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 2.725 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 70.190 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.324 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00503 \quad = 6.474$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.25895$$

$$j = 1 - (k/3)$$

$$= 0.91368$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 272.52596$$

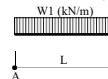
$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 7018.97578$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 32.42703$$

Type g
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.000 \text{ m}$$

$$B \times D = 100 \times 35 \text{ cm}$$

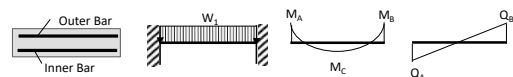
②Load Conditions

$$W1 = 74.070 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 74.07 \text{ kN/m}$$

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

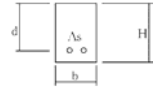
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	3.339	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	86.004	N/mm ²	○
Shearing Stress of Concrete	τ =	0.271	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2589536 \\
 j &= 1 - (k/3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 333.92883 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 8600.42243 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 27.14292
 \end{aligned}$$

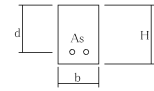
8

【Stress Intensity Calculator】

For Inner 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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	1.670	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	43.020	N/mm ²	○
Shearing Stress of Concrete	τ =	0.271	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

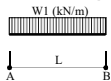
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.25895 \\
 j &= 1 - (k/3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 167.03204 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 4301.95290 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 27.14292
 \end{aligned}$$

9

Type g

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 2.500 \text{ m} \\
 B \times D &= 100 \times 35 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 74.070 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 74.07 \text{ kN/m}
 \end{aligned}$$

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



10

Type g

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	5.218	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	134.388	N/mm ²	○
Shearing Stress of Concrete	τ =	0.350	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2589536 \\
 j &= 1 - (k/3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 521.78916 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 13438.8132 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 35.02312
 \end{aligned}$$

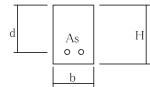
11

【Stress Intensity Calculation】

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

For Inner Bars



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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.609	N/mm ²
Tensile Stress of Reinforcing Bar	σs =	67.194	N/mm ²
Shearing Stress of Concrete	τ =	0.350	N/mm ²

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.25895 \\
 j &= 1 - (k/3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 260.89458 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 6719.40659 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 35.02312
 \end{aligned}$$

12

【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

$$A_w = \frac{1.15 \cdot S_h \cdot s}{\sigma_{sa} \cdot d}$$

$$S_h = Q - S_{ca}$$

$$S_{ca} = b \cdot d \cdot \tau_a$$

where,

Sca : Shear force borne by concrete

Sh : Shear force borne by stirrup reinforcement bars

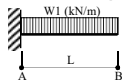
Sca =	82.23	kN
Sh =	-2.23	kN

13

Type g

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



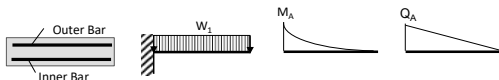
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.750 \text{ m} \\
 B \times D &= 100 \times 35 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 60.420 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 60.42 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars	Q(kN)
W1+w	17.00	35.00
Total	17.00	35.00



14

Type g

Analysis of Side Slab (Vd2 Opening)

【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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.299	N/mm ²
Tensile Stress of Reinforcing Bar	σs =	59.217	N/mm ²
Shearing Stress of Concrete	τ =	0.153	N/mm ²

→ Only concrete doesn'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

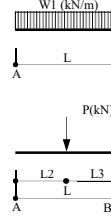
Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2589536 \\
 j &= 1 - (k/3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 229.92265 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5921.71654 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 15.32262
 \end{aligned}$$

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2.1.2.8 MANHOLE TYPE H

Type h Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

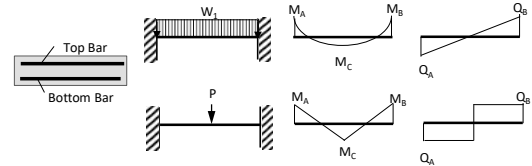
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.600 \text{ m} \quad L3 = 0.600 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 h

Analysis of Top Slab

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.050	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	117.823	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 304.98173$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 11782.28829$$

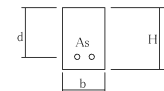
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.812	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	108.642	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

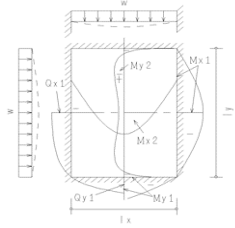
$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 281.21692$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 10864.18790$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

Type h
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 1.200 \text{ m}$$

$$l_y = 1.400 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$w = 84.000 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 84.00 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.2$$

$$\alpha \text{ for } M_{x2} = 0.025$$

$$\alpha \text{ for } M_{x1} = 0.064$$

$$\alpha \text{ for } Q_{x1} = 0.490$$

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 Calculation】

FOR TOP BARS

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 3.03 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 49.40 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.699 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 20.437 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.268 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 69.86813$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2043.67769$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

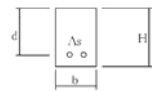
$$= 26.80210$$

【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 7.75 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 49.40 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.787 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 52.272 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.268 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 178.70560$$

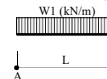
$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 5227.22842$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 26.80210$$

Type h
Analysis of Side Slab Slab (VdI)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

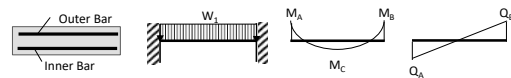
②Load Conditions

$$W1 = 74.577 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 74.58 \text{ kN/m}$$

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

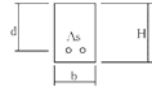
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.064	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 206.37615 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 6036.60573 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 18.44679
 \end{aligned}$$

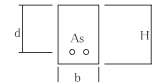
8

【Stress Intensity Calculator】

For Inner 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 =	4.48	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.033	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

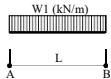
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 103.30337 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3021.67527 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 18.44679
 \end{aligned}$$

9

Type h

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 1.400 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 74.577 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 74.58 \text{ kN/m}
 \end{aligned}$$

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



10

Type h

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.811	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 281.08662 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 8221.92445 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 22.78721
 \end{aligned}$$

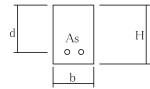
11

【Stress Intensity Calculation】

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

For Inner Bars



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	1.407	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	41.143	N/mm ² ○
Shearing Stress of Concrete	τ =	0.228	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.23529 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 140.65860 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 4114.33463 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 22.78721
 \end{aligned}$$

12

【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

$$A_w = \frac{1.15 \cdot S_h \cdot s}{\sigma_{sa} \cdot d}$$

$$S_h = Q - S_{ca}$$

$$S_{ca} = b \cdot d \cdot \tau_a$$

where,

Sca : Shear force borne by concrete

Sh : Shear force borne by stirrup reinforcement bars

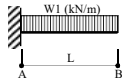
Sca =	66.35	kN
Sh =	-24.35	kN

13

Type h

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



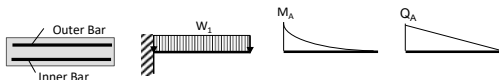
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.550 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 64.827 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 64.83 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars	Q(kN)
W1+w	9.81	26.00
Total	9.81	26.00



14

Type h

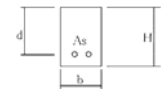
Analysis of Side Slab (Vd2 Opening)

【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 =	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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.262	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	66.167	N/mm ² ○
Shearing Stress of Concrete	τ =	0.141	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

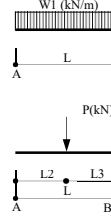
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 226.20670 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 6616.65946 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.10637
 \end{aligned}$$

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2.1.2.9 MANHOLE TYPE I

Type i

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

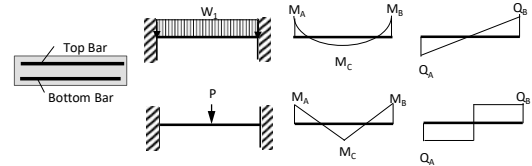
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.600 \text{ m} \quad L3 = 0.600 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 i

Analysis of Top Slab

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.050	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	117.823	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$x = k \cdot d = 3.495$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 304.98173$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 11782.28829$$

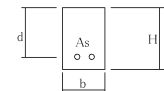
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.812	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	108.642	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$x = k \cdot d = 3.495$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

$$j = 1 - (k / 3) = 0.93702$$

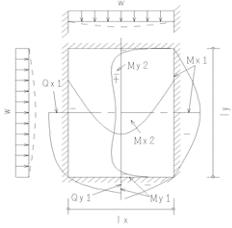
$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 281.21692$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 10864.18790$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

Type i

Analysis of Bottom Slab [Calculation of M and Q]



①Dimensional Conditions

$$l_x = 1.200 \text{ m}$$

$$l_y = 2.100 \text{ m}$$

$$B \times D = 100 \times 35 \text{ cm}$$

②Load Conditions

$$w = 84.400 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 84.40 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.8$$

$$\alpha \text{ for } M_{x2} = 0.038$$

$$\alpha \text{ for } M_{x1} = 0.081$$

$$\alpha \text{ for } Q_{x1} = 0.520$$

Load	Mx2 (kN·m) for top bars	Mx1 (kN·m) for bottom bars	Q(kN)
w	4.62	9.85	52.67

4

Type i

Analysis of Bottom Slab [Stress Intensity Calculation]

FOR TOP 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



$$\text{Bending Moment } M = 4.62 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 52.67 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 35.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 25.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.625 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 16.093 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.231 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00503 \quad = 6.474$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.25895$$

$$j = 1 - (k/3)$$

$$= 0.91368$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 62.48486$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 1609.31355$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 23.05835$$

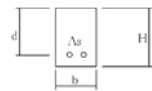
5

[Stress Intensity Calculation]

FOR BOTTOM 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



$$\text{Bending Moment } M = 9.85 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 52.67 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 35.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 25.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.332 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 34.311 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.231 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00503 \quad = 6.474$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.25895$$

$$j = 1 - (k/3)$$

$$= 0.91368$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 133.21989$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 3431.11223$$

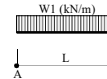
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 23.05835$$

6

Type i

Analysis of Side Slab Slab (Vd1) [Calculation of M and Q]



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 35 \text{ cm}$$

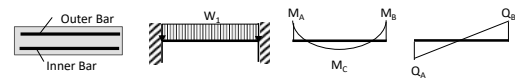
②Load Conditions

$$W1 = 72.993 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 72.99 \text{ kN/m}$$

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



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Type i

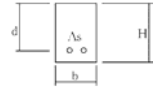
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.185	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	30.514	N/mm ²	○
Shearing Stress of Concrete	τ =	0.140	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2589536 \\
 j &= 1 - (k / 3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 118.47779 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3051.4257 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.00925
 \end{aligned}$$

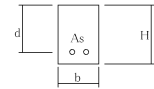
8

【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	0.592	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	15.257	N/mm ²	○
Shearing Stress of Concrete	τ =	0.140	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

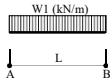
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.25895 \\
 j &= 1 - (k / 3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 59.23889 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 1525.71285 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.00925
 \end{aligned}$$

9

Type i

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 2.100 \text{ m} \\
 B \times D &= 100 \times 35 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 72.993 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 72.99 \text{ kN/m}
 \end{aligned}$$

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



10

Type i

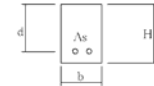
Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	3.629	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	93.459	N/mm ²	○
Shearing Stress of Concrete	τ =	0.280	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2589536 \\
 j &= 1 - (k / 3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 362.87204 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 9345.86204 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 28.01850
 \end{aligned}$$

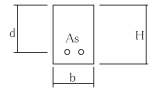
11

【Stress Intensity Calculation】

For Inner 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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	1.815	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	46.747	N/mm ²	○
Shearing Stress of Concrete	τ =	0.280	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.25895 \\
 j &= 1 - (k/3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 1.8150364 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 46.7467270 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 0.2801850
 \end{aligned}$$

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【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	

$$A_w = \frac{1.15 \cdot S_h \cdot s}{\sigma_{sa} \cdot d}$$

$$S_h = Q - S_{ca}$$

$$S_{ca} = b \cdot d \cdot \tau_a$$

where,

Sca : Shear force borne by concrete

Sh : Shear force borne by stirrup reinforcement bars

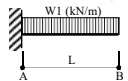
Sca =	82.23	kN
Sh =	-18.23	kN

13

Type i

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



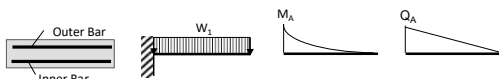
① Dimensional Conditions

L	=	0.450	m
B × D	=	100 × 35	cm

② Load 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



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Type i

Analysis of Side Slab (Vd2 Opening)

【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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	0.836	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	21.527	N/mm ²	○
Shearing Stress of Concrete	τ =	0.074	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

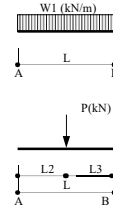
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00503 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2589536 \\
 j &= 1 - (k/3) \\
 &= 0.91368 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 0.8358364 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 21.5271813 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 0.0744241
 \end{aligned}$$

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2.1.2.10 MANHOLE TYPE J

Type j

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.000 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

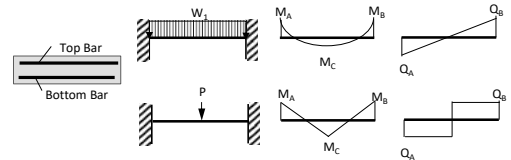
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 1.000 \text{ m} \quad L3 = 1.000 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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



1

Type j

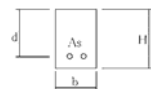
Analysis of Top Slab

【Stress Intensity Calculator】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	4.443	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	124.321	N/mm ² ○
Shearing Stress of Concrete	τ =	0.218	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k / 3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 444.26459$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 12432.11313$$

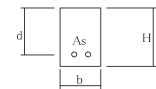
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 21.76556$$

【Stress Intensity Calculator】

FOR BOTTOM BARS

Position of Reinforcing 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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	3.920	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	109.695	N/mm ² ○
Shearing Stress of Concrete	τ =	0.218	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k / 3) = 0.91888$$

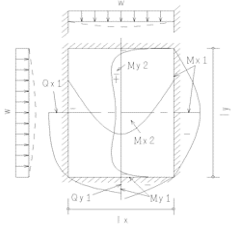
$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 391.99817$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 10969.51158$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 21.76556$$

Type j

Analysis of Bottom Slab [Calculation of M and Q]



①Dimensional Conditions

$$\begin{aligned} l_x &= 2.000 \text{ m} \\ l_y &= 2.700 \text{ m} \\ B \times D &= 100 \times 40 \text{ cm} \end{aligned}$$

②Load Conditions

$$w = 81.840 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 81.84 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$\begin{aligned} l_y/l_x &= 1.4 \\ \alpha \text{ for } M_{x2} &= 0.031 \\ \alpha \text{ for } M_{x1} &= 0.072 \\ \alpha \text{ for } Q_{x1} &= 0.510 \end{aligned}$$

Load	Mx2 (kN·m) for top bars	Mx1 (kN·m) for bottom bars	Q(kN)
w	10.15	23.57	83.48

Type j

Analysis of Bottom Slab [Stress Intensity Calculation]

FOR TOP 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



$$\begin{aligned} \text{Bending Moment } M &= 10.15 \text{ kN} \cdot \text{m} \\ \text{Shear Force } S &= 83.48 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Width of Member } b &= 100.0 \text{ cm} \\ \text{Height of Member } H &= 40.0 \text{ cm} \\ \text{Equivalent Height (Tensile Side) } d &= 30.000 \text{ cm} \\ \text{Total Cross-Sectional (Tensile Side) } A_s &= 12.568 \text{ cm}^2 \\ \text{Modulus of Elasticity } n &= 9.000 \end{aligned}$$

$$\begin{aligned} \text{Compressive Stress of Concrete } \sigma_c &= 1.024 \text{ N/mm}^2 \\ \text{Tensile Stress of Reinforcing Bar } \sigma_s &= 29.256 \text{ N/mm}^2 \\ \text{Shearing Stress of Concrete } \tau &= 0.302 \text{ N/mm}^2 \end{aligned}$$

→ Only concrete doesn't have enough shearing capacity.

$$\begin{aligned} \text{Allowable Compressive Stress of Concrete } \sigma_{ca} &= 8.2 \text{ N/mm}^2 \\ \text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} &= 140.0 \text{ N/mm}^2 \\ \text{Allowable Shear Stress of Concrete } \tau_a &= 0.36 \text{ N/mm}^2 \end{aligned}$$

Single Reinforcing Bar

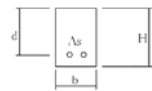
$$\begin{aligned} p &= A_s/(b \cdot d) \\ &= 0.00419 \quad x = k \cdot d \\ k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\ &= 0.23948 \\ j &= 1 - (k/3) \\ &= 0.92017 \\ \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\ &= 102.35728 \\ \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\ &= 2925.55711 \\ \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\ &= 30.24065 \end{aligned}$$

[Stress Intensity Calculation]

FOR BOTTOM 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



$$\begin{aligned} \text{Bending Moment } M &= 23.57 \text{ kN} \cdot \text{m} \\ \text{Shear Force } S &= 83.48 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Width of Member } b &= 100.0 \text{ cm} \\ \text{Height of Member } H &= 40.0 \text{ cm} \\ \text{Equivalent Height (Tensile Side) } d &= 30.000 \text{ cm} \\ \text{Total Cross-Sectional (Tensile Side) } A_s &= 12.568 \text{ cm}^2 \\ \text{Modulus of Elasticity } n &= 9.000 \end{aligned}$$

$$\begin{aligned} \text{Compressive Stress of Concrete } \sigma_c &= 2.377 \text{ N/mm}^2 \\ \text{Tensile Stress of Reinforcing Bar } \sigma_s &= 67.936 \text{ N/mm}^2 \\ \text{Shearing Stress of Concrete } \tau &= 0.302 \text{ N/mm}^2 \end{aligned}$$

→ Only concrete doesn't have enough shearing capacity.

$$\begin{aligned} \text{Allowable Compressive Stress of Concrete } \sigma_{ca} &= 8.2 \text{ N/mm}^2 \\ \text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} &= 140.0 \text{ N/mm}^2 \\ \text{Allowable Shear Stress of Concrete } \tau_a &= 0.36 \text{ N/mm}^2 \end{aligned}$$

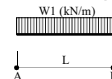
Single Reinforcing Bar

$$\begin{aligned} p &= A_s/(b \cdot d) \\ &= 0.00419 \quad x = k \cdot d \\ k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\ &= 0.23948 \\ j &= 1 - (k/3) \\ &= 0.92017 \\ \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\ &= 237.69076 \\ \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\ &= 6793.63362 \\ \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\ &= 30.24065 \end{aligned}$$

Type j

Analysis of Side Slab Slab (Vd1)

[Calculation of M and Q]



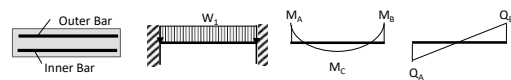
①Dimensional Conditions

$$\begin{aligned} L &= 2.000 \text{ m} \\ B \times D &= 100 \times 40 \text{ cm} \end{aligned}$$

②Load Conditions

$$\begin{aligned} W1 &= 75.600 \text{ kN/m} : \text{Uniform Load} \\ w &= \text{kN/m} : \text{Self Weight} \\ \Sigma W &= 75.60 \text{ kN/m} \end{aligned}$$

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



Type j

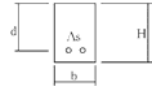
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.541	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	72.635	N/mm ²	○
Shearing Stress of Concrete	τ =	0.221	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 254.12843 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 7263.45215 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 22.09727
 \end{aligned}$$

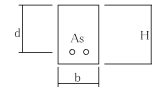
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【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.271	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	36.317	N/mm ²	○
Shearing Stress of Concrete	τ =	0.221	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

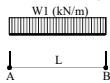
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.23948 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 127.06421 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3631.72607 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 22.09727
 \end{aligned}$$

9

Type j

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 2.700 \text{ m} \\
 B \times D &= 100 \times 40 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 75.600 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 75.60 \text{ kN/m}
 \end{aligned}$$

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



10

Type j

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	4.632	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	132.385	N/mm ²	○
Shearing Stress of Concrete	τ =	0.315	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 463.17932 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 13238.5062 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 31.51577
 \end{aligned}$$

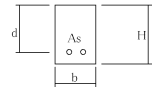
11

【Stress Intensity Calculation】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.316	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00419$$

$$k = \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p = 0.23948$$

$$j = 1 - (k/3) = 0.92017$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 231.64008$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 6620.69428$$

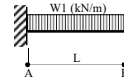
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 31.51577$$

12

Type j

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



①Dimensional Conditions

$$L = 0.850 \text{ m}$$

$$B \times D = 100 \times 45 \text{ cm}$$

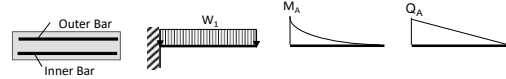
②Load Conditions

$$W1 = 57.600 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 57.60 \text{ kN/m}$$

Load	M(kN·m) for outer bars		Q(kN)
W1+w	20.81		36.00
Total	20.81		36.00



13

Type j

Analysis of Side Slab (Vd2 Opening)

【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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.639	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00359$$

$$k = \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p = 0.2239631$$

$$j = 1 - (k/3) = 0.92535$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 163.94022$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 5112.50665$$

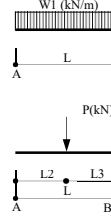
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 11.11554$$

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2.1.2.11 MANHOLE TYPE K

Type k

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad \text{Uniform Load}$$

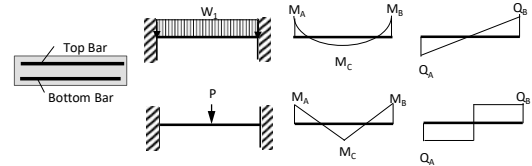
$$P = 52.000 \text{ kN} \quad \text{Point Load}$$

$$L2 = 0.600 \text{ m} \quad L3 = 0.600 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 k

Analysis of Top Slab 【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.050	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	117.823	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 304.98173$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 11782.28829$$

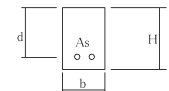
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.812	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	108.642	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00245$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.18895$$

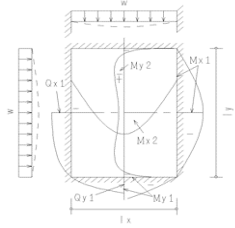
$$j = 1 - (k / 3) = 0.93702$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 281.21692$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 10864.18790$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 18.45994$$

Type k
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 1.200 \text{ m}$$

$$l_y = 1.400 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$w = 96.800 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 96.80 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.2$$

$$\alpha \text{ for } M_{x2} = 0.025$$

$$\alpha \text{ for } M_{x1} = 0.064$$

$$\alpha \text{ for } Q_{x1} = 0.490$$

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 Calculation】

FOR TOP 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



$$\text{Bending Moment } M = 3.49 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 56.92 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.805 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 23.539 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.309 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 80.47517$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j)$$

$$= 2353.93899$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

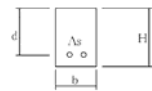
$$= 30.88209$$

【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 8.93 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 56.92 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 2.059 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 60.231 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.309 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 205.91497$$

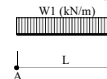
$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j)$$

$$= 6023.11610$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 30.88209$$

Type k
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

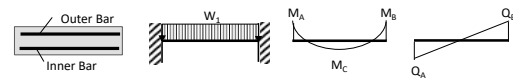
②Load Conditions

$$W1 = 85.408 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 85.41 \text{ kN/m}$$

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

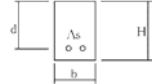
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.364	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 236.35257 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 6913.43114 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 21.15955
 \end{aligned}$$

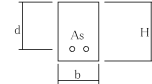
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【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.183	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

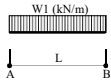
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 118.29158 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3460.08798 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 21.15955
 \end{aligned}$$

9

Type k

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 1.400 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 85.408 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 85.41 \text{ kN/m}
 \end{aligned}$$

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



10

Type k

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	3.217	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 321.67008 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 9409.01116 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 25.49997
 \end{aligned}$$

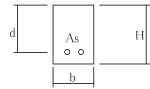
11

【Stress Intensity Calculation】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.610	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	47.079	N/mm ²	○
Shearing Stress of Concrete	τ =	0.255	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

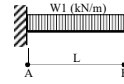
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.23529 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 160.95033 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 4707.87799 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 25.49997
 \end{aligned}$$

12

Type k

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



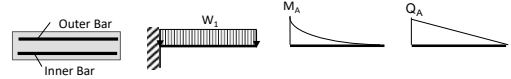
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.250 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 75.658 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 75.66 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars		Q(kN)
W1+w	2.37		8.00
Total	2.37		8.00



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Type k

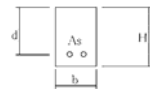
Analysis of Side Slab (Vd2 Opening)

【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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	0.546	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	15.985	N/mm ²	○
Shearing Stress of Concrete	τ =	0.043	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

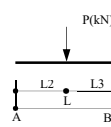
Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2352910 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 54.64933 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 1598.52018 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 4.34042
 \end{aligned}$$

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2.1.2.12 MANHOLE TYPE L

Type 1 Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.400 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

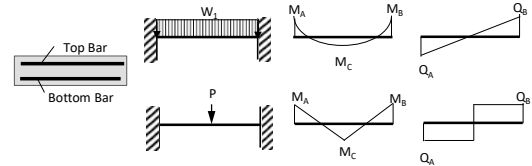
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.700 \text{ m} \quad L3 = 0.700 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.890	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	80.882	N/mm ² ○
Shearing Stress of Concrete	τ =	0.194	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k / 3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 289.03332$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 8088.18654$$

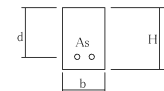
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 19.41253$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	2.634	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	73.715	N/mm ² ○
Shearing Stress of Concrete	τ =	0.194	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

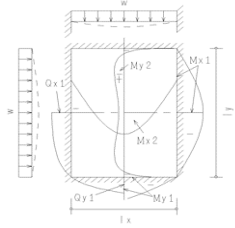
$$j = 1 - (k / 3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 263.42277$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 7371.51178$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 19.41253$$

Type 1
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$\begin{aligned} L_x &= 1.400 \text{ m} \\ L_y &= 2.000 \text{ m} \\ B \times D &= 100 \times 40 \text{ cm} \end{aligned}$$

②Load Conditions

$$w = 100.880 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 100.88 \text{ kN/m}$$

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.

$$\begin{aligned} M &= \alpha \cdot w \cdot L_x^2 \quad (\text{kN} \cdot \text{m}) \\ Q &= \alpha \cdot w \cdot L_x \quad (\text{kN}) \end{aligned}$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	0.019	0.5	0.46
1.4	0.072	0.031	0.059	0.019	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	0.039	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
2.1	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

$$\begin{aligned} l_y/l_x &= 1.5 \\ \alpha \text{ for } M_{x2} &= 0.034 \\ \alpha \text{ for } M_{x1} &= 0.076 \\ \alpha \text{ for } Q_{x1} &= 0.510 \end{aligned}$$

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

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\begin{aligned} \text{Bending Moment } M &= 6.73 \text{ kN} \cdot \text{m} \\ \text{Shear Force } S &= 72.03 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Width of Member } b &= 100.0 \text{ cm} \\ \text{Height of Member } H &= 40.0 \text{ cm} \\ \text{Equivalent Height (Tensile Side) } d &= 30.000 \text{ cm} \\ \text{Total Cross-Sectional (Tensile Side) } A_s &= 8.044 \text{ cm}^2 \\ \text{Modulus of Elasticity } n &= 9.000 \end{aligned}$$

$$\begin{aligned} \text{Compressive Stress of Concrete } \sigma_c &= 0.813 \text{ N/mm}^2 \\ \text{Tensile Stress of Reinforcing Bar } \sigma_s &= 29.847 \text{ N/mm}^2 \\ \text{Shearing Stress of Concrete } \tau &= 0.257 \text{ N/mm}^2 \end{aligned}$$

→ Only concrete doesn't have enough shearing capacity.

$$\begin{aligned} \text{Allowable Compressive Stress of Concrete } \sigma_{ca} &= 8.2 \text{ N/mm}^2 \\ \text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} &= 140.0 \text{ N/mm}^2 \\ \text{Allowable Shear Stress of Concrete } \tau_a &= 0.36 \text{ N/mm}^2 \end{aligned}$$

$$\begin{aligned} \text{Single Reinforcing Bar} \\ p &= A_s / (b \cdot d) \\ &= 0.00268 \\ x &= k \cdot d = 5.906 \\ k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\ &= 0.19688 \\ j &= 1 - (k/3) \\ &= 0.93437 \\ \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\ &= 81.29808 \\ \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\ &= 2984.70443 \\ \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\ &= 25.69637 \end{aligned}$$

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【Stress Intensity Calculation】

FOR BOTTOM 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



$$\begin{aligned} \text{Bending Moment } M &= 15.03 \text{ kN} \cdot \text{m} \\ \text{Shear Force } S &= 72.03 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Width of Member } b &= 100.0 \text{ cm} \\ \text{Height of Member } H &= 40.0 \text{ cm} \\ \text{Equivalent Height (Tensile Side) } d &= 30.000 \text{ cm} \\ \text{Total Cross-Sectional (Tensile Side) } A_s &= 8.044 \text{ cm}^2 \\ \text{Modulus of Elasticity } n &= 9.000 \end{aligned}$$

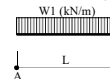
$$\begin{aligned} \text{Compressive Stress of Concrete } \sigma_c &= 1.816 \text{ N/mm}^2 \\ \text{Tensile Stress of Reinforcing Bar } \sigma_s &= 66.657 \text{ N/mm}^2 \\ \text{Shearing Stress of Concrete } \tau &= 0.257 \text{ N/mm}^2 \end{aligned}$$

→ Only concrete doesn't have enough shearing capacity.

$$\begin{aligned} \text{Allowable Compressive Stress of Concrete } \sigma_{ca} &= 8.2 \text{ N/mm}^2 \\ \text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} &= 140.0 \text{ N/mm}^2 \\ \text{Allowable Shear Stress of Concrete } \tau_a &= 0.36 \text{ N/mm}^2 \end{aligned}$$

$$\begin{aligned} \text{Single Reinforcing Bar} \\ p &= A_s / (b \cdot d) \\ &= 0.00268 \\ x &= k \cdot d = 5.906 \\ k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\ &= 0.19688 \\ j &= 1 - (k/3) \\ &= 0.93437 \\ \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\ &= 181.56168 \\ \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\ &= 6665.69205 \\ \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\ &= 25.69637 \end{aligned}$$

Type 1
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



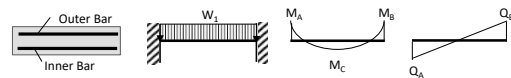
①Dimensional Conditions

$$\begin{aligned} L &= 2.000 \text{ m} \\ B \times D &= 100 \times 40 \text{ cm} \end{aligned}$$

②Load Conditions

$$\begin{aligned} W1 &= 86.706 \text{ kN/m} : \text{Uniform Load} \\ w &= \text{kN/m} : \text{Self Weight} \\ \Sigma W &= 86.71 \text{ kN/m} \end{aligned}$$

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



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Type 1

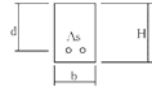
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	3.492	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	128.214	N/mm ²	○
Shearing Stress of Concrete	τ =	0.250	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00268 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.1968801 \\
 j &= 1 - (k/3) \\
 &= 0.93437 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 349.23142 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 12821.3677 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 24.97217
 \end{aligned}$$

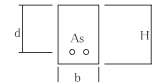
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【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.747	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	64.129	N/mm ²	○
Shearing Stress of Concrete	τ =	0.250	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

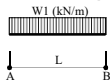
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00268 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.19688 \\
 j &= 1 - (k/3) \\
 &= 0.93437 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 174.67611 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 6412.90134 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 24.97217
 \end{aligned}$$

9

Type 1

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 1.400 \text{ m} \\
 B \times D &= 100 \times 40 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 86.706 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 86.71 \text{ kN/m}
 \end{aligned}$$

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



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Type 1

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.712	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	62.843	N/mm ²	○
Shearing Stress of Concrete	τ =	0.157	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00268 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.1968801 \\
 j &= 1 - (k/3) \\
 &= 0.93437 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 171.17292 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 6284.28852 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 15.69680
 \end{aligned}$$

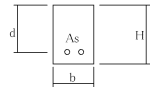
11

【Stress Intensity Calculation】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	0.856	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	31.444	N/mm ²	○
Shearing Stress of Concrete	τ =	0.157	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

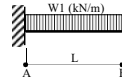
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00268 \\
 k &= \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p \\
 &= 0.19688 \\
 j &= 1 - (k/3) \\
 &= 0.93437 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 85.64686 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3144.36172 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 15.69680
 \end{aligned}$$

12

Type 1

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



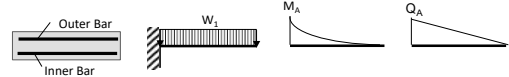
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.250 \text{ m} \\
 B \times D &= 100 \times 40 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 76.956 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 76.96 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars		Q(kN)
W1+w	2.41		4.00
Total	2.41		4.00



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Type 1

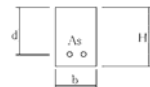
Analysis of Side Slab (Vd2 Opening)

【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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	0.243	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	6.946	N/mm ²	○
Shearing Stress of Concrete	τ =	0.014	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

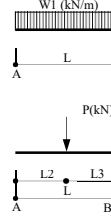
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 24.30355 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 694.63967 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 1.44900
 \end{aligned}$$

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2.1.2.13 MANHOLE TYPE M

Type m

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

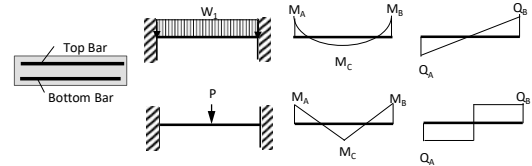
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 1.050 \text{ m} \quad L3 = 1.050 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	4.720	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	132.073	N/mm ² ○
Shearing Stress of Concrete	τ =	0.224	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.24335$$

$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 471.96580$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 13207.29195$$

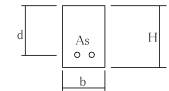
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 22.35382$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	4.145	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	115.984	N/mm ² ○
Shearing Stress of Concrete	τ =	0.224	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.24335$$

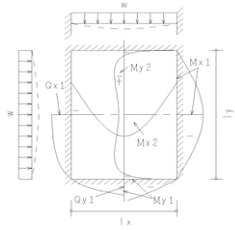
$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 414.47273$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 11598.43025$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 22.35382$$

Type m
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 2.100 \text{ m}$$

$$l_y = 2.600 \text{ m}$$

$$B \times D = 100 \times 45 \text{ cm}$$

②Load Conditions

$$w = 93.040 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 93.04 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.3$$

$$\alpha \text{ for } M_{x2} = 0.029$$

$$\alpha \text{ for } M_{x1} = 0.068$$

$$\alpha \text{ for } Q_{x1} = 0.500$$

Load	Mx2 (kN·m) for top bars	Mx1 (kN·m) for bottom bars	Q(kN)
w	11.90	27.91	97.70

4

Type m
Analysis of Bottom Slab
【Stress Intensity Calculation】

FOR TOP 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



$$\text{Bending Moment } M = 11.90 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 97.70 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 45.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 35.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.937 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 29.235 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.302 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00359 \quad = 7.839$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.22396$$

$$j = 1 - (k/3)$$

$$= 0.92535$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 93.74765$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2923.53816$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 30.16633$$

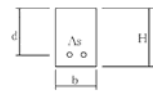
5

【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 27.91 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 97.70 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 45.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 35.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 2.199 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 68.568 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.302 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00359 \quad = 7.839$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.22396$$

$$j = 1 - (k/3)$$

$$= 0.92535$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 219.87369$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

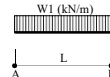
$$= 6856.80253$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 30.16633$$

6

Type m
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

$$B \times D = 100 \times 45 \text{ cm}$$

②Load Conditions

$$W1 = 85.650 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 85.65 \text{ kN/m}$$

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



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Type m

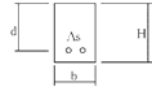
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.480	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	77.339	N/mm ²	○
Shearing Stress of Concrete	τ =	0.219	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00359 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2239631 \\
 j &= 1 - (k/3) \\
 &= 0.92535 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 247.99799 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 7733.86398 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 21.92231
 \end{aligned}$$

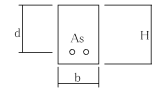
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【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.240	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	38.669	N/mm ²	○
Shearing Stress of Concrete	τ =	0.219	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

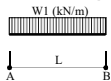
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00359 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.22396 \\
 j &= 1 - (k/3) \\
 &= 0.92535 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 123.99899 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3866.93199 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 21.92231
 \end{aligned}$$

9

Type m

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 2.600 \text{ m} \\
 B \times D &= 100 \times 45 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 85.650 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 85.65 \text{ kN/m}
 \end{aligned}$$

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



10

Type m

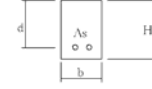
Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	3.801	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	118.538	N/mm ²	○
Shearing Stress of Concrete	τ =	0.287	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00359 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2239631 \\
 j &= 1 - (k/3) \\
 &= 0.92535 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 380.11127 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 11853.8417 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 28.71514
 \end{aligned}$$

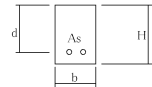
11

【Stress Intensity Calculation】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	1.901	N/mm ² ○
Tensile Stress of Reinforcing Bar	σ _s =	59.281	N/mm ² ○
Shearing Stress of Concrete	τ =	0.287	N/mm ² ○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

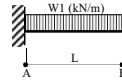
$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00359 & &= 7.839 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.22396 \\
 j &= 1 - (k/3) \\
 &= 0.92535 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 190.09503 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5928.14923 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 28.71514
 \end{aligned}$$

12

Type m

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



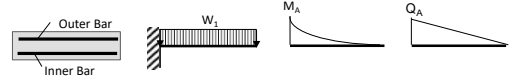
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.800 \text{ m} \\
 B \times D &= 100 \times 45 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 74.775 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 74.78 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars		Q(kN)
W1+w	23.93		43.00
Total	23.93		43.00



13

Type m

Analysis of Side Slab (Vd2 Opening)

【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 =	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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	1.885	N/mm ² ○
Tensile Stress of Reinforcing Bar	σ _s =	58.790	N/mm ² ○
Shearing Stress of Concrete	τ =	0.133	N/mm ² ○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

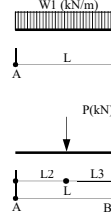
$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00359 & &= 7.839 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2239631 \\
 j &= 1 - (k/3) \\
 &= 0.92535 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 188.51944 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5879.01414 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 13.27689
 \end{aligned}$$

14

2.1.2.14 MANHOLE TYPE N

Type n

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.800 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad \text{Uniform Load}$$

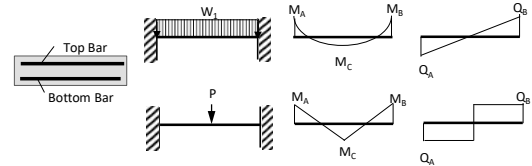
$$P = 52.000 \text{ kN} \quad \text{Point Load}$$

$$L2 = 0.900 \text{ m} \quad L3 = 0.900 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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



1

Type n

Analysis of Top Slab

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.904	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	109.256	N/mm ² ○
Shearing Stress of Concrete	τ =	0.212	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.24335$$

$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 390.43018$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 10925.63354$$

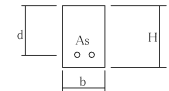
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 21.17730$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.481	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	97.409	N/mm ² ○
Shearing Stress of Concrete	τ =	0.212	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.24335$$

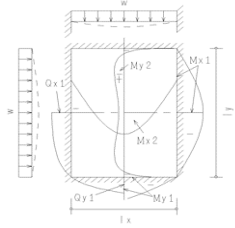
$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 348.09438$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 9740.92629$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 21.17730$$

Type n
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 1.800 \text{ m}$$

$$l_y = 2.100 \text{ m}$$

$$B \times D = 100 \times 40 \text{ cm}$$

②Load Conditions

$$w = 108.200 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 108.20 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.2$$

$$\alpha \text{ for } M_{x2} = 0.025$$

$$\alpha \text{ for } M_{x1} = 0.064$$

$$\alpha \text{ for } Q_{x1} = 0.490$$

Load	Mx2 (kN·m) for top bars	Mx1 (kN·m) for bottom bars	Q(kN)
w	8.77	22.44	95.44

4

Type n
Analysis of Bottom Slab
【Stress Intensity Calculation】

FOR TOP 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



$$\text{Bending Moment } M = 8.77 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 95.44 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 40.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 30.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.884 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 25.278 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.346 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00419 \quad = 7.184$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.23948$$

$$j = 1 - (k/3)$$

$$= 0.92017$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 88.44073$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2527.79664$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 34.57317$$

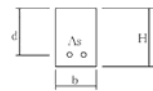
5

【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 22.44 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 95.44 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 40.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 30.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 2.263 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 64.679 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.346 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00419 \quad = 7.184$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.23948$$

$$j = 1 - (k/3)$$

$$= 0.92017$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 226.29532$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

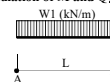
$$= 6467.93120$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 34.57317$$

6

Type n
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

$$B \times D = 100 \times 40 \text{ cm}$$

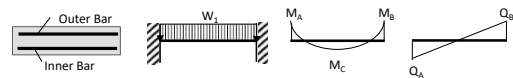
②Load Conditions

$$W1 = 98.973 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 98.97 \text{ kN/m}$$

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



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Type n

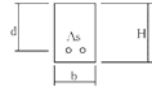
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	3.669	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	104.859	N/mm ²	○
Shearing Stress of Concrete	τ =	0.308	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 366.87271 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 10485.8885 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 30.79127
 \end{aligned}$$

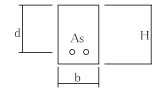
8

【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.834	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	52.429	N/mm ²	○
Shearing Stress of Concrete	τ =	0.308	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

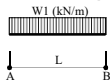
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.23948 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 183.43635 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5242.94423 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 30.79127
 \end{aligned}$$

9

Type n

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 1.800 \text{ m} \\
 B \times D &= 100 \times 40 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 98.973 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ : Self Weight} \\
 \Sigma W &= 98.97 \text{ kN/m}
 \end{aligned}$$

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



10

Type n

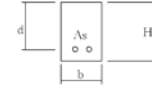
Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.696	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	77.044	N/mm ²	○
Shearing Stress of Concrete	τ =	0.254	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 269.55766 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 7704.44746 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 25.35752
 \end{aligned}$$

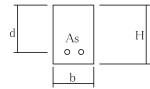
11

【Stress Intensity Calculation】

For Inner 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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	1.348	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	38.537	N/mm ²	○
Shearing Stress of Concrete	τ =	0.254	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.23948 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 134.82925 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 3853.66489 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 25.35752
 \end{aligned}$$

12

【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	

$$A_w = \frac{1.15 \cdot S_h \cdot s}{\sigma_{sa} \cdot d}$$

$$S_h = Q - S_{ca}$$

$$S_{ca} = b \cdot d \cdot \tau_a$$

where,

Sca : Shear force borne by concrete

Sh : Shear force borne by stirrup reinforcement bars

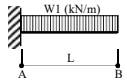
Sca =	99.38	kN
Sh =	-29.38	kN

13

Type n

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



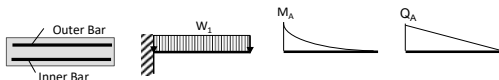
① Dimensional Conditions

L	=	0.450	m
B × D	=	100 × 40	cm

② Load 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



14

Type n

Analysis of Side Slab (Vd2 Opening)

【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 =	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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	0.888	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	25.393	N/mm ²	○
Shearing Stress of Concrete	τ =	0.080	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

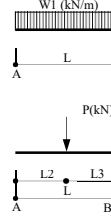
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 88.84411 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 2539.32593 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 7.96951
 \end{aligned}$$

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2.1.2.15 MANHOLE TYPE O

Type o

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

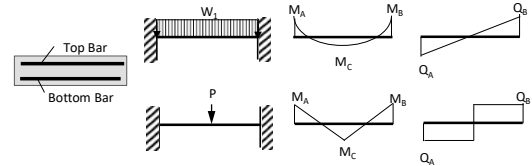
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 1.050 \text{ m} \quad L3 = 1.050 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 o

Analysis of Top Slab

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	4.720	N/mm ² ○
Tensile Stress of Reinforcing Bar	σ _s =	132.073	N/mm ² ○
Shearing Stress of Concrete	τ =	0.224	N/mm ² ○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 471.96580$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 13207.29195$$

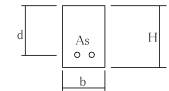
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 22.35382$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	4.145	N/mm ² ○
Tensile Stress of Reinforcing Bar	σ _s =	115.984	N/mm ² ○
Shearing Stress of Concrete	τ =	0.224	N/mm ² ○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 414.47273$$

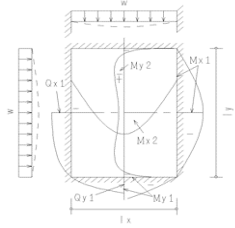
$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 11598.43025$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 22.35382$$

2

3

Type o
Analysis of Bottom Slab
[Calculation of M and Q]



①Dimensional Conditions

$$l_x = 2.100 \text{ m}$$

$$l_y = 2.300 \text{ m}$$

$$B \times D = 100 \times 45 \text{ cm}$$

②Load Conditions

$$w = 103.550 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 103.55 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.1$$

$$\alpha \text{ for } M_{x2} = 0.022$$

$$\alpha \text{ for } M_{x1} = 0.058$$

$$\alpha \text{ for } Q_{x1} = 0.470$$

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 Reinforcing Bar

Diameter	20	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 10.05 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 102.21 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 45.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 35.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.792 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 24.690 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.316 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00359 \quad = 7.839$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.22396$$

$$j = 1 - (k/3)$$

$$= 0.92535$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 79.17344$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2469.03853$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

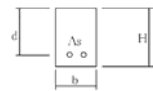
$$= 31.55886$$

【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 26.49 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 102.21 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 45.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 35.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 2.087 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 65.079 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.316 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00359 \quad = 7.839$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.22396$$

$$j = 1 - (k/3)$$

$$= 0.92535$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 208.68700$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

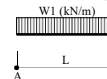
$$= 6507.94336$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 31.55886$$

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)
[Calculation of M and Q]



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

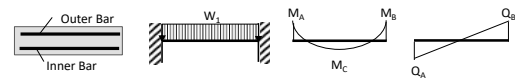
$$B \times D = 100 \times 40 \text{ cm}$$

②Load Conditions

$$W1 = 102.300 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 102.30 \text{ kN/m}$$



Type o

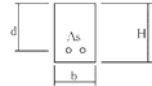
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	3.792	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	108.375	N/mm ²	○
Shearing Stress of Concrete	τ =	0.315	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 379.17575 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 10837.5318 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 31.51577
 \end{aligned}$$

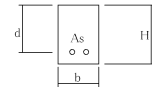
8

【Stress Intensity Calculation】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.896	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	54.188	N/mm ²	○
Shearing Stress of Concrete	τ =	0.315	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\
 &= 0.23948 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 189.58788 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 5418.76589 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 31.51577
 \end{aligned}$$

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【Study on Shear Force Reinforcement】

Diameter	12	mm
Interval of Reinforcing Bar	250	mm

Cross Sectional Area of Shear Reinforcing Bar	A _w =	113.10	mm ²	○
Required Cross Sectional Area of Shear Reinforcing Bar	A _w =	-8.47	mm ²	

$$A_w = \frac{1.15 \cdot S_h \cdot s}{\sigma_{sa} \cdot d}$$

$$S_h = Q - S_{ca}$$

$$S_{ca} = b \cdot d \cdot \tau_a$$

where,

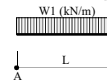
S_{ca} : Shear force beared by concrete
S_h : Shear force beared by stirrup reinforcement bars

S _{ca} =	99.38	kN
S _h =	-12.38	kN

Type o

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

L	=	2.300	m
B × D	=	100 × 40	cm

② Load 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



10

11

Type o

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	4.548	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	129.993	N/mm ²	○
Shearing Stress of Concrete	τ =	0.355	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 454.80921 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 12999.2735 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 35.50053
 \end{aligned}$$

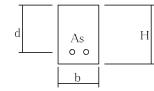
12

【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.274	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	64.996	N/mm ²	○
Shearing Stress of Concrete	τ =	0.355	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

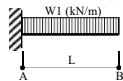
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.23948 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 227.40461 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 6499.63674 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 35.50053
 \end{aligned}$$

13

Type o

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



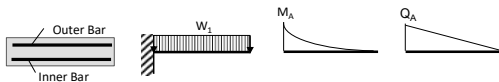
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.650 \text{ m} \\
 B \times D &= 100 \times 50 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 90.300 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 90.30 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars		Q(kN)
W1+w	19.08		37.00
Total	19.08		37.00



14

Type o

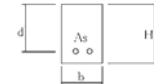
Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.215	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	40.828	N/mm ²	○
Shearing Stress of Concrete	τ =	0.100	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

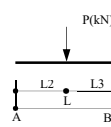
Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00314 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2112124 \\
 j &= 1 - (k/3) \\
 &= 0.92960 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 121.47162 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 4082.7992 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 9.95056
 \end{aligned}$$

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2.1.2.16 MANHOLE TYPE P

Type p Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

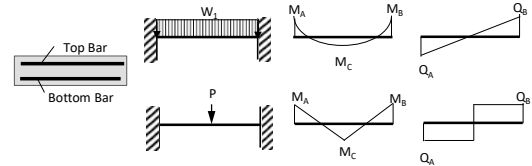
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 1.050 \text{ m} \quad L3 = 1.050 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 p

Analysis of Top Slab

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	4.720	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	132.073	N/mm ² ○
Shearing Stress of Concrete	τ =	0.224	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.24335$$

$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 471.96580$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 13207.29195$$

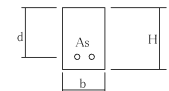
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 22.35382$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	4.145	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	115.984	N/mm ² ○
Shearing Stress of Concrete	τ =	0.224	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.24335$$

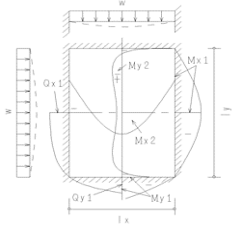
$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 414.47273$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 11598.43025$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 22.35382$$

Type p
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 2.100 \text{ m}$$

$$l_y = 3.000 \text{ m}$$

$$B \times D = 100 \times 50 \text{ cm}$$

②Load Conditions

$$w = 110.460 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 110.46 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	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

$$l_y/l_x = 1.5$$

$$\alpha \text{ for } M_{x2} = 0.034$$

$$\alpha \text{ for } M_{x1} = 0.076$$

$$\alpha \text{ for } Q_{x1} = 0.510$$

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 Calculation】

FOR TOP BARS

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 16.57 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 118.31 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 50.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 40.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 19.636 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.883 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 23.068 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.323 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00491 \quad = 10.254$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.25634$$

$$j = 1 - (k/3)$$

$$= 0.91455$$

$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 88.34955$$

$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2306.75114$$

$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d)$$

$$= 32.34095$$

【Stress Intensity Calculation】

FOR BOTTOM BARS

Position of Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 37.03 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 118.31 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 50.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 40.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 19.636 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.974 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 51.550 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.323 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00491 \quad = 10.254$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.25634$$

$$j = 1 - (k/3)$$

$$= 0.91455$$

$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 197.44017$$

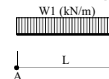
$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 5155.03890$$

$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d)$$

$$= 32.34095$$

Type p
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

$$B \times D = 100 \times 50 \text{ cm}$$

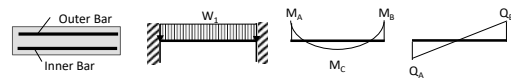
②Load Conditions

$$W1 = 105.050 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 105.05 \text{ kN/m}$$

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

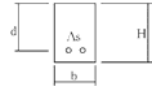
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

Position of Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.059	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00491 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2563418 \\
 j &= 1 - (k/3) \\
 &= 0.91455 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 205.86457 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5374.99466 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 23.23540
 \end{aligned}$$

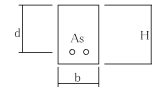
8

【Stress Intensity Calculator】

For Inner Bars

Position of Reinforcing 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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.030	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

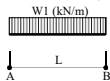
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00491 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.25634 \\
 j &= 1 - (k/3) \\
 &= 0.91455 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 102.95895 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 2688.19339 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 23.23540
 \end{aligned}$$

9

Type p

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



①Dimensional Conditions

$$\begin{aligned}
 L &= 3.000 \text{ m} \\
 B \times D &= 100 \times 50 \text{ cm}
 \end{aligned}$$

②Load Conditions

$$\begin{aligned}
 W1 &= 105.050 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 105.05 \text{ kN/m}
 \end{aligned}$$

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



10

Type p

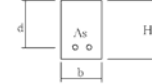
Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

For Outer Bars

Position of Reinforcing 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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	4.201	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	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	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00491 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2563418 \\
 j &= 1 - (k/3) \\
 &= 0.91455 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 420.10022 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 10968.5529 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 35.80985
 \end{aligned}$$

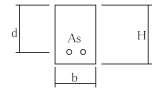
11

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

For Inner Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.101	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	54.850	N/mm ²	○
Shearing Stress of Concrete	τ =	0.358	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

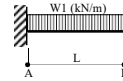
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00491 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.25634 \\
 j &= 1 - (k/3) \\
 &= 0.91455 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 210.07677 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5484.97253 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 35.80985
 \end{aligned}$$

12

Type p

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



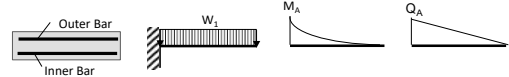
① Dimensional Conditions

$$\begin{aligned}
 L &= 1.050 \text{ m} \\
 B \times D &= 100 \times 60 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 90.800 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 90.80 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars		Q(kN)
W1+w	50.06		69.00
Total	50.06		69.00



13

Type p

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.864	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	55.279	N/mm ²	○
Shearing Stress of Concrete	τ =	0.150	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

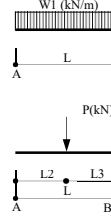
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00393 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2328694 \\
 j &= 1 - (k/3) \\
 &= 0.92238 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 186.44898 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5527.89028 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 14.96135
 \end{aligned}$$

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2.1.2.17 MANHOLE TYPE Q

Type q

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.400 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

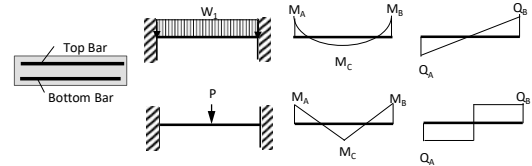
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.700 \text{ m} \quad L3 = 0.700 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 q

Analysis of Top Slab 【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	2.890	N/mm ² ○
Tensile Stress of Reinforcing Bar	σ _s =	80.882	N/mm ² ○
Shearing Stress of Concrete	τ =	0.194	N/mm ² ○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) = 289.03332$$

$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 8088.18654$$

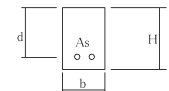
$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d) = 19.41253$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	2.634	N/mm ² ○
Tensile Stress of Reinforcing Bar	σ _s =	73.715	N/mm ² ○
Shearing Stress of Concrete	τ =	0.194	N/mm ² ○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

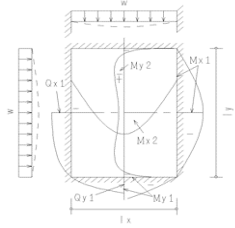
$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) = 263.42277$$

$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 7371.51178$$

$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d) = 19.41253$$

Type q
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 1.400 \text{ m}$$

$$l_y = 2.100 \text{ m}$$

$$B \times D = 100 \times 40 \text{ cm}$$

②Load Conditions

$$w = 135.250 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 135.25 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.5$$

$$\alpha \text{ for } M_{x2} = 0.034$$

$$\alpha \text{ for } M_{x1} = 0.076$$

$$\alpha \text{ for } Q_{x1} = 0.510$$

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 Calculation】

FOR TOP 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



$$\text{Bending Moment } M = 9.02 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 96.57 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 40.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 30.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.910 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 25.999 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.350 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00419 \quad = 7.184$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.23948$$

$$j = 1 - (k/3)$$

$$= 0.92017$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 90.96184$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2599.85470$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 34.98251$$

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【Stress Intensity Calculation】

FOR BOTTOM 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



$$\text{Bending Moment } M = 20.15 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 96.57 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 40.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 30.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 12.568 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 2.032 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 58.079 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.350 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00419 \quad = 7.184$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p}$$

$$= 0.23948$$

$$j = 1 - (k/3)$$

$$= 0.92017$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 203.20190$$

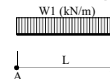
$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 5807.87940$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 34.98251$$

Type q
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

$$B \times D = 100 \times 40 \text{ cm}$$

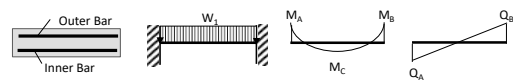
②Load Conditions

$$W1 = 114.000 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 114.00 \text{ kN/m}$$

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



6

7

Type q

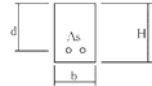
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	4.225	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	120.769	N/mm ²	○
Shearing Stress of Concrete	τ =	0.351	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

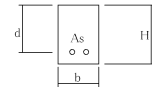
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 422.53894 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 12076.9304 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 35.13828
 \end{aligned}$$

【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	2.113	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	60.385	N/mm ²	○
Shearing Stress of Concrete	τ =	0.351	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

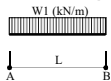
Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.23948 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 211.26947 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 6038.46518 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 35.13828
 \end{aligned}$$

Type q

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 1.400 \text{ m} \\
 B \times D &= 100 \times 40 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 114.000 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 114.00 \text{ kN/m}
 \end{aligned}$$

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



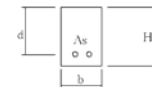
Type q

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σ _c =	1.878	N/mm ²	○
Tensile Stress of Reinforcing Bar	σ _s =	53.669	N/mm ²	○
Shearing Stress of Concrete	τ =	0.206	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

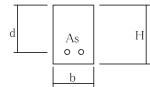
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} \\
 &= 0.2394775 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 187.77267 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 5366.88409 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 20.64827
 \end{aligned}$$

【Stress Intensity Calculation】

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

For Inner Bars



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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	0.939	N/mm ² ○
Tensile Stress of Reinforcing Bar	σ _s =	26.834	N/mm ² ○
Shearing Stress of Concrete	τ =	0.206	N/mm ² ○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

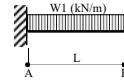
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00419 \\
 k &= \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p \\
 &= 0.23948 \\
 j &= 1 - (k/3) \\
 &= 0.92017 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 93.88634 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 2683.44204 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 20.64827
 \end{aligned}$$

12

Type q

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



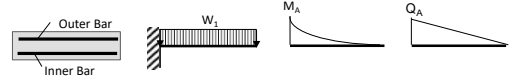
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.250 \text{ m} \\
 B \times D &= 100 \times 45 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 104.250 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 104.25 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars		Q(kN)
W1+w	3.26		3.00
Total	3.26		3.00



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Type q

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	0.257	N/mm ² ○
Tensile Stress of Reinforcing Bar	σ _s =	8.009	N/mm ² ○
Shearing Stress of Concrete	τ =	0.009	N/mm ² ○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

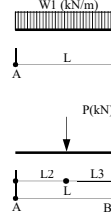
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00359 \\
 k &= \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p \\
 &= 0.2239631 \\
 j &= 1 - (k/3) \\
 &= 0.92535 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 25.68213 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 800.902051 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 0.92629
 \end{aligned}$$

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2.1.2.18 MANHOLE TYPE R

Type r

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

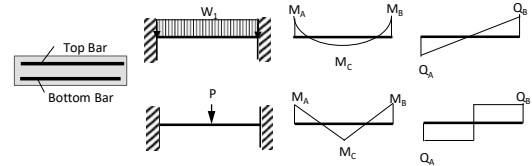
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 1.050 \text{ m} \quad L3 = 1.050 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 r

Analysis of Top Slab 【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	4.720	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	132.073	N/mm ² ○
Shearing Stress of Concrete	τ =	0.224	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.24335$$

$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) = 471.96580$$

$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) = 13207.29195$$

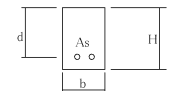
$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d) = 22.35382$$

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR BOTTOM BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	4.145	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	115.984	N/mm ² ○
Shearing Stress of Concrete	τ =	0.224	N/mm ² ○

→ Only concrete doesn'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	ta =	0.36	N/mm ²

Single Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} = 0.24335$$

$$j = 1 - (k/3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) = 414.47273$$

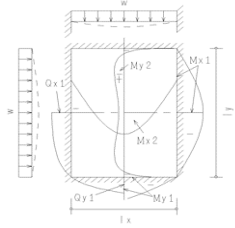
$$\sigma_s = (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) = 11598.43025$$

$$\tau = (S \cdot 10^3) / (b \cdot j \cdot d) = 22.35382$$

2

3

Type r
Analysis of Bottom Slab
【Calculation of M and Q】



①Dimensional Conditions

$$l_x = 2.100 \text{ m}$$

$$l_y = 3.200 \text{ m}$$

$$B \times D = 100 \times 60 \text{ cm}$$

②Load Conditions

$$w = 131.720 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 131.72 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	0.019	0.5	0.46
1.4	0.072	0.031	0.059	0.019	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 1.6$$

$$\alpha \text{ for } M_{x2} = 0.036$$

$$\alpha \text{ for } M_{x1} = 0.078$$

$$\alpha \text{ for } Q_{x1} = 0.520$$

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 Calculation】

FOR TOP BARS

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 20.92 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 143.84 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 60.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 50.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 19.636 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.779 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 23.101 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.312 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00393 \quad x = k \cdot d = 11.643$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.23287$$

$$j = 1 - (k/3) = 0.92238$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 77.91675$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 2310.09718$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 31.18899$$

【Stress Intensity Calculation】

FOR BOTTOM BARS

Position of Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 45.31 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 143.84 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 60.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 50.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 19.636 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.688 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 50.034 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.312 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00393 \quad x = k \cdot d = 11.643$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.23287$$

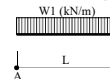
$$j = 1 - (k/3) = 0.92238$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 168.75756$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 5003.37013$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 31.18899$$

Type r
Analysis of Side Slab Slab (Vd1)
【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.100 \text{ m}$$

$$B \times D = 100 \times 60 \text{ cm}$$

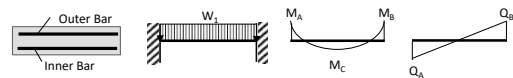
②Load Conditions

$$W1 = 120.050 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 120.05 \text{ kN/m}$$

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

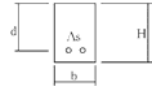
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

Position of Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

For Outer Bars



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)	As =	19.636	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	1.643	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	48.720	N/mm ²	○
Shearing Stress of Concrete	τ =	0.197	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00393 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2328694 \\
 j &= 1 - (k/3) \\
 &= 0.92238 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 164.32539 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 4871.96403 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 19.73163
 \end{aligned}$$

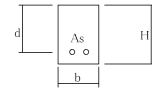
8

【Stress Intensity Calculator】

For Inner Bars

Position of Reinforcing 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)	As =	19.636	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	0.822	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	24.360	N/mm ²	○
Shearing Stress of Concrete	τ =	0.197	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

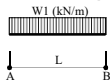
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00393 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.23287 \\
 j &= 1 - (k/3) \\
 &= 0.92238 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 82.16269 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 2435.98201 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 19.73163
 \end{aligned}$$

9

Type r

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q】



① Dimensional Conditions

$$\begin{aligned}
 L &= 3.200 \text{ m} \\
 B \times D &= 100 \times 60 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 120.050 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 120.05 \text{ kN/m}
 \end{aligned}$$

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



10

Type r

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculator】

Position of Reinforcing 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)	As =	19.636	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	3.816	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	113.131	N/mm ²	○
Shearing Stress of Concrete	τ =	0.340	N/mm ²	○

→ Only concrete doesn'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 Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00393 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.2328694 \\
 j &= 1 - (k/3) \\
 &= 0.92238 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 381.57607 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 11313.0715 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 34.04248
 \end{aligned}$$

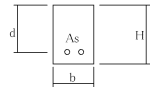
11

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

For Inner Bars



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)	As =	19.636	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	1.908	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	56.571	N/mm ² ○
Shearing Stress of Concrete	τ =	0.340	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

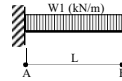
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00393 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.23287 \\
 j &= 1 - (k/3) \\
 &= 0.92238 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 190.80666 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 5657.08788 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 34.04248
 \end{aligned}$$

12

Type r

Analysis of Side Slab (Vd2 Opening)

【Calculation of M and Q】



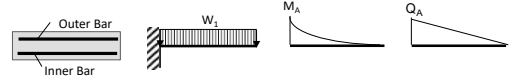
① Dimensional Conditions

$$\begin{aligned}
 L &= 0.700 \text{ m} \\
 B \times D &= 100 \times 60 \text{ cm}
 \end{aligned}$$

② Load Conditions

$$\begin{aligned}
 W1 &= 103.550 \text{ kN/m} : \text{Uniform Load} \\
 w &= \text{ kN/m} : \text{Self Weight} \\
 \Sigma W &= 103.55 \text{ kN/m}
 \end{aligned}$$

Load	M(kN·m) for outer bars		Q(kN)
W1+w	25.37		42.00
Total	25.37		42.00



13

Type r

Analysis of Side Slab (Vd2 Opening)

【Stress Intensity Calculation】

Position of Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm

For Outer Bars



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)	As =	19.636	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	0.945	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	28.015	N/mm ² ○
Shearing Stress of Concrete	τ =	0.091	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

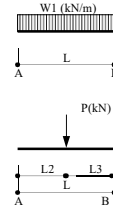
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00393 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} - n \cdot p \\
 &= 0.2328694 \\
 j &= 1 - (k/3) \\
 &= 0.92238 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 94.49082 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 2801.48974 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 9.10691
 \end{aligned}$$

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2.1.2.19 MANHOLE TYPE S

Type S

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

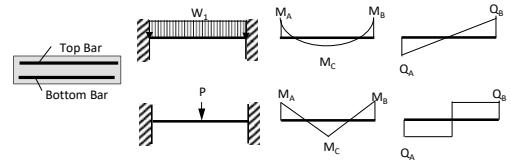
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.600 \text{ m} \quad L3 = 0.600 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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】

Position of Reinforcing Bar

Diameter	12	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	3.050	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	117.823	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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

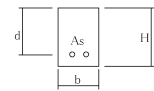
$$\begin{aligned} \text{Single Reinforcing Bar} \\ p &= A_s / (b \cdot d) \\ &= 0.00245 \\ k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\ &= 0.18895 \\ j &= 1 - (k / 3) \\ &= 0.93702 \\ \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\ &= 304.98173 \\ \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\ &= 11782.28829 \\ \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\ &= 18.45994 \end{aligned}$$

【Stress Intensity Calculation】

FOR BOTTOM BARS

Position of Reinforcing 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)	As =	4.524	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	2.812	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	108.642	N/mm ² ○
Shearing Stress of Concrete	τ =	0.185	N/mm ² ○

→ Only concrete doesn'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

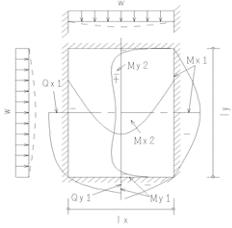
$$\begin{aligned} \text{Single Reinforcing Bar} \\ p &= A_s / (b \cdot d) \\ &= 0.00245 \\ k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\ &= 0.18895 \\ j &= 1 - (k / 3) \\ &= 0.93702 \\ \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\ &= 281.21692 \\ \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\ &= 10864.18790 \\ \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\ &= 18.45994 \end{aligned}$$

2

3

Type s

Analysis of Bottom Slab [Calculation of M and Q]



①Dimensional Conditions

$$l_x = 1.200 \text{ m}$$

$$l_y = 2.600 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$w = 56.490 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 56.49 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	0.083	0.042	0.057	0.01	0.51	0.46
2.2	0.083	0.042	0.057	0.01	0.51	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

$$l_y/l_x = 2.2$$

$$\alpha \text{ for } M_{x2} = 0.040$$

$$\alpha \text{ for } M_{x1} = 0.083$$

$$\alpha \text{ for } Q_{x1} = 0.520$$

Load	Mx2 (kN·m) for top bars	Mx1 (kN·m) for bottom bars	Q(kN)
w	3.26	6.76	35.25

4

Type s

Analysis of Bottom Slab [Stress Intensity Calculation]

FOR TOP 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



$$\text{Bending Moment } M = 3.26 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 35.25 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.752 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 21.988 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.191 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 75.17165$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 2198.80834$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 19.12498$$

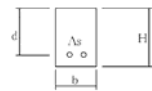
5

[Stress Intensity Calculation]

FOR BOTTOM 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



$$\text{Bending Moment } M = 6.76 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 35.25 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 30.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 20.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 8.044 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.559 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 45.595 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.191 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00402 \quad = 4.706$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.23529$$

$$j = 1 - (k/3)$$

$$= 0.92157$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 155.87740$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 4559.49215$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 19.12498$$

6

Type s

Analysis of Side Slab Slab (Vd1) [Calculation of M and Q]

①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 30 \text{ cm}$$

②Load Conditions

$$W1 = 40.650 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 40.65 \text{ kN/m}$$

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



7

Type s

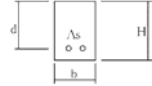
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	1.125	N/mm ²
Tensile Stress of Reinforcing Bar	σ _s =	32.915	N/mm ²
Shearing Stress of Concrete	τ =	0.103	N/mm ²

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\
 &= 0.2352910 \\
 j &= 1 - (k / 3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 112.52688 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 3291.4677 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 10.30850
 \end{aligned}$$

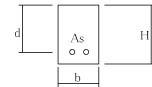
8

【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	0.563	N/mm ²
Tensile Stress of Reinforcing Bar	σ _s =	16.457	N/mm ²
Shearing Stress of Concrete	τ =	0.103	N/mm ²

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

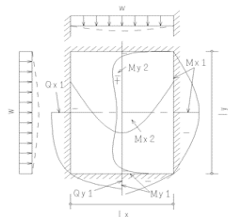
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00402 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\
 &= 0.2352910 \\
 j &= 1 - (k / 3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 56.26344 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 1645.73385 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 10.30850
 \end{aligned}$$

9

Type s

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q by Uniform Load】



①Dimensional Conditions

$$\begin{aligned}
 l_x &= 2.600 \text{ m} \\
 l_y &= 2.750 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

②Load Conditions

$$w = 30.900 \text{ kN/m : Uniform Load}$$

$$\Sigma W = 30.90 \text{ kN/m}$$

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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

$$\begin{aligned}
 l_y / l_x &= 1.1 \\
 \alpha \text{ for } M_{x1} &= 0.058 \\
 \alpha \text{ for } M_{y1} &= 0.054 \\
 \alpha \text{ for } Q_{y1} &= 0.450
 \end{aligned}$$

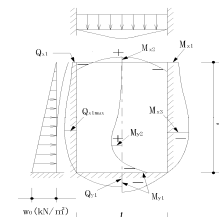
Load	Mx1 (kN·m)	My1 (kN·m)	Q(kN)
Uniform	12.12	11.28	36.16

10

Type s

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

$$\begin{aligned}
 l_x &= 2.600 \text{ m} \\
 l_y &= 2.750 \text{ m} \\
 B \times D &= 100 \times 30 \text{ cm}
 \end{aligned}$$

②Load Conditions

$$p = 9.750 \text{ kN/m : Triangle Load}$$

$$(= 40.65 - 30.90)$$

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

ly/lx	Mx1	Mx1max	My1	Qx1	Qy1
1.0	0.027	0.034	0.033	0.33	0.34
1.1	0.03	0.036	0.036	0.36	0.37
1.2	0.034	0.038	0.038	0.38	0.39
1.3	0.037	0.04	0.04	0.4	0.41
1.4	0.04	0.042	0.042	0.42	0.43
1.5	0.042	0.043	0.043	0.43	0.44
1.6	0.044	0.044	0.044	0.44	0.45
1.7	0.046	0.044	0.044	0.44	0.45
1.8	0.047	0.045	0.045	0.45	0.46
1.9	0.048	0.045	0.045	0.45	0.46
2.0	0.05	0.046	0.046	0.46	0.47
ly/lx	Mx1	Mx1max	My1	Qx1	Qy1

$$\begin{aligned}
 l_y / l_x &= 1.1 \\
 \alpha \text{ for } M_{x1\text{max}} &= 0.030 \\
 \alpha \text{ for } M_{y1} &= 0.036 \\
 \alpha \text{ for } Q_{y1} &= 0.340
 \end{aligned}$$

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

11

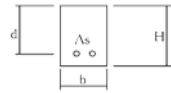
Type s

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	$\sigma_c =$	3.251	N/mm ²	○
Tensile Stress of Reinforcing Bar	$\sigma_s =$	95.102	N/mm ²	○
Shearing Stress of Concrete	$\tau =$	0.243	N/mm ²	○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	$\sigma_{ca} =$	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	$\sigma_{sa} =$	140.0	N/mm ²
Allowable Shear Stress of Concrete	$\tau_a =$	0.36	N/mm ²

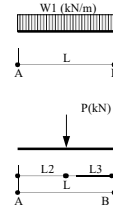
Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00402 & &= 4.706 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.23529 \\
 j &= 1 - (k/3) \\
 &= 0.92157 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 325.12890 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 9510.18332 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 24.29550
 \end{aligned}$$

2.1.2.20 MANHOLE TYPE T

Type t

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 2.000 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

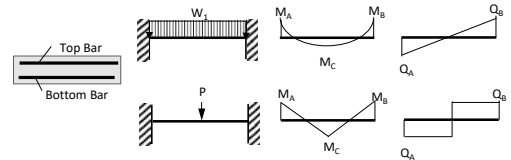
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 1.000 \text{ m} \quad L3 = 1.000 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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



1

Type t

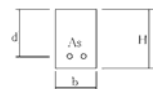
Analysis of Top Slab

【Stress Intensity Calculator】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σc =	4.443	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	124.321	N/mm ² ○
Shearing Stress of Concrete	τ =	0.218	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k / 3) = 0.91888$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 444.26459$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 12432.11313$$

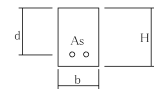
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 21.76556$$

【Stress Intensity Calculator】

FOR BOTTOM BARS

Position of Reinforcing 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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	3.920	N/mm ² ○
Tensile Stress of Reinforcing Bar	σs =	109.695	N/mm ² ○
Shearing Stress of Concrete	τ =	0.218	N/mm ² ○

→ Only concrete doesn'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 Reinforcing Bar

$$p = As / (b \cdot d) = 0.00435$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p = 0.24335$$

$$j = 1 - (k / 3) = 0.91888$$

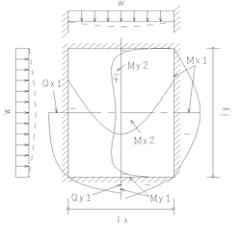
$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 391.99817$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 10969.51158$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 21.76556$$

Type t

Analysis of Bottom Slab [Calculation of M and Q]



①Dimensional Conditions

$$l_x = 2.000 \text{ m}$$

$$l_y = 4.150 \text{ m}$$

$$B \times D = 100 \times 55 \text{ cm}$$

②Load Conditions

$$w = 93.480 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 93.48 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

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	0.018	0.47	0.45
1.2	0.064	0.025	0.056	0.018	0.49	0.45
1.3	0.068	0.029	0.058	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	0.039	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
2.1	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

$$l_y/l_x = 2.1$$

$$\alpha \text{ for } M_{x2} = 0.040$$

$$\alpha \text{ for } M_{x1} = 0.083$$

$$\alpha \text{ for } Q_{x1} = 0.520$$

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 Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 14.96 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 97.22 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 55.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 45.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 19.636 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 0.660 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 18.427 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.235 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00436 \quad = 10.968$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.24372$$

$$j = 1 - (k/3)$$

$$= 0.91876$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 65.98392$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 1842.74178$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 23.51481$$

4

5

[Stress Intensity Calculation]

FOR BOTTOM BARS

Position of Reinforcing Bar

Diameter	25	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	10.0	cm



$$\text{Bending Moment } M = 31.04 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 97.22 \text{ kN}$$

$$\text{Width of Member } b = 100.0 \text{ cm}$$

$$\text{Height of Member } H = 55.0 \text{ cm}$$

$$\text{Equivalent Height (Tensile Side) } d = 45.000 \text{ cm}$$

$$\text{Total Cross-Sectional (Tensile Side) } A_s = 19.636 \text{ cm}^2$$

$$\text{Modulus of Elasticity } n = 9.000$$

$$\text{Compressive Stress of Concrete } \sigma_c = 1.369 \text{ N/mm}^2$$

$$\text{Tensile Stress of Reinforcing Bar } \sigma_s = 38.234 \text{ N/mm}^2$$

$$\text{Shearing Stress of Concrete } \tau = 0.235 \text{ N/mm}^2$$

→ Only concrete doesn't have enough shearing capacity.

$$\text{Allowable Compressive Stress of Concrete } \sigma_{ca} = 8.2 \text{ N/mm}^2$$

$$\text{Allowable Tensile Stress of Reinforcing Bar } \sigma_{sa} = 140.0 \text{ N/mm}^2$$

$$\text{Allowable Shear Stress of Concrete } \tau_a = 0.36 \text{ N/mm}^2$$

Single Reinforcing Bar

$$p = A_s / (b \cdot d) \quad x = k \cdot d$$

$$= 0.00436 \quad = 10.968$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p$$

$$= 0.24372$$

$$j = 1 - (k/3)$$

$$= 0.91876$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j)$$

$$= 136.90781$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j)$$

$$= 3823.44284$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d)$$

$$= 23.51481$$

Type t

Analysis of Side Slab Slab (VdI) [Calculation of M and Q]

①Dimensional Conditions

$$L = 2.000 \text{ m}$$

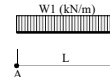
$$B \times D = 100 \times 55 \text{ cm}$$

②Load Conditions

$$W1 = 87.850 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 87.85 \text{ kN/m}$$



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



6

7

Type t

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	1.546	N/mm ²
Tensile Stress of Reinforcing Bar	σ _s =	55.498	N/mm ²
Shearing Stress of Concrete	τ =	0.152	N/mm ²

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00279$$

$$x = k \cdot d = 9.022$$

$$k = \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} = 0.2004827$$

$$j = 1 - (k/3) = 0.93317$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 154.62704$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 5549.81865$$

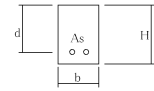
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 15.24072$$

【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	0.773	N/mm ²
Tensile Stress of Reinforcing Bar	σ _s =	27.759	N/mm ²
Shearing Stress of Concrete	τ =	0.152	N/mm ²

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00279$$

$$x = k \cdot d = 9.022$$

$$k = \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} = 0.20048$$

$$j = 1 - (k/3) = 0.93317$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 77.33992$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) = 2775.85672$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 15.24072$$

Type t

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q by Uniform Load】

①Dimensional Conditions

l _x	=	4.150	m
l _y	=	5.750	m
B × D	=	100 × 55	cm

②Load Conditions

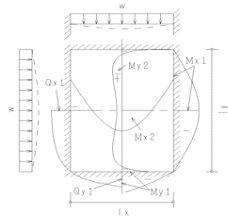
w	=	6.250	kN/m : Uniform Load
ΣW	=	6.25	kN/m

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$



l _y /l _x	M _{x1}	M _{x2}	M _{y1}	M _{y2max}	Q _{x1}	Q _{y1}
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
2.1	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

l _y /l _x	=	1.4
α for M _{x1}	=	0.072
α for M _{y1}	=	0.056
α for Q _{y1}	=	0.460

Load	M _{x1} (kN·m)	M _{y1} (kN·m)	Q (kN)
Uniform	7.76	6.03	11.94

Type t

Analysis of Bottom Slab

【Calculation of M and Q】

①Dimensional Conditions

l _x	=	4.150	m
l _y	=	5.750	m
B × D	=	100 × 55	cm

②Load Conditions

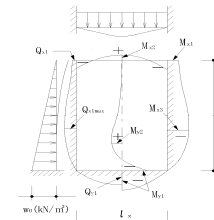
p	=	81.600	kN/m : Triangle Load
(=)	=	87.85 - 6.25	

③Calculation of M and Q for 4-sided (2-way) slab

M and Q are obtained by following equations,

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$



l _y /l _x	M _{x1}	M _{x1max}	M _{y1}	Q _{x1}	Q _{y1}
1.0	0.027	0.034	0.33	0.34	0.34
1.1	0.03	0.036	0.34	0.36	0.36
1.2	0.034	0.038	0.36	0.37	0.37
1.3	0.037	0.04	0.37	0.38	0.38
1.4	0.04	0.042	0.38	0.39	0.39
1.5	0.042	0.043	0.38	0.39	0.39
1.6	0.044	0.044	0.38	0.39	0.39
1.7	0.046	0.044	0.39	0.4	0.4
1.8	0.047	0.045	0.39	0.4	0.4
1.9	0.048	0.045	0.39	0.4	0.4
2.0	0.05	0.046	0.4	0.4	0.4
l _y /l _x	M _{x1}	M _{x1max}	M _{y1}	Q _{x1}	Q _{y1}

l _y /l _x	=	1.4
α for M _{x1max}	=	0.040
α for M _{y1}	=	0.042
α for Q _{y1}	=	0.370

Load	M _{x1max} (kN·m)	M _{y1} (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

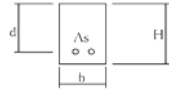
Type t

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】

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 =	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)	As =	12.568	cm ²	
Modulus of Elasticity	n =	9.000		
Compressive Stress of Concrete	σc =	3.435	N/mm ²	○
Tensile Stress of Reinforcing 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 Reinforcing Bar	σsa =	140.0	N/mm ²	
Allowable Shear Stress of Concrete	ta =	0.36	N/mm ²	

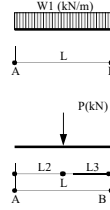
Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00279 & &= 9.022 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.20048 \\
 j &= 1 - (k/3) \\
 &= 0.93317 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 343.46314 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 12327.45652 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 32.68183
 \end{aligned}$$

2.1.2.21 MANHOLE TYPE U

Type u

Analysis of Top Slab 【Calculation of M and Q】



①Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 25 \text{ cm}$$

②Load Conditions

$$W1 = 6.000 \text{ kN/m} \quad : \text{Uniform Load}$$

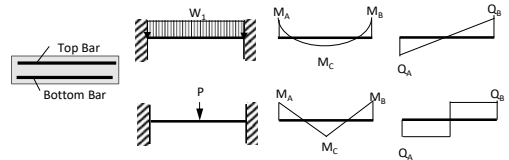
$$P = 52.000 \text{ kN} \quad : \text{Point Load}$$

$$L2 = 0.600 \text{ m} \quad L3 = 0.600 \text{ m}$$

$$w = 6.00 \text{ kN/m} \quad : \text{Self Weight}$$

$$\Sigma W = 12.00 \text{ kN/m}$$

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 Calculator】

Position of Reinforcing Bar

Diameter	16	mm
Interval of Reinforcing Bar	250	mm
Number of Reinforcing Bar	4.0	per meter
Cover Concrete	6.5	cm

FOR TOP BARS



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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	2.415	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	67.572	N/mm ²	○
Shearing Stress of Concrete	τ =	0.188	N/mm ²	○

→ Only concrete doesn'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

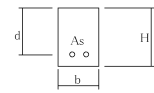
$$\begin{aligned} \text{Single Reinforcing Bar} \\ p &= A_s / (b \cdot d) \\ &= 0.00435 \\ k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\ &= 0.24335 \\ j &= 1 - (k / 3) \\ &= 0.91888 \\ \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\ &= 241.47087 \\ \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\ &= 6757.21914 \\ \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\ &= 18.82427 \end{aligned}$$

【Stress Intensity Calculator】

FOR BOTTOM BARS

Position of Reinforcing 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)	As =	8.044	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	σc =	2.227	N/mm ²	○
Tensile Stress of Reinforcing Bar	σs =	62.307	N/mm ²	○
Shearing Stress of Concrete	τ =	0.188	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

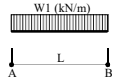
Allowable Compressive Stress of Concrete	σca =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σsa =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τa =	0.36	N/mm ²

$$\begin{aligned} \text{Single Reinforcing Bar} \\ p &= A_s / (b \cdot d) \\ &= 0.00435 \\ x &= k \cdot d \\ &= 4.502 \\ k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) / 2} \cdot n \cdot p \\ &= 0.24335 \\ j &= 1 - (k / 3) \\ &= 0.91888 \\ \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\ &= 222.65496 \\ \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\ &= 6230.68258 \\ \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\ &= 18.82427 \end{aligned}$$

Type u

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



① Dimensional Conditions

$$L = 1.200 \text{ m}$$

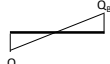
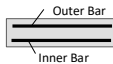
$$B \times D = 100 \times 55 \text{ cm}$$

② Load Conditions

$$W1 = 95.210 \text{ kN/m} : \text{Uniform Load}$$

$$\Sigma W = 95.21 \text{ kN/m}$$

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



4

Type u

Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculation】

For Top 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



$$\text{Bending Moment } M = 11.43 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 31.00 \text{ kN}$$

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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	$\sigma_c =$	0.603	N/mm ²	○
Tensile Stress of Reinforcing Bar	$\sigma_s =$	21.657	N/mm ²	○
Shearing Stress of Concrete	$\tau =$	0.074	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	$\sigma_{ca} =$	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	$\sigma_{sa} =$	140.0	N/mm ²
Allowable Shear Stress of Concrete	$\tau_a =$	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00279$$

$$x = k \cdot d = 9.022$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} = 0.2004827$$

$$j = 1 - (k/3) = 0.93317$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 60.34097$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 2165.73667$$

$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 7.38223$$

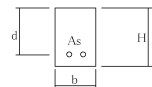
5

【Stress Intensity Calculation】

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

For Bottom Bars



$$\text{Bending Moment } M = 5.72 \text{ kN} \cdot \text{m}$$

$$\text{Shear Force } S = 31.00 \text{ kN}$$

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)	As =	12.568	cm ²
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	$\sigma_c =$	0.302	N/mm ²	○
Tensile Stress of Reinforcing Bar	$\sigma_s =$	10.838	N/mm ²	○
Shearing Stress of Concrete	$\tau =$	0.074	N/mm ²	○

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	$\sigma_{ca} =$	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	$\sigma_{sa} =$	140.0	N/mm ²
Allowable Shear Stress of Concrete	$\tau_a =$	0.36	N/mm ²

Single Reinforcing Bar

$$p = A_s / (b \cdot d) = 0.00279$$

$$x = k \cdot d = 9.022$$

$$k = \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) \cdot n \cdot p} = 0.20048$$

$$j = 1 - (k/3) = 0.93317$$

$$\sigma_c = (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) = 30.19688$$

$$\sigma_s = (M \cdot 10^{-5}) / (b \cdot d^2 \cdot p \cdot j) = 1083.81573$$

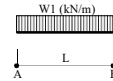
$$\tau = (S \cdot 10^{-3}) / (b \cdot j \cdot d) = 7.38223$$

6

Type u

Analysis of Side Slab Slab (Vd1)

【Calculation of M and Q】



① Dimensional Conditions

$$L = 1.200 \text{ m}$$

$$B \times D = 100 \times 55 \text{ cm}$$

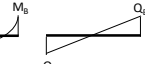
② Load Conditions

$$W1 = 71.750 \text{ kN/m} : \text{Uniform Load}$$

$$w = \text{ kN/m} : \text{Self Weight}$$

$$\Sigma W = 71.75 \text{ kN/m}$$

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



7

Type u

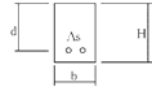
Analysis of Side Slab Slab (Vd1)

【Stress Intensity Calculator】

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

For Outer Bars



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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	0.455	N/mm ²
Tensile Stress of Reinforcing Bar	σ _s =	16.314	N/mm ²
Shearing Stress of Concrete	τ =	0.057	N/mm ²

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00279 \\
 k &= \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p \\
 &= 0.2004827 \\
 j &= 1 - (k/3) \\
 &= 0.93317 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 45.45370 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 1631.40794 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 5.71527
 \end{aligned}$$

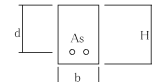
8

【Stress Intensity Calculator】

For Inner 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 =	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
Modulus of Elasticity	n =	9.000	
Compressive Stress of Concrete	σ _c =	0.228	N/mm ²
Tensile Stress of Reinforcing Bar	σ _s =	8.167	N/mm ²
Shearing Stress of Concrete	τ =	0.057	N/mm ²

→ Only concrete doesn't have enough shearing capacity.

Allowable Compressive Stress of Concrete	σ _{ca} =	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	σ _{sa} =	140.0	N/mm ²
Allowable Shear Stress of Concrete	τ _a =	0.36	N/mm ²

Single Reinforcing Bar

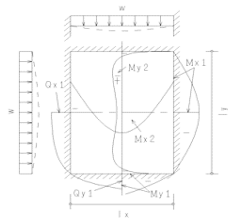
$$\begin{aligned}
 p &= A_s / (b \cdot d) \\
 &= 0.00279 \\
 k &= \sqrt{2 \cdot n \cdot p + (n \cdot p)^2} - n \cdot p \\
 &= 0.20048 \\
 j &= 1 - (k/3) \\
 &= 0.93317 \\
 \sigma_c &= (2 \cdot M \cdot 10^{-5}) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 22.75324 \\
 \sigma_s &= (M \cdot 10^{-5}) / (b \cdot d^2 \cdot 2 \cdot p \cdot j) \\
 &= 816.65136 \\
 \tau &= (S \cdot 10^{-3}) / (b \cdot j \cdot d) \\
 &= 5.71527
 \end{aligned}$$

9

Type u

Analysis of Side Slab Slab (Vd2)

【Calculation of M and Q by Uniform Load】



①Dimensional Conditions

l _x	=	4.750	m
l _y	=	5.850	m
B × D	=	100 × 55	cm

②Load Conditions

w = 6.250 kN/m : Uniform Load

$$\Sigma W = 6.25 \text{ kN/m}$$

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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

l _y /l _x	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

l _y /l _x	=	1.3
α for Mx1	=	0.068
α for My1	=	0.056
α for Qy1	=	0.460

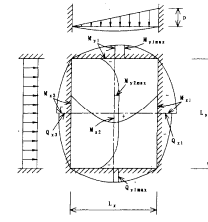
Load	Mx1 (kN·m)	My1 (kN·m)	Q(kN)
Uniform	9.59	7.90	13.66

10

Type u

Analysis of Bottom Slab

【Calculation of M and Q】



①Dimensional Conditions

l _x	=	4.750	m
l _y	=	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.

$$M = \alpha \cdot w \cdot l_x^2 \quad (\text{kN} \cdot \text{m})$$

$$Q = \alpha \cdot w \cdot l_x \quad (\text{kN})$$

l _y /l _x	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		

l _y /l _x	=	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

11

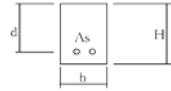
Type u

Analysis of Side Slab Slab (Vd2)

【Stress Intensity Calculation】

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 =	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
Modulus of Elasticity	n =	9.000	

Compressive Stress of Concrete	$\sigma_c =$	3.861	N/mm ²	○
Tensile Stress of Reinforcing Bar	$\sigma_s =$	138.584	N/mm ²	○
Shearing Stress of Concrete	$\tau =$	0.292	N/mm ²	○

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete	$\sigma_{ca} =$	8.2	N/mm ²
Allowable Tensile Stress of Reinforcing Bar	$\sigma_{sa} =$	140.0	N/mm ²
Allowable Shear Stress of Concrete	$\tau_a =$	0.36	N/mm ²

Single Reinforcing Bar

$$\begin{aligned}
 p &= A_s / (b \cdot d) & x &= k \cdot d \\
 &= 0.00279 & &= 9.022 \\
 k &= \sqrt{(2 \cdot n \cdot p + (n \cdot p)^2) - n \cdot p} \\
 &= 0.20048 \\
 j &= 1 - (k/3) \\
 &= 0.93317 \\
 \sigma_c &= (2 \cdot M \cdot 10^5) / (b \cdot d^2 \cdot k \cdot j) \\
 &= 386.11887 \\
 \sigma_s &= (M \cdot 10^5) / (b \cdot d^2 \cdot p \cdot j) \\
 &= 13858.44097 \\
 \tau &= (S \cdot 10^3) / (b \cdot j \cdot d) \\
 &= 29.18598
 \end{aligned}$$

2.2 Sluiceway

2.2.1 Conditions and Outline of Structural Analysis of Sluiceway

2.2.1.1 Categorizing of Calculation Type

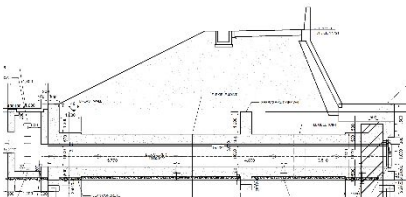
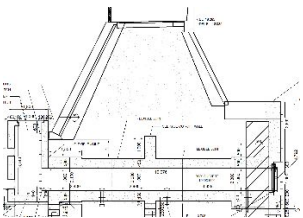
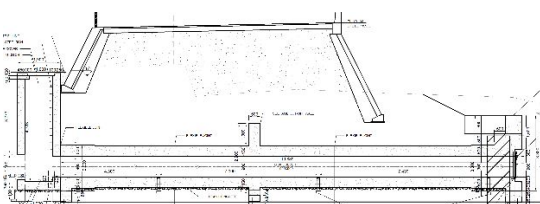
Sluiceways designed in this project can be categorized into several types of calculation models based on similarity in proportion and soil condition. Following tables explain categorization of all sluiceways.

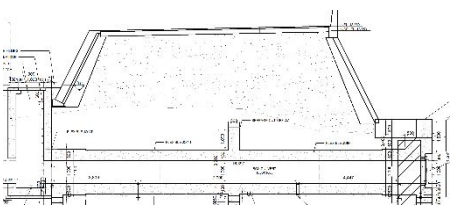
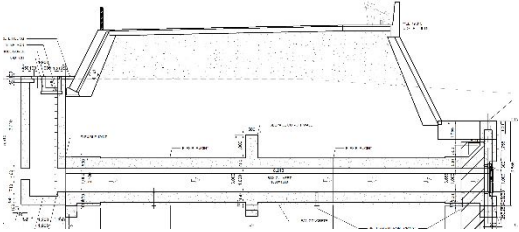
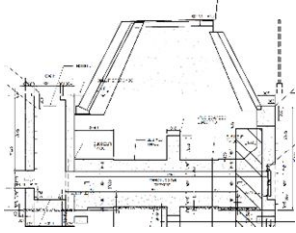
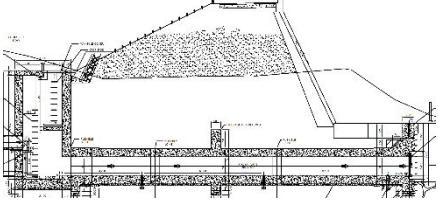
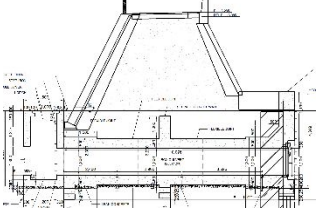
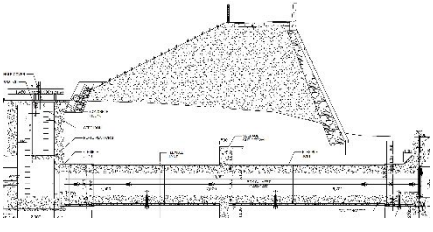
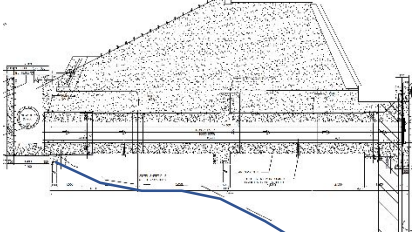
Table 2.2.1 Grouping of Sluiceway and Selection of Calculation Model Type

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
	CP3	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
		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
		6+060	MR125A	1000.00	17.700	17.400	11.700	12.700	4.700	5.700	4.250			0.26	TYPE-J
RIGHT BANK	CP1	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
	CP2	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.

$$S_x = \sum_{i=1}^n \frac{-3a_i \cdot q_i}{E_m \cdot \pi} \log \sin \left(\tan^{-1} \frac{a_i}{H} \right) \cdot \left\{ 1.0 - \frac{0.75}{\pi} \left[\left(1 + \frac{x}{a_i} \right) \log \left| 1 + \frac{x}{a_i} \right| + \left(1 - \frac{x}{a_i} \right) \log \left| 1 - \frac{x}{a_i} \right| \right] \right\}$$

Where,

S = Immediate Settlement on x_i , m

q_i = Load of Embankment, tf/m^2 or kN/m^2

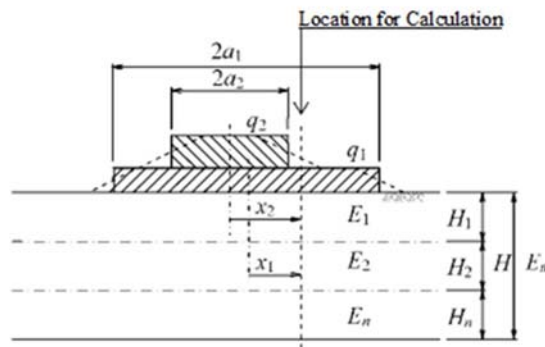
E_m = Modulus of Deformation of the ground, tf/m^2 or kN/m^2

a_i = 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 each uniform load, m



Source: JICA Study Team

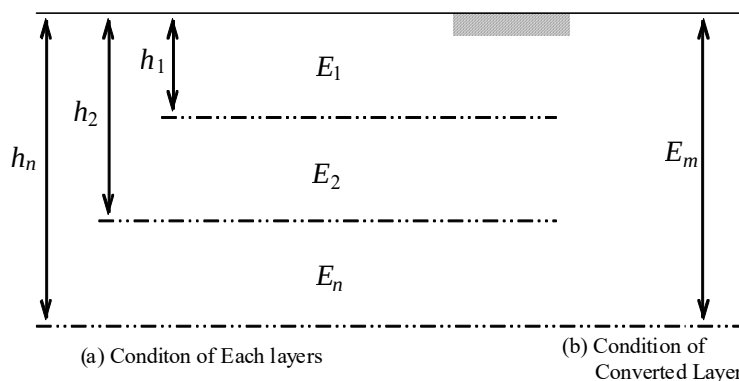
Figure 2.2.1 Calculation Model for Immediate Settlement

$$E_m = \frac{\log \frac{(B+2h_n \tan \theta)L}{(L+2h_n \tan \theta)B}}{\sum_{i=1}^n \frac{1}{E_{mi}} \log \frac{(B+2h_i \tan \theta)(L+2h_{i-1} \tan \theta)}{(L+2h_i \tan \theta)(B+2h_{i-1} \tan \theta)}}$$

Where,

E_m = Converted modulus of deformation (Figure R 6.2.3) of the ground, in $B \neq L$ considering several layers, kgf/cm^2 or kN/m^2

B	=	Load width, m
L	=	Load Length, m
H _n	=	Depth for considering the effect, more than 3 times of load width, m
H _i	=	Depth to the bottom of each layer, m
E _{mi}	=	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:

$$\begin{aligned}
 S_c &= \frac{e_1 - e_2}{1 + e_1} H \\
 &= m_v H \Delta p \\
 &= \frac{a_v}{1 + e_1} H \Delta p
 \end{aligned}$$

Where,

S_c	: Total consolidation settlement (m)
e_1, e_2	: Initial void ratio after embankment
H	: Thickness of compressive stratum (m)
m_v	: Coefficient of volume compressibility (m ² /kN)
Δp	: Increased compressive stress (kN/m ²)
a_v	: 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 E_m used in calculation of immediate settlement can be calculated as $E_m = 700N$, 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 (kN/m ²)	-	-	-	26.7	-	6,643
		-	-	-	18.8 - 34.7	-	474.7 - 19,460.7
	Es (kN/m ²)	6,936	5,469	14,756	15,747	26,759	31,057
		$\Rightarrow$ 6,900	$\Rightarrow$ 5,400	$\Rightarrow$ 14,700	$\Rightarrow$ 15,700	$\Rightarrow$ 26,700	
	Pc (kg/cm ³)	-	-	-	100.9	-	-
		-	-	-	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

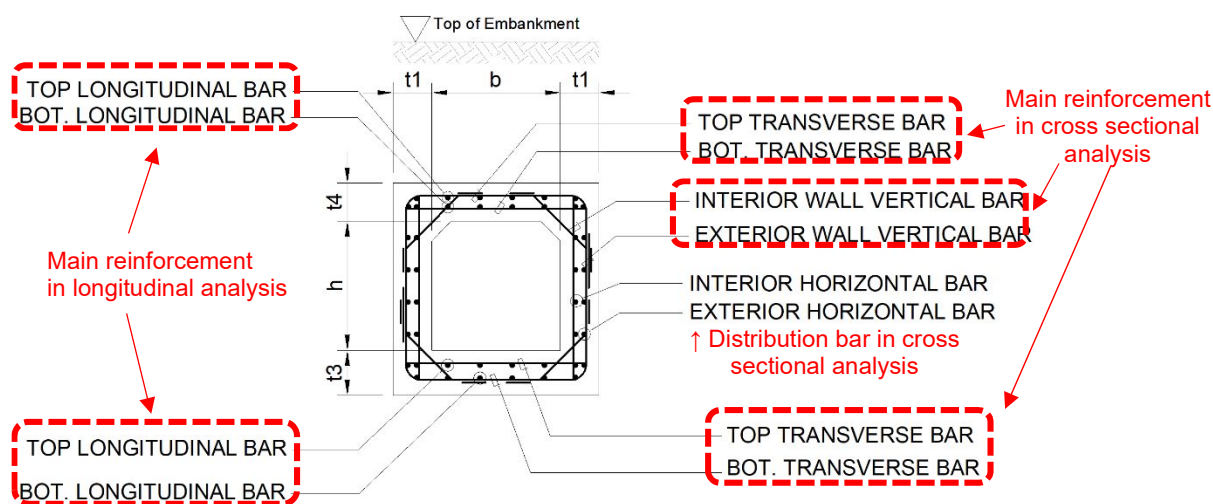
Item			Design Condition
Material Unit Weight	Concrete Reinforced		24.0 kN/m ³
	Concrete Plain		23.5kN/m ³
	Structural Steel		77.0 kN/m ³
	Water		9.8 kN/m ³
Soil Condition	Quality of Soil		
	Unit Weight	Damped and Wet Condition	19.0 kN/m ³
		Saturated Condition	20.0 kN/m ³
		Submerged Condition	10.0 kN/m 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)
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)
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)
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)
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)
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)
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)
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)
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)
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)

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
		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
		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
		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
		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
		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
		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
		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
		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
		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
		2	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250	D16(A)	@250	D12(A)	@250

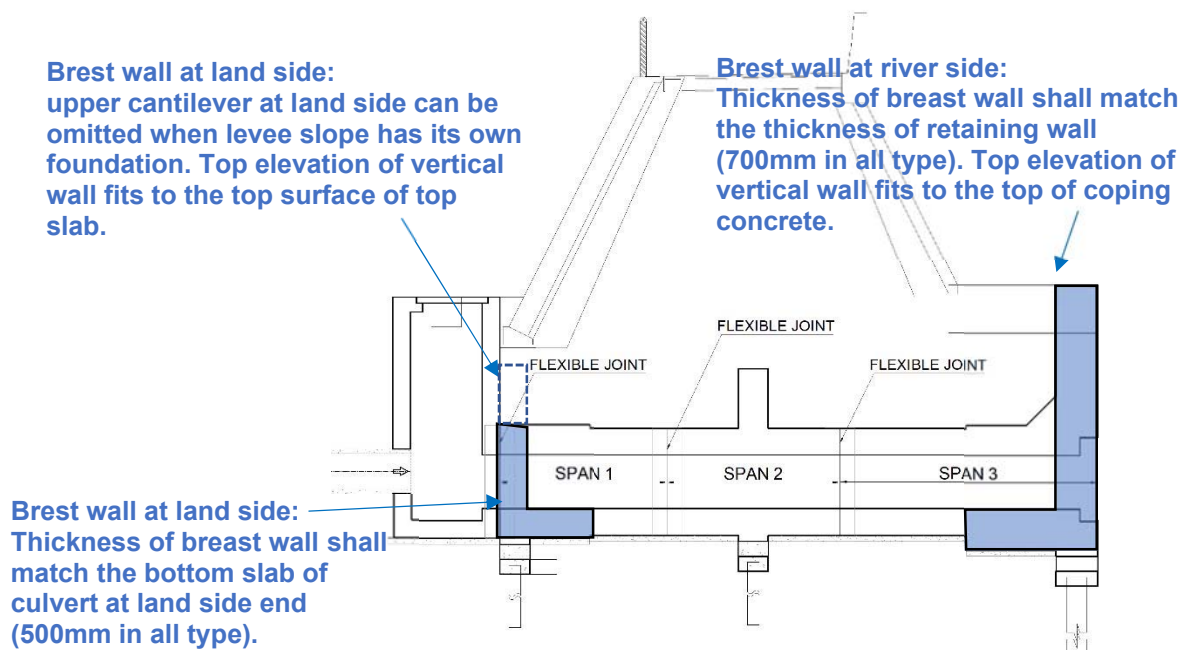
Source: JICA Study Team

(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

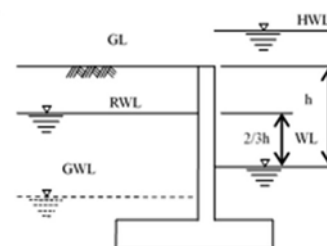


Figure 2.2.5 Water Level Conditions for Breast Wall at River Side

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

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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)

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

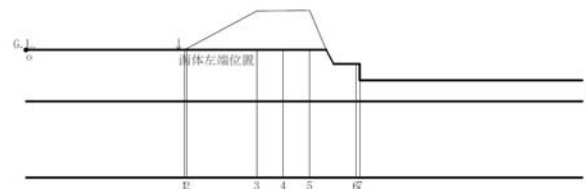
Span/ Block	Length of Block (m)	Depth for Subgrade Reaction(n)
1- 1	1.500	11.700
1- 2	5.000	5.700
2- 1	5.000	5.700
3- 1	2.580	5.700
3- 2	2.200	11.700

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 Left 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

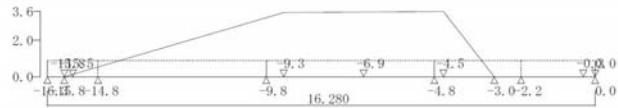
Span No	Block No	Flange		Reinforcing Bar				
		Portion	b (mm)	t (mm)	Outside		Inside	
					Diameter@Pitch (Number)	Cover (mm)	Diameter@Pitch (Number)	Cover (mm)
1	1	Top Slab	2000.0	500.0	D16@250 (6)	90.0	D16@250 (8)	90.0
		Bottom Slab	2000.0	500.0	D16@250 (6)	115.0	D16@250 (8)	90.0
	2	Top Slab	1900.0	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	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	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

No	Calculation Point (m)	Name
1	-15.780	Box end (land side)
2	-15.531	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 Summary 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

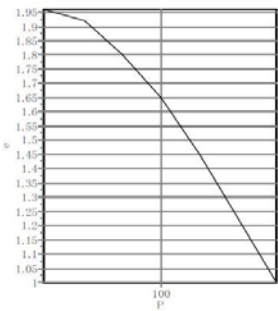


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

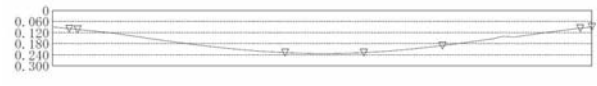
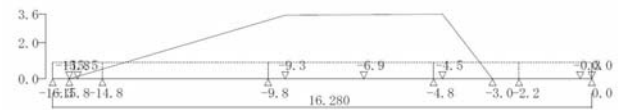
No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/m³)	Unit Weight (Saturated) (kN/m³)	Pre-Consolidation Stress q0 (kN/m²)	Elastic Modulus Es (kN/m²)
1	Adobe BL	Sand	4.550	17.500	18.500	0.0	6900.0
2	Dc1	Clay	11.430	17.500	18.500	0.0	15700.0

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 Summary 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

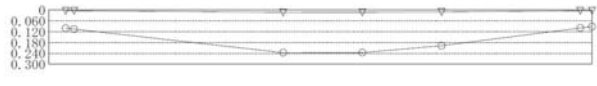
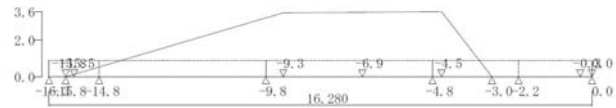


2.3 Residual Settlement

2.3.1 Summary of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vauce	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 Longitudinal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B} \cdot \frac{d^4 w}{dx^4} + k_v (w - w_g) = q \text{ (Swag)}$$

$$\frac{EA}{U} \cdot \frac{d^2 u}{dx^2} + k_s (u - u_g) = p \text{ (Displacement in axial direction of Box Culvert)}$$

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/cm²) {kN/m²}
- 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/cm²) {kN/m²}
- 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

$$E_{om} = \frac{\log \left(\frac{(B+2h_v \cdot \tan \theta) \cdot L}{(L+2h_v \cdot \tan \theta) \cdot B} \right)}{\sum \frac{1}{E} \log \left(\frac{(B+2h_v \cdot \tan \theta) \cdot (L+2h_v \cdot \tan \theta)}{(L+2h_v \cdot \tan \theta) \cdot (B+2h_v \cdot \tan \theta)} \right)}$$

In case of B=L

$$E_{om} = \frac{\frac{1}{B+2h_v \cdot \tan \theta} + \frac{1}{B}}{\sum \frac{1}{E} \left(\frac{1}{B+2h_v \cdot \tan \theta} + \frac{1}{B+2h_v \cdot \tan \theta} \right)}$$

Thus,

- E_{om} : Converted Modulus of Deformation
- B : Loading Width = Width of Culvert
- L : Loading Length = Length of a span
- h_v : 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/m²)
- θ : Angle of Load Dispersion ($\theta=30^\circ$)

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.

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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

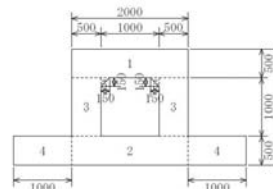
Span3-Block2 River Side

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

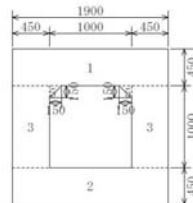


Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ³)	Ioi (m ⁴)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.022	1.450	0.0326	0.0473	0.00003
Total	4.022		3.2826	4.2348	0.14586

$$Y_g = \frac{\sum (A_i \cdot Y_i) \sum A_i}{\sum A_i} = \frac{3.2826}{4.022} = 0.8161 \text{ (m)}$$

$$I = \frac{\sum (A_i \cdot Y_i^2) + \sum I_{oi} - Y_g^2 \cdot \sum A_i}{2} = \frac{4.2348 + 0.14586 - 0.6660 \cdot 4.022}{2} = 1.70183 \text{ (m}^4\text{)}$$

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

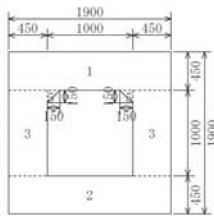
$$Y_g = \frac{\sum (A_i \cdot Y_i) \sum A_i}{\sum A_i} = \frac{2.5110}{2.632} = 0.9538 \text{ (m)}$$

$$I = \frac{\sum (A_i \cdot Y_i^2) + \sum I_{oi} - Y_g^2 \cdot \sum A_i}{2} = \frac{3.2984 + 0.10388 - 0.9098 \cdot 2.632}{2} = 1.00722 \text{ (m}^4\text{)}$$

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Span2-Block1 Center

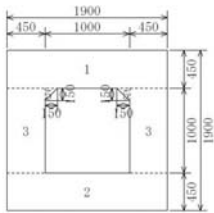


Position	Ai (m²)	Yi (m)	Ai·Yi (m³)	Ai·Yi² (m⁴)	loi (m³)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.632 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma lo_i - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.632 = 1.00722 \text{ (m}^4\text{)}$$

Span3-Block1 River Side



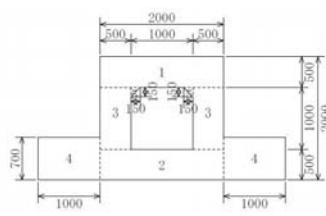
Position	Ai (m²)	Yi (m)	Ai·Yi (m³)	Ai·Yi² (m⁴)	loi (m³)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.632 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma lo_i - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.632 = 1.00722 \text{ (m}^4\text{)}$$

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Span3-Block2 River Side



Position	Ai (m²)	Yi (m)	Ai·Yi (m³)	Ai·Yi² (m⁴)	loi (m³)
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

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.5226 / 4.423 = 0.7965 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma lo_i - Y_g^2 \cdot \Sigma A_i = 4.3438 + 0.18219 - 0.6344 \cdot 4.423 = 1.72015 \text{ (m}^4\text{)}$$

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3.2.3 Table of Modulus of Subgrade Reaction

Coefficient of Lateral Shear Reaction of Soil

$$k_c = \lambda \cdot k_v$$

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

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3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

$$W = (A_1 + A_2 + A_3) \cdot \gamma_c \text{ (kN/m)}$$

A1: Cross Sectional Area (Excluding Hunch) (m²)

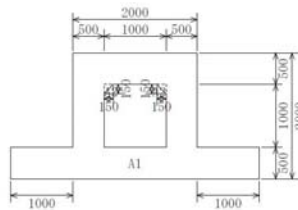
A2: Area of Upper Side Hunch (m²)

A3: Area of Lower Side Hunch (m²)

γc: Unit Weight (Concrete) (kN/m³)

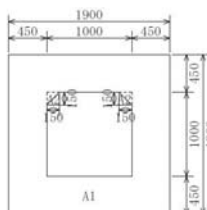
Span No. 1-1 Land Side

$$W = (4.000 + 0.022 + 0.000) \cdot 24.000 = 96.540 \text{ (kN/m)}$$



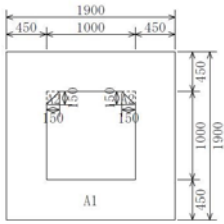
Span No. 1-2 Land Side

$$W = (2.610 + 0.022 + 0.000) \cdot 24.000 = 63.180 \text{ (kN/m)}$$

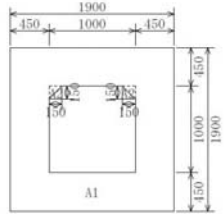


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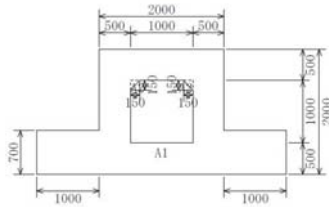
Span No. 2-1 Center
 $W = (2.610 + 0.022 + 0.000) \cdot 24.000$
 $= 63.180 \text{ (kN/m)}$



Span No. 3-1 River Side
 $W = (2.610 + 0.022 + 0.000) \cdot 24.000$
 $= 63.180 \text{ (kN/m)}$



Span No. 3-2 River Side
 $W = (4.400 + 0.022 + 0.000 + 0.000) \cdot 24.000$
 $= 106.140 \text{ (kN/m)}$



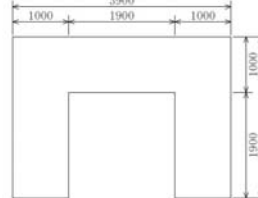
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2) Seepage Cutoff Wall Body Weight

$A1 = X1 \cdot L2$
 $A2 = L1 \cdot Y1 \cdot 2$
 $W = (A1 + A2) \cdot B \cdot \gamma_c \text{ (kN)}$
 $X1$: 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)
 γ_c : Unit Weight (Concrete) (kN/m³)

SpanNo.2-SpanDistance from Base Point (2.400)

$A1 = 3.900 \cdot 1.000$
 $= 3.900 \text{ (m}^2\text{)}$
 $A2 = 1.000 \cdot 1.900 \cdot 2$
 $= 3.800 \text{ (m}^2\text{)}$
 $W = (3.900 + 3.800) \cdot 0.500 \cdot 24.00$
 $= 92.400 \text{ (kN)}$



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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

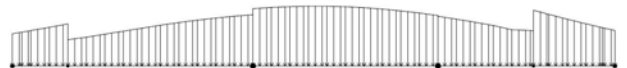
Span2 Name of Span: [Center]

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

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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~-1.780	1.900	69412.8	145.2	143.2	-10081.708	-9937.712
2-(31)	-2.280~-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



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2) Equivalent Load for Ground Settlement

[Seismic Condition]

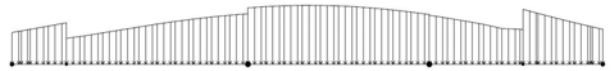
Span1 Name of Span: [Land Side]							
Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m ²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-16.280~-16.030	4.000	200404.6	91.2	95.8	-18280.237	-19199.627
1-(2)	-16.030~-15.780	4.000	200404.6	95.8	100.5	-19199.627	-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/m ²)	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

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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-(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~-1.780	1.900	138825.5	145.2	143.2	-20163.416	-19873.423
2-(31)	-1.780~-1.280	4.000	221073.1	143.2	132.4	-31650.668	-29274.863
2-(32)	-1.280~-0.780	4.000	221073.1	132.4	120.0	-29274.863	-26539.150
2-(33)	-0.780~-0.280	4.000	221073.1	120.0	108.3	-26539.150	-23934.993
2-(34)	-0.280~-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



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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 Condition 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 Seismic 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



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3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data 1	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 Data 1	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	Engaging Load (Dead Load)1	Gate Structure · Breast Wall (Dead Load)1	1.0000
6	Engaging 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 Data 1	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	Engaging Load (Dead Load)2	Seismic Load	1.0000
6	Engaging Load (Dead Load)2	Gate Structure · Breast Wall (Dead Load)2	1.0000

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3.4 Displacement between Sluiceway and Adjoining Levee

3.4.1 Normal Condition

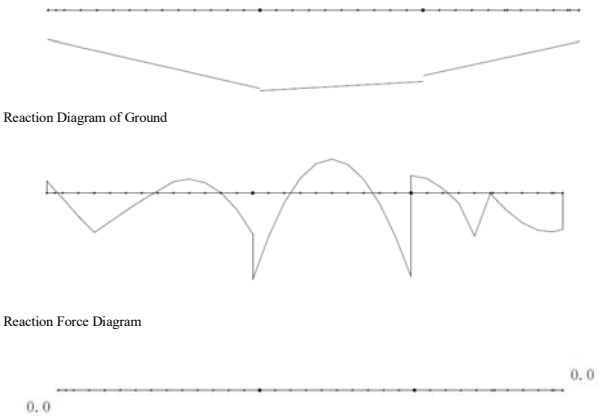
1) Calculation Case1 - Load: [Normal Condition]

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

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Displacement Diagram



Reaction Force Diagram

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

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3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]									
Num ber	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]									
Num ber	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

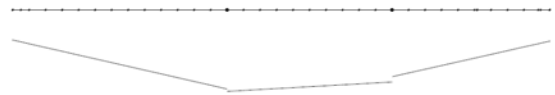
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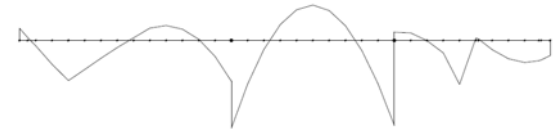
Span3 Name of Span: [River Side]

Num ber	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



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2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Num ber	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]

Num ber	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

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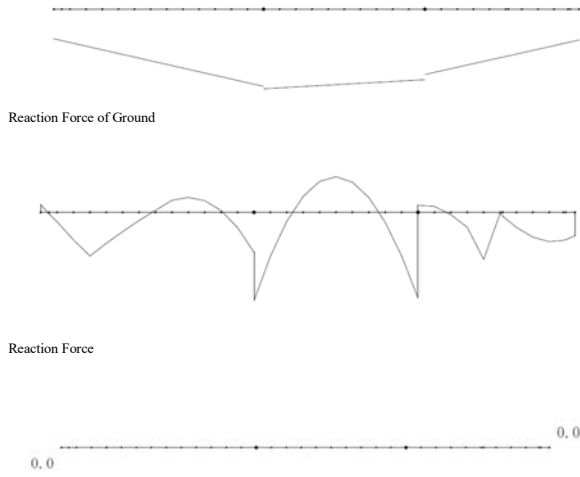
2-112

Span3 Name of Span: [River Side]

Num ber	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

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Displacement Diagram



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Num ber	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]

Num ber	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

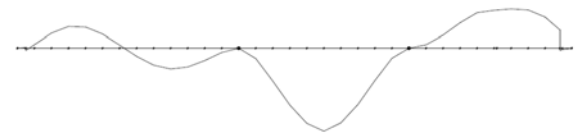
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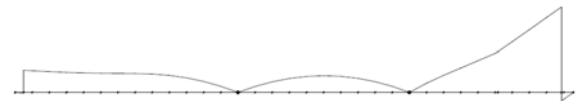
Span3 Name of Span: [River Side]

Num ber	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

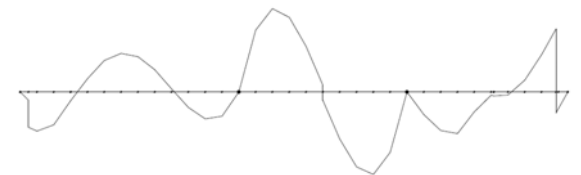
Bending Moment



Axial Force



Shear Force



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3.5.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side →River Side]

Span1 Name of Span: [Land Side]

Num ber	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]

Num ber	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

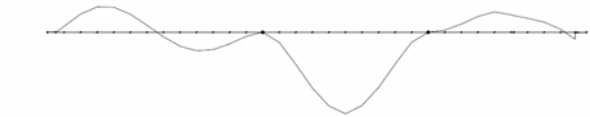
Span3 Name of Span: [River Side]

Num ber	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

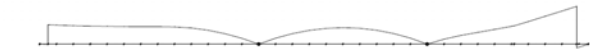
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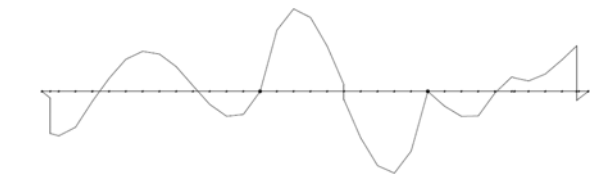
Bending Moment



Axial Force



Shear Force



Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Num ber	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]

Num ber	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

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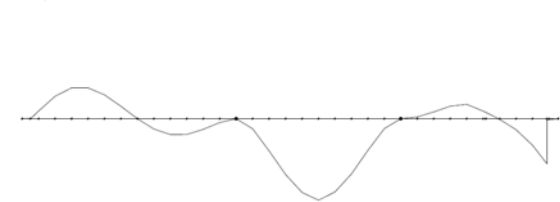
41

Span3 Name of Span: [River Side]

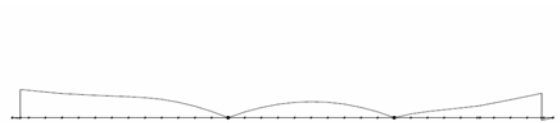
Num ber	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	11.500	0.002	0.000	0.000
2	12.000	33.778	-76.841	-19.571
3	12.500	56.077	-122.977	-71.724
4	13.000	72.545	-102.692	-131.479
5	13.500	89.228	58.134	-150.993
6	14.000	106.582	177.113	-80.320
7	14.080	109.420	174.142	-66.287
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

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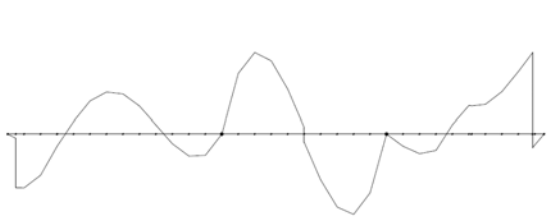
Bending Moment



Axial Force



Shear Force



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3.6 Design of Flexible Joint

Opening
Opening = (Lateral Displacement of Span in Right Side) - (Lateral Displacement of Span in Left Side)

Bending Angle
 $\theta = \left| \theta_1 - \theta_2 \right|$ - Initial Bending Angle
Thus,
 θ_1 : Angle of Displacement (Left Side) (rad)
 θ_2 : 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)	θ_1 (Degree) (rad)	θ_2 (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	

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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)	θ_1 (Degree) (rad)	θ_2 (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)	θ_1 (Degree) (rad)	θ_2 (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

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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

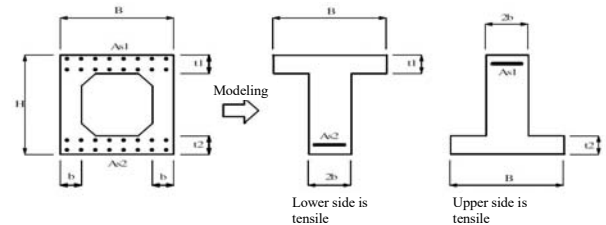
3.7.1 Calculation Condition

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

$$x = \frac{n \cdot (A_s \cdot d + A_s' \cdot d') + B \cdot t^2 / 2}{n \cdot (A_s + A_s') + B \cdot t}$$

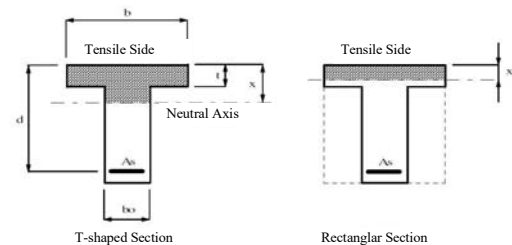
Thus,

- x : Position of Neutral Axis (mm)
- n : Ratio of Young modulus = 9.0
- A_s : Area of Re-bar in tensile side (mm²)
- A_s' : Area of Re-bar in compressive side (mm²)
- 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.



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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	1.900	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

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 As (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Tensile Side As (mm ²)
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

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3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1

Item		Sym bol	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		21.158	-219.102	21.158	-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	d3 As3	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom	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

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Calculation Case1: Normal Condition

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block2

Item		Sym bol	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

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3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Symb ol	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

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Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Symb ol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Symb ol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition

Span3-Block2

Item		Sym bol	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

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2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Sym bol	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

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Span1-Block2

Item		Sym bol	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	-----

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Span2-Block1

Item		Sym bol	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	-----

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Span3-Block1

Item		Sym bol	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		Sym bol	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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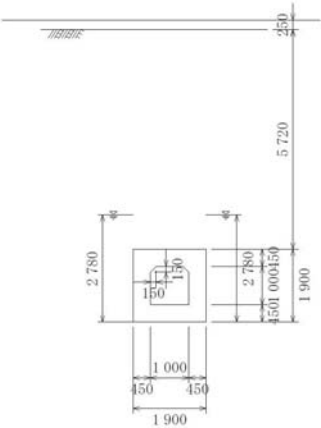
2.2.2.1 SLUICEWAY TYPE A

(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	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil(Wet)	γ_t	kN/m ³	19.00
Soil(Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	σ_{sa}	N/mm ² Normal (General)	140.00
		N/mm ² Normal (Harsh)	140.00
		N/mm ² Seismic	186.00
Allow Compressive Strength	$\sigma_{sa'}$	N/mm ² Normal	140.00
		N/mm ² Seismic	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		Right Corner	D16	250	
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		Right Sidewall	D13	250	

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		Right Corner	D16	250	
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 A _w (mm ² /m)
Top Slab	100	0.0
Side Wall	100	0.0
Bottom Slab	100	0.0

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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

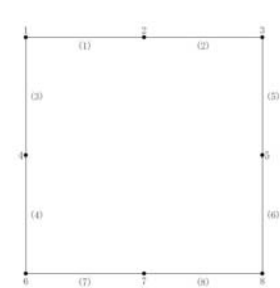
Live Load	
Intensity of Distribution Load Q _w (kN/m ²)	10.000

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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	Num ber	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

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Bottom Slap					

4) Supporting Point

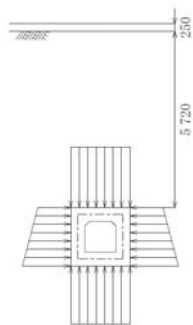
Point	Horizontal (kN/m)	Vertical (kN/m)	Rotate (kN.m/rad)
6	-1	-1	0
8	0	-1	0

(Note) -1: Fixed, 0: Free

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1.2.2 Load

1) Dead Load (case-1) [RWL]



Weight of Box Culvert

- (1) Top Slab
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
 (2) Left Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
 (3) Right Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$

Surcharge Load

- (1) Pavement and Embankment

Pavement (Above Water Level)	$= 1.000 \times 0.250 \times 22.60 = 5.65 \text{ (kN/m}^2\text{)}$
Embankment (Above Water Level)	$= 1.000 \times 4.840 \times 18.00 = 87.12 \text{ (kN/m}^2\text{)}$
Embankment (Below Water Level)	$= 1.000 \times 0.880 \times 9.20 = 8.10 \text{ (kN/m}^2\text{)}$
Water Pressure	$= 0.880 \times 9.80 = 8.62 \text{ (kN/m}^2\text{)}$

$$\Sigma w_d = 109.49 \text{ (kN/m}^2\text{)}$$

- (2) Surcharge Load at Road

Surcharge	$= 0.000 \text{ (kN/m}^2\text{)}$
Snow Load	$= 0.00 \text{ (kN/m}^2\text{)}$

$$\Sigma q_d = 0.000 \text{ (kN/m}^2\text{)}$$

- (3) Load Acting on Top Slab

Uniformly Distributed Load	$w = 109.49 + 0.00 = 109.49 \text{ (kN/m}^2\text{)}$

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Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

$$p_i = K_o \times (q_d + \gamma_o \times \gamma_a + Z_u \times \gamma + (Z_o - Z_u) \times \gamma') + (Z_o - Z_u) \times \gamma_w$$

K_o : Coefficient of Earth Pressure at Rest = 0.500

Z_o : Depth of Calculation Point from Embankment Top(m)

- (1) Left Side Wall

Symbol	Calculation Point	Z_o (m)	p (kN/m ²)
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	Z_o (m)	p (kN/m ²)
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

$$U = 2.780 \times 1.900 \times 9.80 = 51.76 \text{ (kN/m)}$$

$$w = \frac{-51.76}{1.900} = -27.24 \text{ (kN/m}^2\text{)}$$

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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		138.20		0.890	123.06
	Right Side Wall		-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

$$\bar{x} = \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)}$$

$$e = \frac{B}{2} - \bar{x} = 0.000 \text{ (m)}$$

- (2) Subgrade Reaction Intensity

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_l = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 104.70 \text{ (kN/m}^2\text{)}$$

$$q_r = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 104.70 \text{ (kN/m}^2\text{)}$$

$$q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 104.70 \text{ (kN/m}^2\text{)}$$

$$q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 104.70 \text{ (kN/m}^2\text{)}$$

Thus, T : Thickness of Side Wall

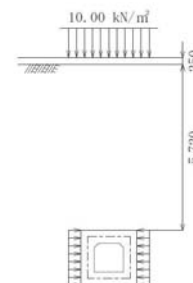
q_l : Subgrade Reaction Intensity on Left Edge

q_r : Subgrade Reaction Intensity on Right Edge

q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

q_r' : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface $q_L = 10.000 \text{ (kN/m}^2\text{)}$

Load

- (1) Vertical Load Effecting Top Slab

$$w_l = q_L = 10.00 \text{ (kN/m}^2\text{)}$$

- (2) Horizontal Load Acting on Left Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

- (3) Horizontal Load Effecting on Right Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

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

$$\bar{x} = \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)}$$

$$e = \frac{B}{2} - \bar{x} = 0.000 \text{ (m)}$$

9

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(2) Subgrade Reaction Intensity
 $M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$
 $q_l = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$
 $q_r = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$
 $q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$
 $q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$

Thus, T : Thickness of Side Wall
 q_l : Subgrade Reaction Intensity on Left Edge
 q_r : Subgrade Reaction Intensity on Right Edge
 q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
 q_r' : 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

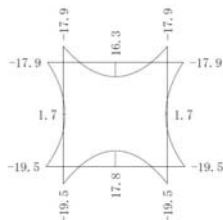
Load Number
13: Member Distribution Load (X Direction)
14: Member Distribution Load (Y Direction)

11

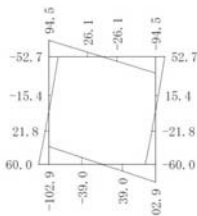
12

1.2.4 Calculation Results of Frame Analysis

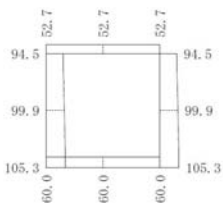
Bending Moment



Shear Force



Axial Force



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1.2.5 Stress Intensity Calculation

Bending Stress Intensity

Top Slab

Item	Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	-17.941	16.301	-17.941
Axial Force	N	0.000	0.000	0.000
Section Width	b	1.000	1.000	1.000
Section Height	h	0.450	0.450	0.450
Outside Cover	d1	90.0	90.0	90.0
Inside Cover	d2	90.0	90.0	90.0
Required Area of Re-Bar	External	371.7	0.0	371.7
	Internal	0.0	337.1	0.0
Re-Bar	External	D16 @ 250 D- @ 794.4	D16 @ 250 D- @ 794.4	D16 @ 247 D- @ 804.0
	Internal	D16 @ 250 D- @ 794.4	D16 @ 250 D- @ 794.4	D16 @ 250 D- @ 794.4
Neutral Axis	X	0.065	0.065	0.065
Stress Intensity	σ_c	N/mm ²	1.63	1.48
	σ_s	N/mm ²	66.75	60.65
	σ_s'	N/mm ²	0.00	0.00
Allowable Stress	σ_{ca}	N/mm ²	8.20	8.20
	σ_{sa}	N/mm ²	140.00	140.00
Minimum Re-Bar Sectional Area	σ_{sa}'	N/mm ²	-186.00	-186.00
	min	mm ²		
	req	mm ²	495.6	449.5
Case	inp	mm ²	794.4	804.0
	---	---	Dead-1+Live-1	Dead-1+Live-1

※Axial force is not considered.

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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

$$\tau_m = \frac{S}{b \times d} \leq \tau_a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm ²)	τa (N/mm ²)	Cases	L (m)
Top Slab	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

1 Calculation of Land Side Breast Wall 1

1.1 Design Conditions 1

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2.2.2.1 SLUICEWAY TYPE A

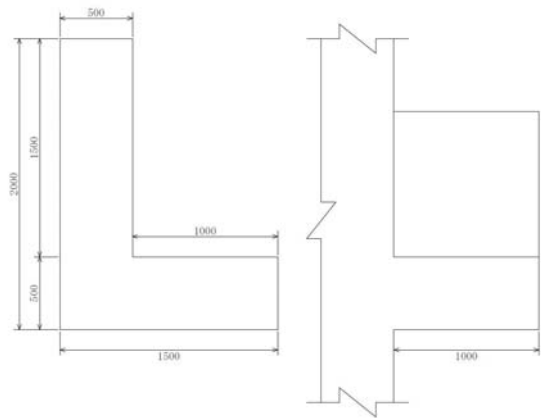
(3) BREAST WALL - LAND SIDE

1 Calculation of Land Side Breast Wall

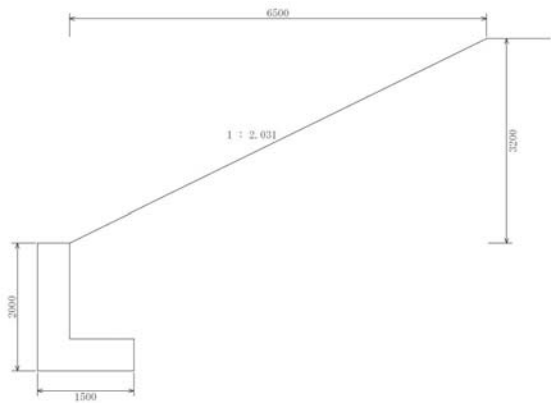
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Critical Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁵	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	σ_{sa}	N/mm ² Normal (General)	140.00
		N/mm ² Normal (Harsh)	140.00
		N/mm ² Seismic	186.00
Allow Compressive Strength	σ_{sa}'	N/mm ² Normal	140.00
		N/mm ² Seismic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φ_{res}	○	30
Peak Angle of Internal Friction	φ_{peak}	○	30
Coefficient of Lateral Earth Pressure at-rest	K_0		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 A _w (mm ² /m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

1.1.4 Loads

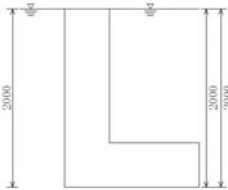
■Basic Load

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>

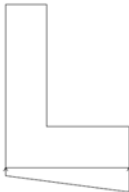
	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front



2) Subgrade Reaction

2-1) Normal <Case 1>

	(kN/m ²), (m)
Toe	36.87
Heel	109.70
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m ²), (m)
Toe	45.79
Heel	54.06
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 $W=20.727$ (kN/m)

※ ξ_A (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned}\text{Converted Load } q_0' &= (W+q_0 \cdot wq_0)/B \\ &= (20.727+10.00 \times 0.000)/1.500 \\ &= 13.818 \text{ (kN/m}^2\text{)}\end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 13.818 \times 0.500 = 6.909 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned}p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.000 + 6.909 \\ &= 6.909 \text{ (kN/m}^2\text{)}\end{aligned}$$

Earth Pressure at Junction

$$\begin{aligned}p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 1.500 + 6.909 \\ &= 14.559 \text{ (kN/m}^2\text{)}\end{aligned}$$

Design Earth Pressure

$$\begin{aligned}P &= p_3 \\ &= 14.559 \text{ (kN/m}^2\text{)}\end{aligned}$$

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γ_t : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

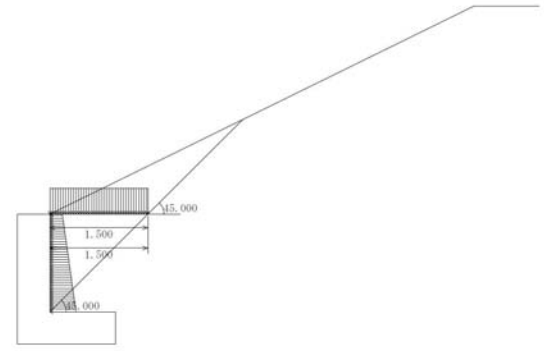
γ_w : Unit Weight of Water (kN/m³)

q_0 : Surcharge (kN/m²)

w_{q_0} : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)



1-2) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.500 \times 9.80 = 14.700 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : 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

$$H = B \cdot \gamma_c \cdot kh = 0.500 \times 24.00 \times 0.20 = 2.400$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : 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

Embankment Height under the water level surface

Angle between the vertical wall and vertical plane

Unit Weight of Soil (Wet)

Unit Weight of Soil (Saturated)

Unit Weight of Water

Surcharge

Load width of Surcharge

Width of Converted Load

Internal Friction Angle of Soil

Angle between Ground Surface and Horizontal Plane

Friction Angle (Soil and Concrete)

Design Horizontal Seismic Coefficient

Apparent Horizontal Seismic Coefficient underwater

Compound Angle in Seismic Condition

Compound Angle in Seismic Condition underwater

h_1	=	0.000	(m)
H_2	=	1.500	(m)
θ	=	0.00	(degree)
γ_t	=	19.00	(kN/m ³)
γ_{sat}	=	20.00	(kN/m ³)
γ_w	=	9.80	(kN/m ³)
q_0	=	5.00	(kN/m ²)
w_{q_0}	=	0.000	(m)
B	=	1.646	(m)
ϕ	=	30.00	(degree)
α	=	0.00	(degree)
δ_E	=	0.00	(degree)
kh	=	0.20	(degree)
kh	=	0.303	(degree)
$\theta_0 = \tan^{-1}(kh)$	=	11.310	(degree)
$\theta_0 = \tan^{-1}(kh')$	=	16.855	(degree)

■Active Angle of Rupture in Seismic Condition

$$\begin{aligned}\cot(\xi_{EA} - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_s) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_s)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \\ \cot(\xi_{EA} - \alpha) &= 0.85094\end{aligned}$$

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

$$\begin{aligned}\cot(\xi_{EA}' - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_s') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_s')}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 16.855^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 16.855^\circ)}} \\ \cot(\xi_{EA}' - \alpha) &= 1.09764\end{aligned}$$

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

$$\begin{aligned}K_{EA} &= \frac{\cos^2(\phi - \theta_s - \theta)}{\cos \theta_s' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_s' + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_s')}{\cos(\theta + \theta_s' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2} \\ &= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \\ &\quad \times \frac{1}{\left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2} \\ &= 0.4733\end{aligned}$$

In case $\phi - \alpha - \theta_s' < 0$, $\sin(\phi - \alpha - \theta_s') = 0$.

$$\begin{aligned}K_{EA}' &= \frac{\cos^2(\phi - \theta_s' - \theta)}{\cos \theta_s' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_s' + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_s')}{\cos(\theta + \theta_s' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2} \\ &= \frac{\cos^2(30.00^\circ - 16.855^\circ - 0.00^\circ)}{\cos(16.855^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 16.855^\circ + 0.00^\circ)} \\ &\quad \times \frac{1}{\left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 16.855^\circ)}{\cos(0.00^\circ + 16.855^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2} \\ &= 0.5726\end{aligned}$$

In case $\phi - \alpha - \theta_s' < 0$, $\sin(\phi - \alpha - \theta_s') = 0$.

Weight of Embankment $W = 21.819$ (kN/m)

$$\begin{aligned}\text{Converted Load } q_0' &= \frac{W + q_0 \cdot w_{q_0}}{B} \\ &= \frac{21.819 + 5.00 \times 0.000}{1.646} \\ &= 13.252 \text{ (kN/m}^2\text{)}\end{aligned}$$

Earth Pressure at the Top

$$P_1 = q_0' \cdot K_{EA} = 13.252 \times 0.4733 = 6.272 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned}P_2 &= K_{EA} \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.4733 \times 19.00 \times 0.000 + 6.272 \\ &= 6.272 \text{ (kN/m}^2\text{)}\end{aligned}$$

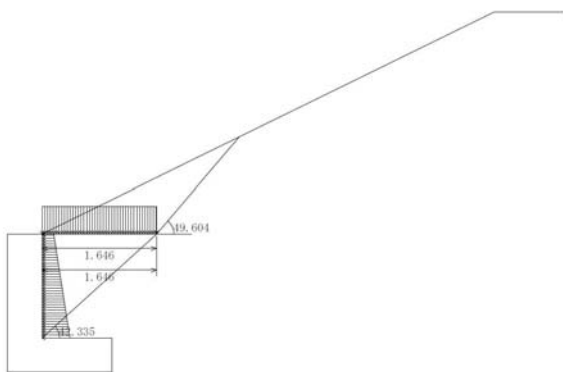
Earth Pressure at Junction

$$\begin{aligned}P_3 &= K_{EA} \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.5726 \times (20.00 - 9.80) \times 1.500 + 6.272 \\ &= 15.032 \text{ (kN/m}^2\text{)}\end{aligned}$$

Design Earth Pressure

$$P_{1E} = P_3 \cdot \cos \delta = 15.032 \cdot \cos(0.00^\circ) = 15.032 \text{ (kN/m}^2\text{)}$$

Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.500 \times 9.80 = 14.700 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m ²)	L (m)	P·l/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) = 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 (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) = 16.07		
Shear Force S (kN/m)	Σ(P·l) = 32.13		

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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	mm	410.0
	As1	mm ²	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	mm	410.0
	As1	mm ²	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

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2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	29.26
Re-bar	d1	mm	410.0
	As1	mm ²	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	mm	410.0
	As1	mm ²	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

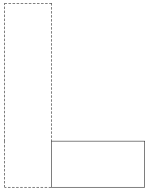
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1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$Sw = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

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



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.492 \times 19.00 + 1.500 \times 20.00 = 39.354$$

Thus,

Pw1 : Weight 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)

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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)	Unit (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



$$Sw = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

Thus,

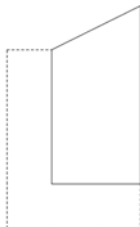
Sw : Weight of Wall (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

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2-2) Weight of the Embankment



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.492 \times 19.00 + 1.500 \times 20.00 = 39.354$$

Thus,

Pw1 : Weight 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	48.55
Edge	54.06

2-4) Uplift Force

	Calculating Formula Height of Water Level × Unit Weight of Water (γ_w)	Unit (kN/m ²)
Base	2.000 × 9.80	19.600
Edge	2.000 × 9.80	19.600

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1.3.2 Summary of Cross-Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m ²)	L (m)	P × P/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)	$\Sigma(P \cdot P/2) = 19.37$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 38.75$		

1-2) Edge

	P (kN/m ²)	L (m)	P × P/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)	$\Sigma(P \cdot P/2) = 38.97$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 77.95$		

2) Seismic Condition-1

2-1) Base

	P (kN/m ²)	L (m)	P × P/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)	$\Sigma(P \cdot P/2) = 13.07$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 26.15$		

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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	-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•l ² /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	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	19.37	38.97
Re-bar	d1	mm	385.0	385.0
	Asl	mm ²	794.4	794.4
Required Area of Re-bar	Lower	mm ²	374.9	767.1
Neutral Axis	X	m	0.067	0.067
Stress Intensity	σc	N/mm ²	1.59	3.19
	σs	N/mm ²	67.27	135.33
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	499.9	1022.8
	inp	mm ²	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	13.07	11.15
Re-bar	d1	mm	385.0	385.0
	Asl	mm ²	794.4	794.4
Required Area of Re-bar	Upper	mm ²	188.2	160.2
	Lower	mm ²	0.067	0.067
Neutral Axis	X	m	1.07	0.91
Stress Intensity	σc	N/mm ²	45.39	38.73
	σs	N/mm ²	12.30	12.30
Allowable Value	σca	N/mm ²	186.00	186.00
	σsa	N/mm ²	186.00	186.00
Minimum of Re-bar Area	min	mm ²		
	req	mm ²	250.9	213.6
	inp	mm ²	794.4	794.4

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(2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	38.75	77.95
Re-bar	d1	mm	385.0	385.0
	Asl	mm ²	794.4	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	0.101	0.202
Allowable Value	ta	N/mm ²	0.360	0.360
	ta2	N/mm ²	1.600	1.600

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	26.15	22.31
Re-bar	d1	mm	385.0	385.0
	Asl	mm ²	794.4	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	0.068	0.058
Allowable Value	ta	N/mm ²	0.540	0.540
	ta2	N/mm ²	2.400	2.400

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1 Calculation of River Side Breast Wall.....1

1.1 Design Condition 1

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1.3 Calculation of Bottom Slab 14

1.3.1 Load 14

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1.3.3 Stress Intensity Calculation.....19

2.2.2.1 SLUICeway TYPE A

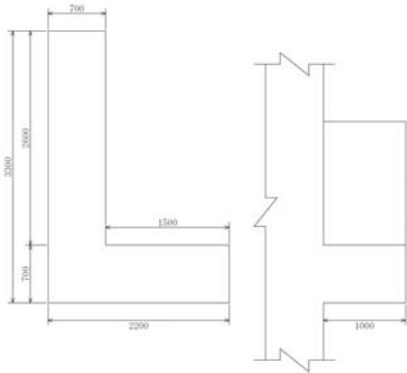
(4) BREAST WALL - RIVER SIDE

1 Calculation of River Side Breast Wall

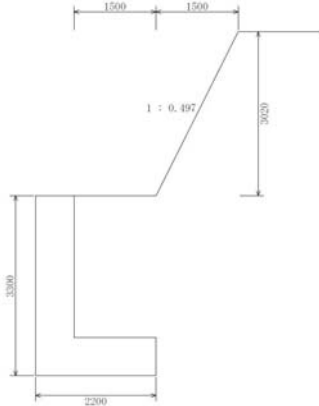
1.1 Design Condition

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil(Wet)	γ_t	kN/m ³	19.00
Soil(Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	osa	N/mm ²	Normal (General)	140.00
		N/mm ²	Normal (Harsh)	140.00
		N/mm ²	Seismic	186.00
Allow Compressive Strength	osa'	N/mm ²	Normal	140.00
		N/mm ²	Seismic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φ_{res}	○	30
Peak Angle of Internal Friction	φ_{peak}	○	30
Coefficient of Lateral Earth Pressure at-rest	K_o		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
	Back Face	90.0	D16	250
Bottom Slab	Top Face	90.0	D16	250
	Bottom Face	115.0	D16	250

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement A _w (mm ² /m)
Side Wall	100	0.0
Bottom Slab	100	0.0

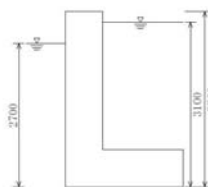
1.1.4 Loads

■Basic Load

1)Water Level

1-1) Normal Condition Number of Cases [1]

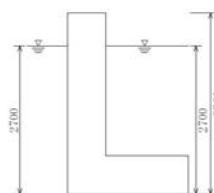
<Case 1>	
	(m)
Toe	2.700
Heel	3.100



1-2) Seismic Condition Number of Cases [1]

<Case 1>

(m)	
Toe	2.700
Heel	2.700
Direction	Back → Front



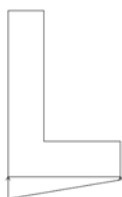
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2)Subgrade Reaction

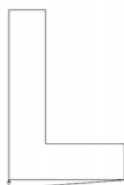
2-1) Normal <Case 1>

	(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

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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 · w_{q0})/B
= (106.727+ 10.00× 2.620)/ 2.600
= 51.126 (kN/m²)

Earth Pressure at the Top

p₁ = q₀' · K₀ = 51.126× 0.500 = 25.563 (kN/m²)

Earth Pressure at Water Level

p₂ = K₀ · γ_w · h₁+p₁
= 0.500× 19.00× 0.200+ 25.563
= 27.463 (kN/m²)

Earth Pressure at Bottom Surface of Base

p₃ = K₀ · (γ_{sat}-γ_w) · h₂+p₂
= 0.500× (20.00- 9.80)× 2.400+ 27.463
= 39.703 (kN/m²)

Design Earth Pressure

P = p₃
= 39.703 (kN/m²)

Thus,

K₀ : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γ_t : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

q₀ : Surcharge (kN/m²)

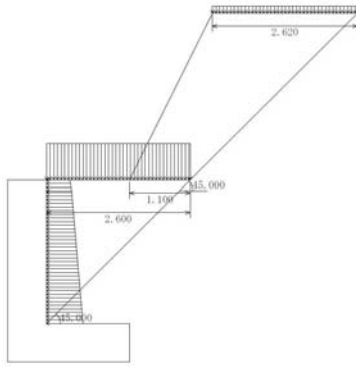
w_{q0} : Width of Surcharge (m)

h₁ : Height above Water Surface (m)

h₂ : Height under Water Surface (m)

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■Converted Loads Acting on Breast Wall



1-2) Water Pressure

$$P_h = h \cdot \gamma_w = 2.400 \times 9.80 = 23.520 \text{ (kN/m}^2\text{)}$$

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

$$H = B \cdot \gamma_c \cdot kh = 0.700 \times 24.00 \times 0.20 = 3.360$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : Unit Weight of Concrete (kN/m³)

Kh : Design Horizontal Seismic Coefficient

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Thus,

$$\cot(\xi_{is} - 0.00^\circ) = \frac{1}{\tan(\xi_{is})} = 1.10859$$

$$\xi_{is} = \tan^{-1}\left(\frac{1}{1.10859}\right) = 42.052^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{ea} = \frac{\cos(\phi - \theta - \alpha)}{\cos^2(\phi - \theta - \alpha)} \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta)}{\cos(\theta + \theta_s + \delta) \cdot \cos(\theta - \alpha)}} \right] \cdot \frac{1}{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}$$

$$= \frac{\cos(11.310^\circ) \times \cos(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)}{1} \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]$$

$$= 0.4733$$

In case $\phi - \alpha - \theta_s < 0$, $\sin(\phi - \alpha - \theta_s) = 0$.

$$K_{ea} = \frac{\cos^2(\phi - \theta_s - \theta)}{\cos^2(\phi - \theta_s - \theta)} \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_s)}{\cos(\theta + \theta_s + \delta) \cdot \cos(\theta - \alpha)}} \right] \cdot \frac{1}{\cos^2(30.00^\circ - 17.041^\circ - 0.00^\circ)}$$

$$= \frac{\cos(17.041^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 17.041^\circ + 0.00^\circ)}{1} \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 17.041^\circ)}{\cos(0.00^\circ + 17.041^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]$$

$$= 0.5765$$

In case $\phi - \alpha - \theta_s < 0$, $\sin(\phi - \alpha - \theta_s) = 0$.

$$\text{Weight of Embankment } W = 101.142 \text{ (kN/m)}$$

$$\text{Converted Load } q_0' = (W + q_0 \cdot wq_0) / B$$

$$= (101.142 + 5.00 \times 2.298) / 2.728$$

$$= 41.290 \text{ (kN/m}^2\text{)}$$

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_s	=	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	$\theta_0 = \tan^{-1}(kh)$	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	$\theta_0 = \tan^{-1}(kh')$	=	17.041	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{is} - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_s) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_s)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$$\cot(\xi_{is} - \alpha) = 0.85094$$

Thus,

$$\cot(\xi_{is} - 0.00^\circ) = \frac{1}{\tan(\xi_{is})} = 0.85094$$

$$\xi_{is} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{is}' - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_s') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_s')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 17.041^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 17.041^\circ)}}$$

$$\cot(\xi_{is}' - \alpha) = 1.10859$$

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Earth Pressure at the Top

$$P1 = q_0' \cdot K_{EA} = 41.290 \times 0.4733 = 19.541 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$P2 = K_{EA} \cdot \gamma_s \cdot h1 + p1$$

$$= 0.4733 \times 19.00 \times 0.600 + 19.541$$

$$= 24.936 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Junction

$$P3 = K_{EA} \cdot (\gamma_{sat} - \gamma_w) \cdot h2 + p2$$

$$= 0.5765 \times (20.00 - 9.80) \times 2.000 + 24.936$$

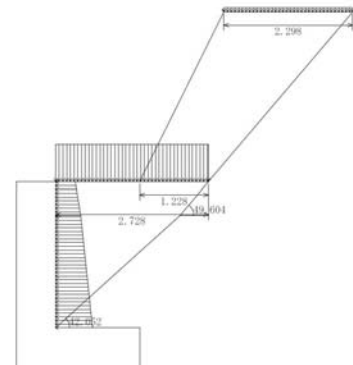
$$= 36.697 \text{ (kN/m}^2\text{)}$$

Design Earth Pressure

$$P_{HE} = P3 \cdot \cos \delta = 36.697 \times \cos(0.00^\circ)$$

$$= 36.697 \text{ (kN/m}^2\text{)}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h \cdot \gamma_w = 2.000 \times 9.80 = 19.600 \text{ (kN/m}^2\text{)}$$

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

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1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m ²)	L (m)	P•l/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•l/2) = 31.61	
Shear Force	S (kN/m)	Σ(P•l) = 63.22	

2) Seismic Condition-1

	P (kN/m ²)	L (m)	P•l/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•l/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	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	31.61
Re-bar	d1 As1	mm mm ²	610.0 794.4
Required Area of Re-bar	Back	mm ²	383.0
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm ²	1.26
	σs	N/mm ²	68.47
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	510.7
	inp	mm ²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	26.47
Re-bar	d1 As1	mm mm ²	610.0 794.4
Required Area of Re-bar	Back	mm ²	239.7
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm ²	1.05
	σs	N/mm ²	57.33
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	319.6
	inp	mm ²	794.4

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2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	63.22
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	0.104
Allowable Value	τa	N/mm ²	0.360
	τa2	N/mm ²	1.600

■Seismic Condition-1

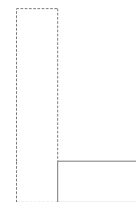
	Symbol	Unit	Junction
Shear Force	S	kN	52.94
Re-bar	d1 As1	mm mm ²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm ²	0.087
Allowable Value	τa	N/mm ²	0.540
	τa2	N/mm ²	2.400

1.3 Calculation of Bottom Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$S_w = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

Thus,

S_w : 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



$$Pw1 = (h1 \cdot \gamma_1 + h2 \cdot \gamma_{sat}) = 0.200 \times 19.00 + 2.400 \times 20.00 = 51.800$$

$$Pw2 = (h1 \cdot \gamma_1 + h2 \cdot \gamma_{sat}) = 0.200 \times 19.00 + 2.400 \times 20.00 = 51.800$$

Thus,

$Pw1$: Weight 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_1 : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

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1-3) Subgrade Reaction Force

	Intensity of subgrade reaction (kN/m ²)
Base	79.12
Edge	15.12

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ _w)	Unit (kN/m ²)
Base	2.827× 9.80	27.707
Edge	3.100× 9.80	30.380

(2)) Seismic Condition-1

2-1) Self-weight of Wall



$$S_w = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

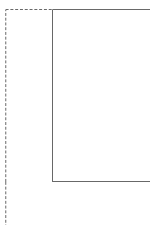
Thus,

S_w : 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



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$$P_{w1} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 0.600 \times 19.00 + 2.000 \times 20.00 = 51.400$$

$$P_{w2} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 0.600 \times 19.00 + 2.000 \times 20.00 = 51.400$$

Thus,

P_{w1} : Weight of Embankment at basis (kN/m²)

P_{w2} : Weight of Embankment at edge (kN/m²)

H_1 : Height of Embankment above water (m)

H_2 : 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)	Unit (kN/m ²)
Base	2.700× 9.80	26.460
Edge	2.700× 9.80	26.460

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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 (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×L/2) = 19.11		
Shear Force S (kN/m)	Σ(P×L) = 38.23		

1-2) Edge

	P (kN/m ²)	L (m)	P×L/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×L/2) = 11.55		
Shear Force S (kN/m)	Σ(P×L) = 23.10		

2) Seismic Condition-1

2-1) Base

	P (kN/m ²)	L (m)	P×L/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×L/2) = 6.53		
Shear Force S (kN/m)	Σ(P×L) = -13.06		

2-2) Edge

	P (kN/m ²)	L (m)	P×L/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×L/2) = -20.87		
Shear Force S (kN/m)	Σ(P×L) = -41.74		

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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	mm	585.0	585.0
	Asl	mm ²	794.4	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	mm	90.0	90.0
	Asl	mm ²	794.4	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	mm	585.0	585.0
	Asl	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	0.065	0.038
	τa	N/mm ²	0.360	0.360
Allowable Value	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	mm	90.0	90.0
	Asl	mm ²	794.4	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
	τa	N/mm ²	0.540	0.540
Allowable Value	τa2	N/mm ²	2.400	2.400

2.2.2.2 SLUICEWAY TYPE B

(1) BOX - LONGITUDINAL

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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)

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

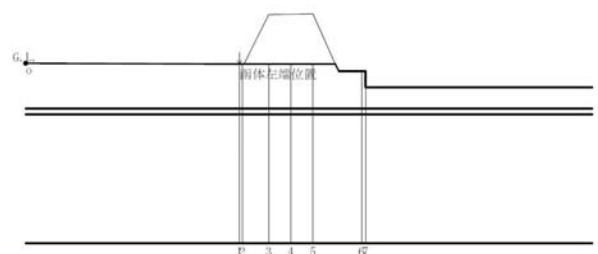
Span/ Block	Length of Block (m)	Depth for Subgrade Reaction(n)
1- 1	1.500	12.000
1- 2	1.600	5.700
2- 1	2.900	5.700
3- 1	2.926	5.700
3- 2	2.200	11.700

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

Span No	Block No	Flange		Reinforcing Bar				
		Portion	b (mm)	t (mm)	Outside Diameter@Pitch (Number)	Cover (mm)	Inside 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

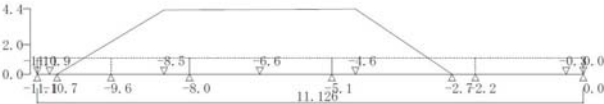
No	Calculation Point (m)	Name
1	-11.126	Box end (land side)
2	-10.876	Breast wall (land side)
3	-8.543	Levee end (land side)
4	-6.593	Levee center
5	-4.643	Levee end (river side)
6	-0.350	Breast wall (river side)
7	0.000	Box end (river side)



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2.1.2 Summary 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

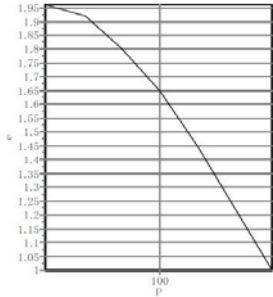


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

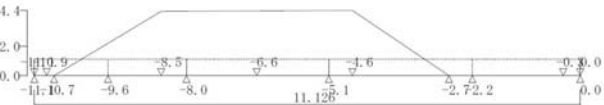
No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/m³)	Unit Weight (Saturated) (kN/m³)	Pre-Consolidation Stress q0 (kN/m²)	Elastic Modulus Es (kN/m²)
1	Adobe BL	Sand	4.000	17.500	18.500	0.0	7000.0
2	As	Sand	4.510	17.500	18.500	0.0	7000.0
3	Dc1	Clay	15.920	17.500	18.500	0.0	17500.0

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



2.2.2 Summary 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

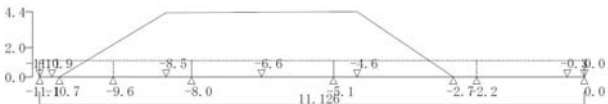


2.3 Residual Settlement

2.3.1 Summary of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vauce	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

3 Calculation of Box Culvert regarding Longitudinal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B} \cdot \frac{d^4 w}{dx^4} + k_v (w - w_g) = q \text{ (Swag)}$$

$$\frac{EA}{U} \cdot \frac{d^2 u}{dx^2} + k_s (u - u_g) = p \text{ (Displacement in axial direction of Box Culvert)}$$

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/cm²) {kN/m²}
- 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/cm²) {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}

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3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{om} = \frac{\log \frac{(B+2h_v \cdot \tan \theta) \cdot L}{(L+2h_v \cdot \tan \theta) \cdot B}}{\sum \frac{1}{E_i \log \frac{(B+2h_v \cdot \tan \theta)(L+2h_v \cdot \tan \theta)}{(L+2h_v \cdot \tan \theta)(B+2h_v \cdot \tan \theta)}}}$$

In case of B=L

$$E_{om} = \frac{\frac{1}{B+2h_v \cdot \tan \theta} + \frac{1}{B}}{\sum \frac{1}{E_i \left(\frac{1}{B+2h_v \cdot \tan \theta} + \frac{1}{B+2h_v \cdot \tan \theta} \right)}}$$

Thus,

- E_{om} : Converted Modulus of Deformation
- B : Loading Width = Width of Culvert
- L : Loading Length = Length of a span
- h_a : Depth for Calculation
- h_a : Depth from the ground to the bottom Elevation of Each Layer (m)
- E_i : Converted Modulus of Deformation of Each Layer (kN/m²)
- θ : Angle of Load Dispersion ($\theta=30^\circ$)

Span1-Block1 Land Side

B	4.000 (m)		
L	3.100 (m)		
h _a	12.000 (m)		
Layer	Layer Thickness (m)	Depth (m)	E _i (kN/m ²)
1	0.410	0.410	28000.0
2	11.590	12.000	70000.0
Total	12.000		
E _{om}	57216.6 (kN/m ²)		

※Layer Thickness and Depths are the values based on subgrade Surface.

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Span1-Block2 Land Side

B	1.900 (m)		
L	3.100 (m)		
h _a	5.700 (m)		
Layer	Layer Thickness (m)	Depth (m)	E _i (kN/m ²)
1	0.410	0.410	28000.0
2	5.290	5.700	70000.0
Total	5.700		
E _{om}	52339.3 (kN/m ²)		

※Layer Thickness and Depths are values Calculated from the subgrade

Span3-Block2 River Side

B	4.000 (m)		
L	5.126 (m)		
h _a	11.700 (m)		
Layer	Layer Thickness (m)	Depth (m)	E _i (kN/m ²)
1	0.410	0.410	28000.0
2	11.290	11.700	70000.0
Total	11.700		
E _{om}	58824.0 (kN/m ²)		

※Layer and Depth is the values from the subgrade

Span2-Block1 Center

B	1.900 (m)		
L	2.900 (m)		
h _a	5.700 (m)		
Layer	Layer Thickness (m)	Depth (m)	E _i (kN/m ²)
1	0.410	0.410	28000.0
2	5.290	5.700	70000.0
Total	5.700		
E _{om}	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)		
h _a	5.700 (m)		
Layer	Layer Thickness (m)	Depth (m)	E _i (kN/m ²)
1	0.410	0.410	28000.0
2	5.290	5.700	70000.0
Total	5.700		
E _{om}	53835.5 (kN/m ²)		

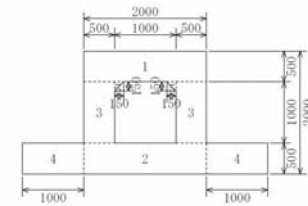
※Layer and Depth is the values from the subgrade

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3.2.2 Dimensions of Box Culvert

Span1-Block1 Land Side

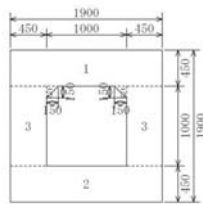


Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ⁴)	I _{oi} (m ⁴)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.022	1.450	0.0326	0.0473	0.00003
Total	4.022		3.2826	4.2348	0.14586

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.2826 / 4.022 = 0.8161 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 4.2348 + 0.14586 - 0.6660 \cdot 4.022 = 1.70183 \text{ (m}^4\text{)}$$

Span1-Block2 Land Side



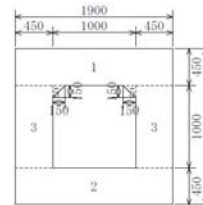
Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ⁴)	I _{oi} (m ⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.632 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.632 = 1.00722 \text{ (m}^4\text{)}$$

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Span2-Block1 Center

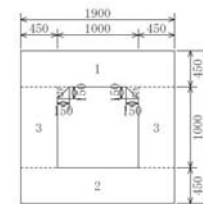


Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ⁴)	I _{oi} (m ⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.632 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.632 = 1.00722 \text{ (m}^4\text{)}$$

Span3-Block1 River Side



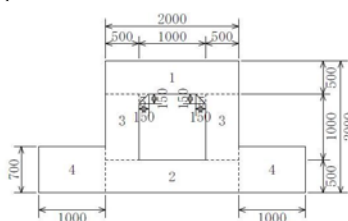
Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ⁴)	I _{oi} (m ⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.022	1.400	0.0315	0.0441	0.00003
Total	2.632		2.5110	3.2984	0.10388

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.632 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.632 = 1.00722 \text{ (m}^4\text{)}$$

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Span3-Block2 River Side



Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ⁴)	I _{oi} (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

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.5226 / 4.423 = 0.7965 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 4.3438 + 0.18219 - 0.6344 \cdot 4.423 = 1.72015 \text{ (m}^4\text{)}$$

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3.2.3 Table of Modulus of Subgrade Reaction

Coefficient of Lateral Shear Reaction of Soil

$$k_c = \lambda \cdot k_v$$

Thus,

k_s : 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)

k_v : 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	-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	10315.5	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)	$k_v \cdot B$ (kN/m ²)	$k_s \cdot B$ (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)	$k_v \cdot B$ (kN/m ²)	$k_s \cdot B$ (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	$k_v \cdot B$ (kN/m ²)	$k_s \cdot B$ (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

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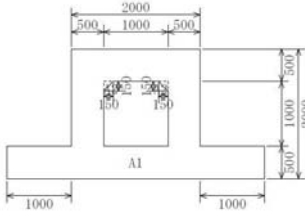
3.3 Load

3.3.1 Dead Load (Body Weight)

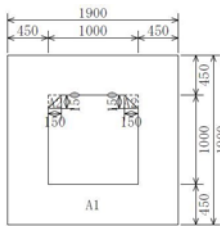
1) Weight of Main Body

$W = (A1 + A2 + A3) \cdot \gamma_c \text{ (kN/m)}$
A1: Cross Sectional Area (Excluding Hunch) (m²)
A2: Area of Upper Side Hunch (m²)
A3: Area of Lower Side Hunch (m²)
 γ_c : Unit Weight (Concrete) (kN/m³)

Span No. 1-1 Land Side
 $W = (4.000 + 0.023 + 0.000) \cdot 24.000$
 $= 96.540 \text{ (kN/m)}$

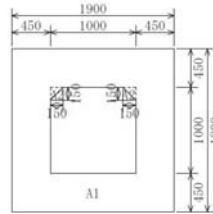


Span No. 1-2 Land Side
 $W = (2.610 + 0.023 + 0.000) \cdot 24.000$
 $= 63.180 \text{ (kN/m)}$

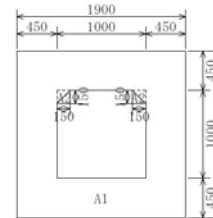


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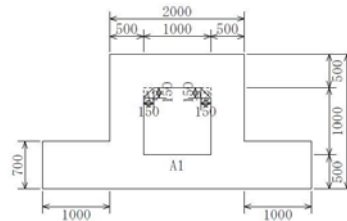
Span No. 2-1 Center
 $W = (2.610 + 0.023 + 0.000) \cdot 24.000$
 $= 63.180 \text{ (kN/m)}$



Span No. 3-1 River Side
 $W = (2.610 + 0.023 + 0.000) \cdot 24.000$
 $= 63.180 \text{ (kN/m)}$



Span No. 3-2 River Side
 $W = (4.400 + 0.023 + 0.000 + 0.000) \cdot 24.000$
 $= 106.140 \text{ (kN/m)}$



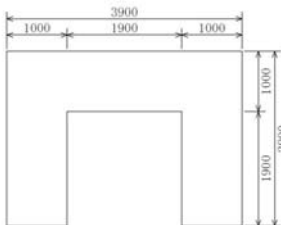
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2) Seepage Cutoff Wall Body Weight

$A1 = X1 \cdot L2$
 $A2 = L1 \cdot Y1 \cdot 2$
 $W = (A1 + A2) \cdot B \cdot \gamma_c \text{ (kN)}$
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)
 γ_c : Unit Weight (Concrete) (kN/m³)

SpanNo.2-SpanDistance from Base Point (1.450)

$A1 = 3.900 \cdot 1.000$
 $= 3.900 \text{ (m}^2\text{)}$
 $A2 = 1.000 \cdot 1.900 \cdot 2$
 $= 3.800 \text{ (m}^2\text{)}$
 $W = (3.900 + 3.800) \cdot 0.500 \cdot 24.00$
 $= 92.400 \text{ (kN)}$



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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

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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/m ²)	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

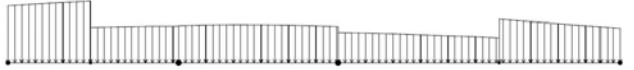
Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m ²)	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

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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	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



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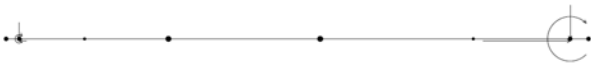
3.3.3 Point Load from Breast Walls

1) Normal Condition (Case Number: 1)

Case of Normal Condition 1

Name of Normal Load: [Gate Piers and Breast Walls (Normal) 1]

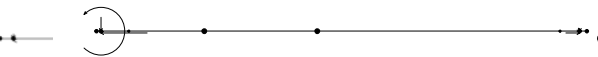
Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN·m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-40.40	93.20	-47.97
3	Right Breast Wall	10.776	497.78	193.79	-257.58



2) Seismic Condition (Total Number: 2)

Case of Seismic Condition 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 Seismic 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



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3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data 1	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 Data 1	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	Engaging Load (Dead Load)1	Gate Structure ·Breast Wall (Dead Load)1	1.0000
6	Engaging 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 Data 1	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	Engaging Load (Seismic)2	Seismic Load :Land Side →River Side	1.0000
6	Engaging Load (Dead Load)2	Gate Structure ·Breast Wall (Dead Load)2	1.0000

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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

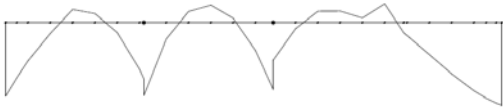
Span3 Name of Span: [River Side]

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]

Num ber	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]

Num ber	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

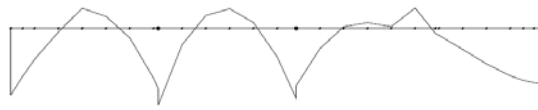
Span3 Name of Span: [River Side]

Num ber	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



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2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Num ber	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

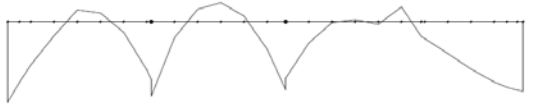
Span2 Name of Span: [Center]

Num ber	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

Displacement Diagram



Reaction Force of Ground



Reaction Force



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Span3 Name of Span: [River Side]

Num ber	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

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3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Num ber	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

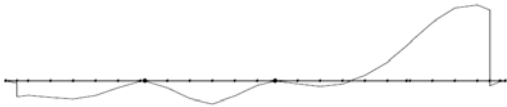
Span2 Name of Span: [Center]

Num ber	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]

Num ber	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



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Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Num ber	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]

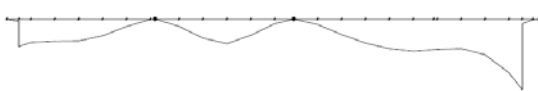
Num ber	Distance X (m)	Axial Force N (kN)	Shear Force S (kN)	Moment M (kN.m)
1	3.100	-0.001	0.000	0.000
2	3.600	36.277	151.055	47.610
3	4.100	57.517	126.409	121.771
4	4.600	63.703	-61.549	157.580
5	5.100	54.710	-143.057	104.144
6	5.600	30.430	-129.806	30.316
7	6.000	-0.001	0.000	0.000

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Span3 Name of Span: [River Side]

Num ber	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

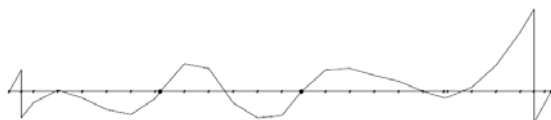
Bending Moment



Axial Force



Shear Force



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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,

θ_1 : Angle of Displacement (Left Side) (rad)

θ_2 : 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)	θ_1 (Degree) (rad)	θ_2 (Degree) (rad)	Bending Angle θ (Degree) (rad)
Span (2- 1)	0.00000	-0.52829	0.13220	0.66049
	0.00000	-0.00922	0.00231	0.01153
Span (3- 2)	0.00000	0.13220	0.96582	0.83362
	0.00000	0.00231	0.01686	0.01453

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	

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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

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3.7 Stress Intensity Analysis

3.7.1 Calculation Condition

It is considered that double reinforced section which bending moment is acting on.

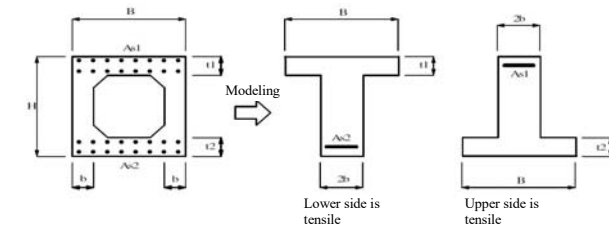
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.

Position of Neutral Axis

$$x = \frac{n \cdot (A_s \cdot d + A_s' \cdot d') + B \cdot t^2 / 2}{n \cdot (A_s + A_s') + B \cdot t}$$

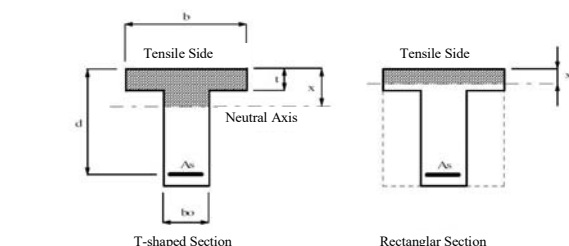
Thus,

- x : Position of Neutral Axis (mm)
- n : Ratio of Young modulus = 9.0
- A_s : Area of Re-bar in tensile side (mm²)
- A_s' : Area of Re-bar in compressive side (mm²)
- 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.



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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	

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Calculation Condition (In Case Bottom Slab is Tensile)

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 A _s (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side A _s ' (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)

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 A _s (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Tensile Side A _s ' (mm ²)
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

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3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1

Item		Sym bol	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

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Calculation Case1: Normal Condition

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block2

Item		Symb ol	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

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3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition

Span3-Block2

Item		Sym bol	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

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2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Sym bol	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	900.0	1000.0	900.0	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	----

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Span1-Block2

Item		Sym bol	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	----

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Span2-Block1

Item		Sym bol	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		Sym bol	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		Sym bol	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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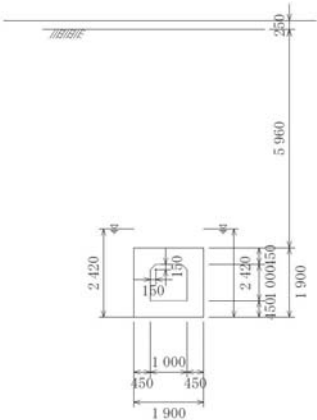
2.2.2.2 SLUICEWAY TYPE B

(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	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil(Wet)	γ_t	kN/m ³	19.00
Soil(Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Craterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	osa	N/mm ² Normal (General)	140.00
		N/mm ² Normal (Harsh)	140.00
		N/mm ² Seismic	186.00
Allow Compressive Strength	osa'	N/mm ² Normal	140.00
		N/mm ² Seismic	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
—	—	—		—	—	—	

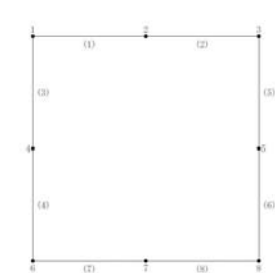
Cover					
Location		Cover(mm)		Location	
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Midwall		—	—		—

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

1.2 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

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	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/m ²)	10.000

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

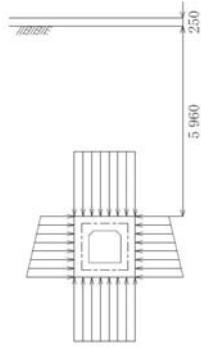
4) Supporting Point

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
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (2) Left Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (3) Right Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level)	$= 1.000 \times 0.250 \times 22.60 = 5.65 \text{ (kN/m}^2\text{)}$
Embankment (Above Water Level)	$= 1.000 \times 5.440 \times 19.00 = 103.36 \text{ (kN/m}^2\text{)}$
Embankment (Below Water Level)	$= 1.000 \times 0.520 \times 10.20 = 5.30 \text{ (kN/m}^2\text{)}$
Water Pressure	$= 0.520 \times 9.80 = 5.10 \text{ (kN/m}^2\text{)}$

$$\Sigma w_d = 119.41 \text{ (kN/m}^2\text{)}$$

(2) Surcharge Load at Road

Surcharge =	10.000 (kN/m ²)
Snow Load =	0.00 (kN/m ²)

$$\Sigma q_d = 10.000 \text{ (kN/m}^2\text{)}$$

(3) Load Acting on Top Slab

Uniformly Distributed Load

$$w = 119.41 + 10.00 = 129.41 \text{ (kN/m}^2\text{)}$$

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

$$p_i = K_o \times (q_d + \gamma_o \times \gamma_a + Z_u \times \gamma + (Z_o - Z_u) \times \gamma') + (Z_o - Z_u) \times \gamma_w$$

K_o : Coefficient of Earth Pressure at Rest = 0.500

Z_o : Depth of Calculation Point from Embankment Top (m)

(1) Left Side Wall

Symbol	Calculation Point	Z_o (m)	p (kN/m ²)
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	Z_o (m)	p (kN/m ²)
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

$$U = 2.420 \times 1.900 \times 9.80 = 45.06 \text{ (kN/m)}$$

$$w = \frac{-45.06}{1.900} = -23.72 \text{ (kN/m}^2\text{)}$$

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

$$\bar{X} = \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)}$$

$$e = \frac{B}{2} - \bar{X} = 0.000 \text{ (m)}$$

(2) Subgrade Reaction Intensity

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_l = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 128.15 \text{ (kN/m}^2\text{)}$$

$$q_r = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 128.15 \text{ (kN/m}^2\text{)}$$

$$q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 128.15 \text{ (kN/m}^2\text{)}$$

$$q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 128.15 \text{ (kN/m}^2\text{)}$$

Thus, T : Thickness of Side Wall

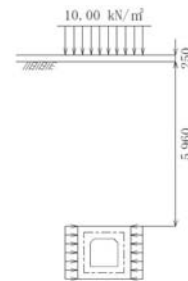
q_l : Subgrade Reaction Intensity on Left Edge

q_r : Subgrade Reaction Intensity on Right Edge

q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

q_r' : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface $q_L = 10.000 \text{ (kN/m}^2\text{)}$

Load

(1) Vertical Load Effecting Top Slab

$$w_l = q_L = 10.00 \text{ (kN/m}^2\text{)}$$

(2) Horizontal Load Acting on Left Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

(3) Horizontal Load Effecting on Right Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

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

$$\bar{X} = \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)}$$

$$e = \frac{B}{2} - \bar{X} = 0.000 \text{ (m)}$$

$$(2) \text{ Subgrade Reaction Intensity}$$

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_l = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_r = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

Thus, T : Thickness of Side Wall
 q_l : Subgrade Reaction Intensity on Left Edge
 q_r : Subgrade Reaction Intensity on Right Edge
 q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
 q_r' : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

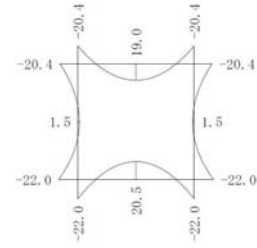
Dead Load + Live Load

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

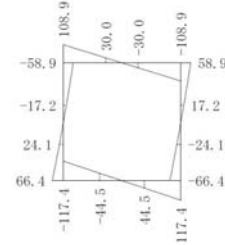
Load Number
13: Member Distribution Load (X Direction)
14: Member Distribution Load (Y Direction)

1.2.4 Calculation Results of Frame Analysis

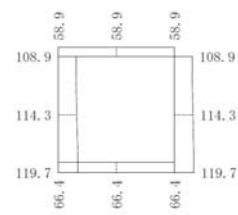
Bending Moment



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	-20.444	19.033	-20.444
Axial Force	N	0.000	0.000	0.000
Section Width	b	1.000	1.000	1.000
Section Height	h	0.450	0.450	0.450
Outside Cover	d1	90.0	90.0	90.0
Inside Cover	d2	90.0	90.0	90.0
Required Area of Re-Bar	External	424.8	0.0	424.8
	Internal	0.0	394.9	0.0
Re-Bar	External	D16 @ 250 D-@-794.4	D16 @ 250 D-@-794.4	D16 @ 247 D-@-804.0
	Internal	D16 @ 250 D-@-794.4	D16 @ 250 D-@-794.4	D16 @ 250 D-@-794.4
Neutral Axis	X	0.065	0.065	0.065
Stress Intensity	oc	1.86	1.73	1.85
	os	76.07	70.82	75.18
	os'	0.00	0.00	0.00
Allowable Stress	oca	8.20	8.20	8.20
	osa	140.00	140.00	140.00
	osa'	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	req	566.4	526.5	566.4
	inp	794.4	794.4	804.0
Case	---	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	-20.444	1.470	-22.035
Axial Force	N	108.902	114.302	119.702
Section Width	b	1.000	1.000	1.000
Section Height	h	0.450	0.450	0.450
Outside Cover	d1	90.0	90.0	90.0
Inside Cover	d2	90.0	90.0	90.0
Required Area of Re-Bar	External	0.0	0.0	0.0
	Internal	0.0	0.0	0.0
Re-Bar Arrangement	External	D16 @ 250 D-@-794.4	D16 @ 250 D-@-794.4	D16 @ 250 D-@-794.4
	Internal	D13 @ 250 D-@-506.8	D13 @ 250 D-@-506.8	D13 @ 250 D-@-506.8
Neutral Axis	X	0.184	1.414	0.189
Stress Intensity	oc	1.28	0.30	1.36
	os	11.03	0.00	11.14
	os'	0.00	-2.01	0.00
Allowable Stress	oca	8.20	8.20	8.20
	osa	140.00	140.00	140.00
	osa'	-186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	min			
	req	0.0	0.0	0.0
	inp	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	Ext ermal	mm ²	0.0	0.0	0.0
	Inter nal	mm ²	0.0	0.0	0.0
Re-Bar	Ext ermal	mm ²	D16 @ 247 D- @- 804.0	D16 @ 250 D- @- 794.4	D16 @ 250 D- @- 794.4
	Inter nal	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

$$\tau_m = \frac{S}{b \times d} \leq \tau_a$$

$$b = 1000 \text{ (mm)}$$

Member	Location	S (kN)	d (mm)	τm (N/mm2)	τa (N/mm2)	Cases	L (m)
Top Slab	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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1.2.3 Stress Calculation.....11

1.3 Calculation of Heel Slab 13

1.3.1 Load 13

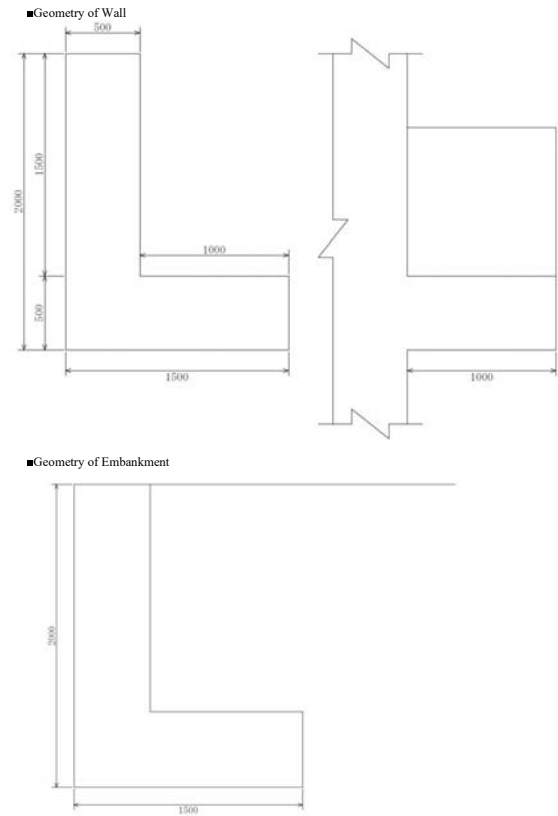
1.3.2 Summary of Cross Sectional Force.....16

1.3.3 Stress Intensity Calculation.....18

1 Calculation of Land Side Breast Wall

1.1 Design Conditions

1.1.1 Dimensions



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 A _w (mm ² /m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

1.1.3 Loads

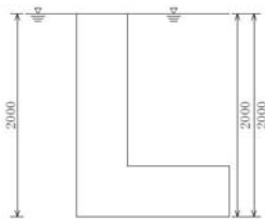
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

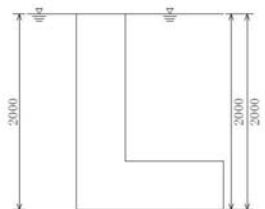
	(m)
Toe	2.000
Heel	2.000



1-2) Seismic Condition Number of Cases [1]

<Case 1>

	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front

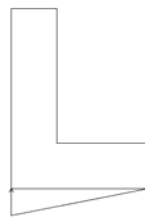


3

2) Subgrade Reaction

2-1) Normal <Case 1>

	(kN/m ²), (m)
Toe	154.13
Heel	0.00
Load Width	1.500



2-2) Seismic <Case 1>

	(kN/m ²), (m)
Toe	130.64
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

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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_s (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load $q_0' = (W + q_0 \cdot w_{q0})/B$
 $= (0.000 + 10.00 \times 1.500) / 1.500$
 $= 10.000$ (kN/m²)

Earth Pressure at the Top

$p_1 = q_0' \cdot K_0 = 10.000 \times 0.500 = 5.000$ (kN/m²)

Earth Pressure at Water Level

$p_2 = K_0 \cdot \gamma_s \cdot h_1 + p_1$
 $= 0.500 \times 19.00 \times 0.000 + 5.000$
 $= 5.000$ (kN/m²)

Earth Pressure at Junction

$p_3 = K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2$
 $= 0.500 \times (20.00 - 9.80) \times 1.500 + 5.000$
 $= 12.650$ (kN/m²)

Design Earth Pressure

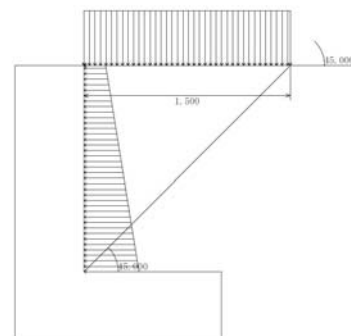
$P = p_3$
 $= 12.650$ (kN/m²)

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.50
 B : Converted Load Width (m)
 γ_t : 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)

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■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

$P_h = h_h \cdot \gamma_w = 1.500 \times 9.80 = 14.700$ (kN/m²)

Thus,

h_h : 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

$H = B \cdot \gamma_c \cdot kh = 0.500 \times 24.00 \times 0.20 = 2.400$

Thus,

H : Inertia Force (kN/m²)
 B : Thickness of Vertical Wall (m)
 γ_c : Unit Weight of Concrete (kN/m³)
 kh : Design Horizontal Seismic Coefficient

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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/m³)
Unit Weight of Soil (Saturated)	γsat	=	20.00	(kN/m³)
Unit Weight of Water	γw	=	9.80	(kN/m³)
Surcharge	q0	=	5.00	(kN/m²)
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)	δE	=	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	θ0 = tan⁻¹(kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	θ0 = tan⁻¹(kh')	=	19.026	(degree)

■Active Angle of Rupture in Seismic Condition

$$\cot(\xi_{sa} - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$$\cot(\xi_{sa} - \alpha) = 0.85094$$

Thus,

$$\cot(\xi_{sa} - 0.00^\circ) = \frac{1}{\tan(\xi_{sa})} = 0.85094$$

$$\xi_{sa} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{sa}' - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 19.026^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.026^\circ)}}$$

$$\cot(\xi_{sa}' - \alpha) = 1.24217$$

Thus,

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$$P2 = K_{sa} \cdot \gamma_s \cdot h1 + p1$$

$$= 0.4733 \times 19.00 \times 0.000 + 2.366$$

$$= 2.366 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Junction

$$P3 = K_{sa}' \cdot (\gamma_{sat} - \gamma_w) \cdot h2 + p2$$

$$= 0.6214 \times (20.00 - 9.80) \times 1.500 + 2.366$$

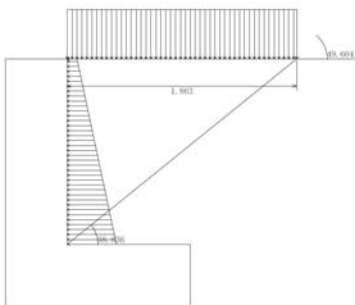
$$= 11.874 \text{ (kN/m}^2\text{)}$$

Design Earth Pressure

$$P_R = P3 \cdot \cos \delta = 11.874 \times \cos(0.00^\circ)$$

$$= 11.874 \text{ (kN/m}^2\text{)}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.500 \times 9.80 = 14.700 \text{ (kN/m}^2\text{)}$$

Thus,

$$h_h : \text{Height from the base of Vertical Wall to Water Surface in Back Side (m)}$$

$$\gamma_w : \text{Unit Weight of Water (kN/m}^3\text{)}$$

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$$\cot(\xi_{sa}' - 0.00^\circ) = \frac{1}{\tan(\xi_{sa}')} = 1.24217$$

$$\xi_{sa}' = \tan^{-1}\left(\frac{1}{1.24217}\right) = 38.836^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{sa} = \frac{\cos^2(\phi - \theta_0 - \theta)}{\cos \theta_0 \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0 + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2$$

$$= 0.4733$$

In case $\phi - \alpha - \theta_0 < 0$, $\sin(\phi - \alpha - \theta_0) = 0$.

$$K_{sa}' = \frac{\cos^2(\phi - \theta_0' - \theta)}{\cos \theta_0' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0' + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0')}{\cos(\theta + \theta_0' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2}$$

$$= \frac{\cos^2(30.00^\circ - 19.026^\circ - 0.00^\circ)}{\cos(19.026^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 19.026^\circ + 0.00^\circ)} \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.026^\circ)}{\cos(0.00^\circ + 19.026^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2$$

$$= 0.6214$$

In case $\phi - \alpha - \theta_0' < 0$, $\sin(\phi - \alpha - \theta_0') = 0$.

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/m²)

Earth Pressure at the Top

$$P1 = q0' \cdot K_{sa} = 5.000 \times 0.4733 = 2.366 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

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1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m²)	L (m)	P · L/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) = 13.68		
Shear Force S (kN/m)	Σ(P · L) = 27.35		

2) Seismic Condition-1

	P (kN/m²)	L (m)	P · L/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) = 14.49		
Shear Force S (kN/m)	Σ(P · L) = 28.97		

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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

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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

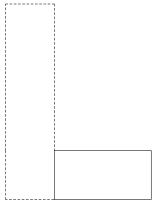
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1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$S_w = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

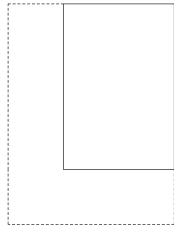
Thus,

S_w : 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



$$P_{w1} = (h_1 \cdot \gamma_c + h_2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

$$P_{w2} = (h_1 \cdot \gamma_c + h_2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

Thus,

P_{w1} : Weight of Embankment at basis (kN/m²)

P_{w2} : Weight of Embankment at edge (kN/m²)

H_1 : Height of Embankment above water (m)

H_2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

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1-3) Subgrade Reaction Force

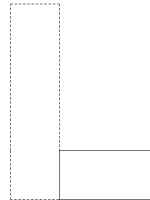
	Intensity of subgrade reaction (kN/m ²)
Base	102.75
Edge	0.00

1-4) Uplift Force

	Calculating Formula Height of Water Level × Unit Weight of Water (γ_w)	Unit (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



$$S_w = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

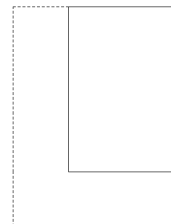
Thus,

S_w : Weight of Wall (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



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$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$
 $Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$
 Thus,
 $Pw1$: Weight 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	87.09
Edge	0.00

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unit (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 (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) $\Sigma(P \times L/2) = -35.18$			
Shear Force S (kN/m) $\Sigma(P \times L) = 70.35$			

1-2) Edge

	P (kN/m ²)	L (m)	P×L/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) $\Sigma(P \times L/2) = -16.20$			
Shear Force S (kN/m) $\Sigma(P \times L) = -32.40$			

2) Seismic Condition-1

2-1) Base

	P (kN/m ²)	L (m)	P×L/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) $\Sigma(P \times L/2) = 29.85$			
Shear Force S (kN/m) $\Sigma(P \times L) = 59.69$			

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2-2) Edge

	P (kN/m ²)	L (m)	P×L/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) $\Sigma(P \times L/2) = -13.70$			
Shear Force S (kN/m) $\Sigma(P \times L) = -27.40$			

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	mm	385.0	90.0
	As1	mm ²	1146.0	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	σ_c	N/mm ²	2.47	1.03
	σ_s	N/mm ²	85.61	36.95
Allowable Value	σ_{ca}	N/mm ²	8.20	8.20
	σ_{sa}	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	mm	385.0	90.0
	As1	mm ²	1146.0	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	σ_c	N/mm ²	2.10	0.87
	σ_s	N/mm ²	72.64	31.25
Allowable Value	σ_{ca}	N/mm ²	12.30	12.30
	σ_{sa}	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

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(2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	70.35	-32.40
Re-bar	d1	mm	385.0	90.0
	As1	mm ²	1146.0	1146.0
Effective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	tm	N/mm ²	0.183	0.079
	ta	N/mm ²	0.360	0.360
Allowable Value	ta2	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	mm	385.0	90.0
	As1	mm ²	1146.0	1146.0
Effective Height	d	mm	385.0	410.0
Cross Section Width	b	mm	1000.0	1000.0
Average Shear Stress Intensity	tm	N/mm ²	0.155	0.067
	ta	N/mm ²	0.540	0.540
Allowable Value	ta2	N/mm ²	2.400	2.400

1 Calculation of River Side Breast Wall.....1

1.1 Design Condition 1

1.1.1 Dimensions.....1

1.1.2 Reinforcement Arrangement.....2

1.1.3 Loads.....3

1.2 Calculation of Vertical Wall 5

1.2.1 Load 5

1.2.2 Summary of Cross-sectional Internal Forces 9

1.2.3 Stress Calculation.....10

1.3 Calculation of Bottom Slab 12

1.3.1 Load 12

1.3.2 Summary of Cross-Sectional Force 15

1.3.3 Stress Intensity Calculation.....17

2.2.2.2 SLUICeway TYPE B

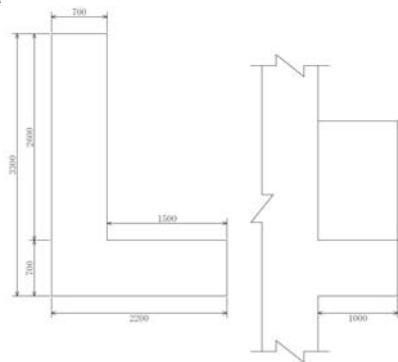
(4) BREAST WALL - RIVER SIDE

1 Calculation of River Side Breast Wall

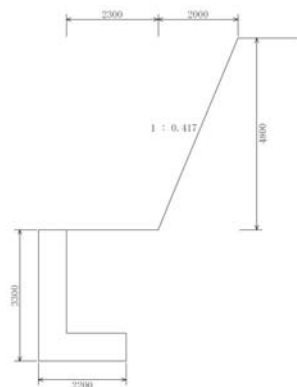
1.1 Design Condition

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 A _w (mm ² /m)
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.3 Loads

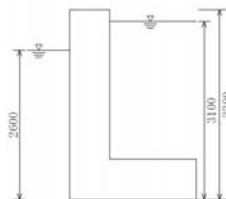
■Basic Load

1)Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

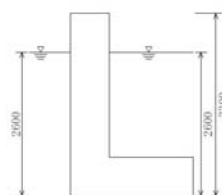
	(m)
Toe	2.600
Heel	3.100



1-2) Seismic Condition Number of Cases [1]

<Case 1>

	(m)
Toe	2.600
Heel	2.600
Direction	Back → Front



3

2)Subgrade Reaction

2-1) Normal <Case 1>

	(kN/m ²), (m)
Toe	173.05
Heel	21.72
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m ²), (m)
Toe	108.03
Heel	9.82
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

4

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_s (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot w_0) / B \\ &= (155.040 + 10.00 \times 3.100) / 2.600 \\ &= 71.554 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 71.554 \times 0.500 = 35.777 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.200 + 35.777 \\ &= 37.677 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Bottom Surface of Base

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 2.400 + 37.677 \\ &= 49.917 \text{ (kN/m}^2\text{)} \end{aligned}$$

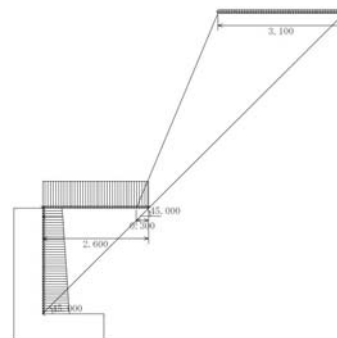
Design Earth Pressure

$$\begin{aligned} P &= p_3 \\ &= 49.917 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

- K_0 : Coefficient of Earth Pressure at Rest = 0.50
- B : Converted Load Width (m)
- γ_t : 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_0 : 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

$$P_h = h_h \cdot \gamma_w = 2.400 \times 9.80 = 23.520 \text{ (kN/m}^2\text{)}$$

Thus,

- h_h : 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

$$H = B \cdot \gamma_c \cdot k_h = 0.700 \times 24.00 \times 0.20 = 3.360$$

Thus,

- H : Inertia Force (kN/m²)
- B : Thickness of Vertical Wall (m)
- γ_c : Unit Weight of Concrete (kN/m³)
- k_h : Design Horizontal Seismic Coefficient

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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/m³)
Unit Weight of Soil (Dry)	γsat	=	20.00	(kN/m³)
Unit Weight of Water	γw	=	9.80	(kN/m³)
Surcharge	q0	=	5.00	(kN/m²)
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)	δEa	=	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	θ ₀ = tan ⁻¹ (kh)	=	11.310	(degree)
Compound Angle in Seismic Condition underwater	θ ₀ = tan ⁻¹ (kh')	=	16.638	(degree)

■Active Angle of Rupture in Seismic Condition

$$\begin{aligned} \cot(\xi_{\text{se}} - \alpha) &= -\tan(\phi + \delta_{\text{E}} + \theta - \alpha) + \sec(\phi + \delta_{\text{E}} + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_{\text{E}} + \theta) \cdot \sin(\phi + \delta_{\text{E}})}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \\ \cot(\xi_{\text{se}} - \alpha) &= 0.85094 \\ \text{Thus,} \\ \cot(\xi_{\text{se}} - 0.00^\circ) &= \frac{1}{\tan(\xi_{\text{se}})} = 0.85094 \\ \xi_{\text{se}} &= \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604(^\circ) \end{aligned}$$

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■Active Angle of Rupture underwater in Seismic Condition

$$\begin{aligned} K_{\text{Ea}} &= \frac{\cos^2(\phi - \theta - \theta)}{\cos \theta_{\text{se}} \cdot \cos^2 \theta \cdot \cos(\theta + \theta_{\text{se}} + \delta)} \left[1 + \sqrt{\frac{\sin(\phi + \delta_{\text{E}}) \cdot \sin(\phi - \alpha - \theta)}{\cos(\theta + \theta_{\text{se}} + \delta) \cdot \cos(\theta - \alpha)}} \right]^2 \\ &= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \\ &\quad \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2 \\ &= 0.4733 \end{aligned}$$

However, $\phi - \alpha - \theta < 0$ のときは $\sin(\phi - \alpha - \theta)$

Weight of Embankment	W	=	127.653 (kN/m)
Converted Load	q0'	=	(W + q0 · wq0) / B
		=	(127.653 + 5.00 × 2.442) / 2.657
		=	52.631 (kN/m²)

Earth Pressure at the Top

$$P1 = q0' \cdot K_{\text{EA}} = 52.631 \times 0.4733 = 24.908 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} P2 &= K_{\text{EA}} \cdot \gamma_{\text{t}} \cdot h1 + p1 \\ &= 0.4733 \times 19.00 \times 0.700 + 24.908 \\ &= 31.203 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Junction

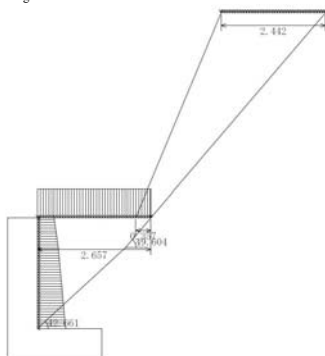
$$\begin{aligned} P3 &= K_{\text{EA}} \cdot (\gamma_{\text{sat}} - \gamma_{\text{w}}) \cdot h2 + p2 \\ &= 0.5681 \times (20.00 - 9.80) \times 1.900 + 31.203 \\ &= 42.212 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P_{\text{HE}} &= P3 \cdot \cos \delta = 42.212 \times \cos(0.00^\circ) \\ &= 42.212 \text{ (kN/m}^2\text{)} \end{aligned}$$

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■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.900 \times 9.80 = 18.620 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

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	49.92	1.000	24.96
Σ	73.44	----	36.72
Bending Moment M (kN.m/m)	Σ(P · l²/2) = 36.72		
Shear Force S (kN/m)	Σ(P · l) = 73.44		

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	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 · l²/2) = 32.10		
Shear Force S (kN/m)	Σ(P · l) = 64.19		

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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	36.72
Re-bar	d1	mm	610.0
	As1	mm²	794.4
Required Area of Re-bar	Back	mm²	446.1
Neutral Axis	X	m	0.087
	xc	N/mm²	1.46
Stress Intensity	σs	N/mm²	79.53
	σca	N/mm²	8.20
Allowable Value	σsa	N/mm²	140.00
	min	mm²	
Minimum Area of Re-Bar	req	mm²	594.7
	inp	mm²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	32.10
Re-bar	d1	mm	610.0
	As1	mm²	794.4
Required Area of Re-bar	Back	mm²	291.5
Neutral Axis	X	m	0.087
	xc	N/mm²	1.28
Stress Intensity	σs	N/mm²	69.52
	σca	N/mm²	12.30
Allowable Value	σsa	N/mm²	186.00
	min	mm²	
Minimum Area of Re-Bar	req	mm²	388.7
	inp	mm²	794.4

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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	tm	N/mm ²	0.120
Allowable Value	ta	N/mm ²	0.360
	ta2	N/mm ²	1.600

■Seismic Condition-1

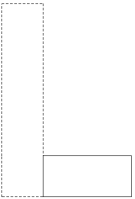
	Symbol	Unit	Junction
Shear Force	S	kN	64.19
Re-bar	d1 As1	mm mm ²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	tm	N/mm ²	0.105
Allowable Value	ta	N/mm ²	0.540
	ta2	N/mm ²	2.400

1.3 Calculation of Bottom Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$Sw = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

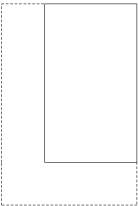
Thus,

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



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.200 \times 19.00 + 2.400 \times 20.00 = 51.800$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.200 \times 19.00 + 2.400 \times 20.00 = 51.800$$

Thus,

Pw1 : Weight 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/m ²)
Base	124.90
Edge	21.72

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unit (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



$$Sw = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

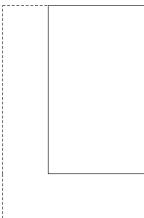
Thus,

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



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.700 \times 19.00 + 1.900 \times 20.00 = 51.300$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.700 \times 19.00 + 1.900 \times 20.00 = 51.300$$

Thus,

Pw1 : Weight 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	76.78
Edge	9.82

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unit (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/m ²)	L (m)	P·L/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·L/2) = 41.67			
Shear Force S (kN/m) Σ(P·L) = 83.34			

1-2) Edge

	P (kN/m ²)	L (m)	P·L/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·L/2) = -8.25			
Shear Force S (kN/m) Σ(P·L) = -16.50			

2) Seismic Condition-1

2-1) Base

	P (kN/m ²)	L (m)	P·L/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·L/2) = 17.08			
Shear Force S (kN/m) Σ(P·L) = 34.16			

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2-2) Edge

	P (kN/m ²)	L (m)	P·L/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·L/2) = -16.40			
Shear Force S (kN/m) Σ(P·L) = -32.80			

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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	41.67	-8.25
Re-bar	d1 As1	mm mm ²	585.0 794.4	90.0 794.4
Required Area of Re-bar	Upper	mm ²		98.3
	Lower	mm ²	530.0	
Neutral Axis	X	m	0.085	0.087
Stress Intensity	σc	N/mm ²	1.77	0.33
	σs	N/mm ²	94.20	17.87
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	706.6	131.1
	inp	mm ²	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 mm ²	585.0 794.4	90.0 794.4
Required Area of Re-bar	Upper	mm ²		147.7
	Lower	mm ²	160.6	
Neutral Axis	X	m	0.085	0.087
Stress Intensity	σc	N/mm ²	0.73	0.65
	σs	N/mm ²	38.62	35.52
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	214.2	196.9
	inp	mm ²	794.4	794.4

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(2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	83.34	-16.50
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	0.142	0.027
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	34.16	-32.80
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	0.058	0.054
Allowable Value	τa	N/mm ²	0.540	0.540
	τa2	N/mm ²	2.400	2.400

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2.2.2.3 SLUCEWAY TYPE C

(1) BOX - LONGITUDINAL

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Structural Calculation of Sluiceway Type-C

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1

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)

1.2.1 Span and Block

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

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) 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

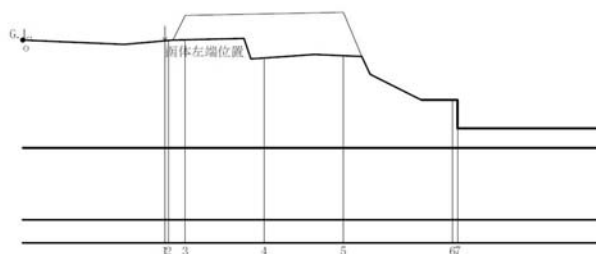
Main Re-bar

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	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

2.1 Immediate Settlement

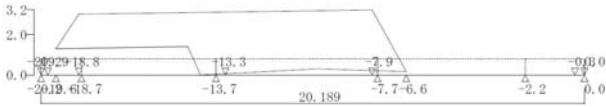
2.1.1 Settlement Calculation Points

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 Summary 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



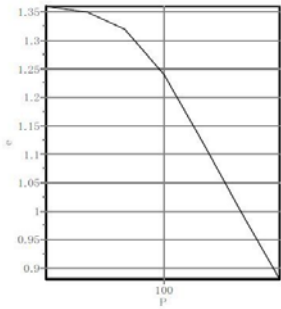
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2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/ m ³)	Unit Weight (Saturated) (kN/ m ³)	Pre-Consolidation Stress q ₀ (kN/m ²)	Elastic Modulus Es (kN/m ²)
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

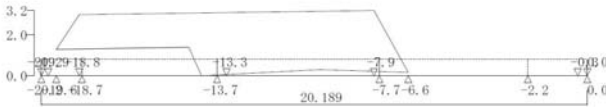
No	Consolidation Pressure P(kN/m ²)	Void Ratio e
1	12.0000	1.3600
2	25.0000	1.3500
3	50.0000	1.3200
4	100.0000	1.2400
5	200.0000	1.1200
6	400.0000	1.0000
7	800.0000	0.8800



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2.2.2 Summary 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



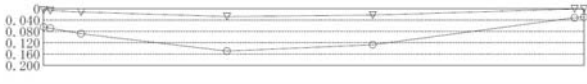
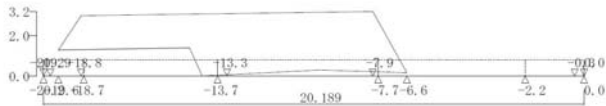
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2.3 Residual Settlement

2.3.1 Summary of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Vauc	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), hence the foundation is taken as flexible



▽ : Immediate Settlement
○ : Residual Settlement

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3 Calculation of Box Culvert regarding Longitudinal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B} \cdot \frac{d^4 w}{dx^4} + k_v (w - w_g) = q \text{ (Swag)}$$
$$\frac{EA}{U} \cdot \frac{d^2 u}{dx^2} + k_s (u - u_g) = p \text{ (Displacement in axial direction of Box Culvert)}$$

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

$$E_{om} = \frac{\log \frac{(B+2h_v \cdot \tan \theta) \cdot L}{(L+2h_v \cdot \tan \theta) \cdot B}}{\sum \frac{1}{E_i \log \frac{(B+2h_v \cdot \tan \theta)(L+2h_{v-1} \cdot \tan \theta)}{(L+2h_v \cdot \tan \theta)(B+2h_{v-1} \cdot \tan \theta)}}$$

In case of B=L

$$E_{om} = \frac{\frac{1}{B+2h_v \cdot \tan \theta} + \frac{1}{B}}{\sum \frac{1}{E_i \left(\frac{1}{B+2h_v \cdot \tan \theta} + \frac{1}{B+2h_{v-1} \cdot \tan \theta} \right)}}$$

Thus

- E_{om} : 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/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/m ²)
1	4.850	4.850	21600.0
2	7.150	12.000	62800.0
Total	12.000		
Eom	26529.8 (kN/m ²)		

※Layer Thickness and Depths are the values based on subgrade Surface.

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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	4.850	4.850	21600.0
2	0.850	5.700	62800.0
Total	5.700		
Eom	22431.0 (kN/m ²)		

※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/m ²)
1	4.850	4.850	21600.0
2	0.850	5.700	62800.0
Total	5.700		
Eom	22412.7 (kN/m ²)		

※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/m ²)
1	4.850	4.850	21600.0
2	0.850	5.700	62800.0
Total	5.700		
Eom	22468.7 (kN/m ²)		

※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/m ²)
1	4.850	4.850	21600.0
2	7.150	12.000	62800.0
Total	12.000		
Eom	26782.8 (kN/m ²)		

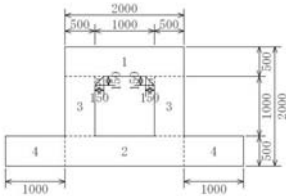
※Layer and Depth is the values from the subgrade

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3.2.2 Dimensions of Box Culvert

Span1-Block1 Land Side

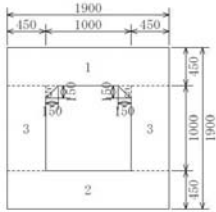


Positi on	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ⁴)	Ioi (m ⁴)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.023	1.450	0.0326	0.0473	0.00003
Total	4.023		3.2826	4.2348	0.14586

$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.2826 / 4.023 = 0.8161 \text{ (m)}$

$I = \Sigma(A_i \cdot Y_i^2) / \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 4.2348 + 0.14586 - 0.6660 \cdot 4.023 = 1.70183 \text{ (m}^4\text{)}$

Span1-Block2 Land Side



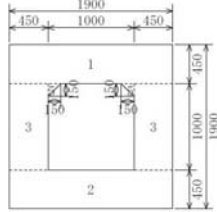
Positi on	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ⁴)	Ioi (m ⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.633 = 0.9538 \text{ (m)}$

$I = \Sigma(A_i \cdot Y_i^2) / \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.633 = 1.00722 \text{ (m}^4\text{)}$

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Span2-Block1 Center

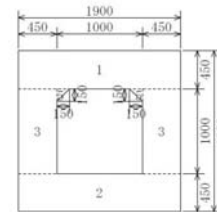


Positi on	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ⁴)	Ioi (m ⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8122	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.633 = 0.9538 \text{ (m)}$

$I = \Sigma(A_i \cdot Y_i^2) / \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.633 = 1.00722 \text{ (m}^4\text{)}$

Span3-Block1 River Side



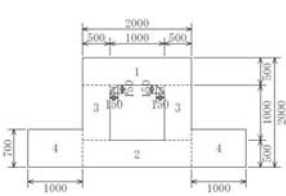
Positi on	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ⁴)	Ioi (m ⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.633 = 0.9538 \text{ (m)}$

$I = \Sigma(A_i \cdot Y_i^2) / \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.633 = 1.00722 \text{ (m}^4\text{)}$

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Span3-Block2 River Side



Positi on	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ⁴)	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

$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.5226 / 4.423 = 0.7965 \text{ (m)}$

$I = \Sigma(A_i \cdot Y_i^2) / \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 4.3438 + 0.18219 - 0.6344 \cdot 4.423 = 1.72015 \text{ (m}^4\text{)}$

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3.2.3 Table of Modulus of Subgrade Reaction

Coefficient of Lateral Shear Reaction of Soil

$k_v = \lambda \cdot k_v$

Thus,

k_s : 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)

k_v : 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	-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)	$k_v \cdot B$ (kN/m ²)	$k_s \cdot B$ (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	44572.2	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)	$k_v \cdot B$ (kN/m ²)	$k_s \cdot B$ (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	$k_v \cdot B$ (kN/m ²)	$k_s \cdot B$ (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

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3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

$$W = (A1 + A2 + A3) \cdot \gamma_c \quad (\text{kN/m})$$

A1: Cross Sectional Area (Excluding Hunch) (m²)

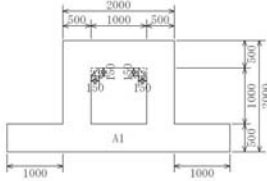
A2: Area of Upper Side Hunch (m²)

A3: Area of Lower Side Hunch (m²)

γ_c : Unit Weight (Concrete) (kN/m³)

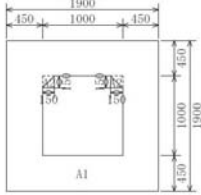
Span No. 1-1 Land Side

$$W = (4.000 + 0.023 + 0.000) \cdot 24.000 \\ = 96.540 \text{ (kN/m)}$$



Span No. 1-2 Land Side

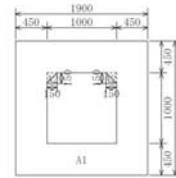
$$W = (2.610 + 0.023 + 0.000) \cdot 24.000 \\ = 63.180 \text{ (kN/m)}$$



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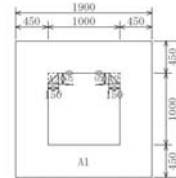
Span No. 2-1 Center

$$W = (2.610 + 0.023 + 0.000) \cdot 24.000 \\ = 63.180 \text{ (kN/m)}$$



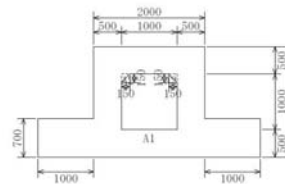
Span No. 3-1 River Side

$$W = (2.610 + 0.023 + 0.000) \cdot 24.000 \\ = 63.180 \text{ (kN/m)}$$



Span No. 3-2 River Side

$$W = (4.400 + 0.023 + 0.000) \cdot 24.000 \\ = 106.140 \text{ (kN/m)}$$



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2) Seepage Cutoff Wall Body Weight

$$A1 = X1 \cdot L2$$

$$A2 = L1 \cdot Y1 \cdot 2$$

$$W = (A1 + A2) \cdot B \cdot \gamma_c \quad (\text{kN})$$

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)

γ_c : Unit Weight (Concrete) (kN/m³)

SpanNo.2-SpanDistance from Base Point (3.000)

$$A1 = 3.900 \cdot 1.000$$

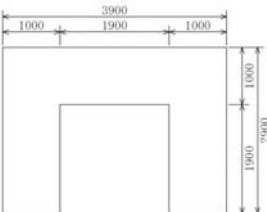
$$= 3.900 \text{ (m}^2\text{)}$$

$$A2 = 1.000 \cdot 1.900 \cdot 2$$

$$= 3.800 \text{ (m}^2\text{)}$$

$$W = (3.900 + 3.800) \cdot 0.500 \cdot 24.00$$

$$= 92.400 \text{ (kN)}$$



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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

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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)	-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



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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/m ²)	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/m ²)	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

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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)	-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



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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]

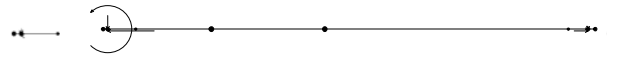
Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN·m)
1	Gate Structure	19.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-40.40	93.20	-47.97
3	Right Breast Wall	19.289	466.72	150.06	-282.66



2) Seismic Condition (Total Number: 2)

Case of Seismic Condition 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 Seismic 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



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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)l	Gate Structure -Breast Wall (Normal)l	1.0000
6	Arbitrary Load (Normal)l	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)l	Surcharge in Seismic Condition	1.0000
6	Ingaging Load (Dead Load)l	Gate Structure -Breast Wall (Dead Load)l	1.0000
7	Ingaging Load (Seismic)l	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)l	Surcharge in Seismic Condition	1.0000

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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

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Span3 Name of Span: [River Side]

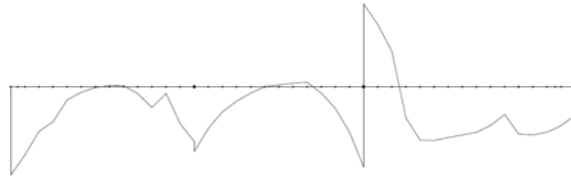
Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	32.9	18.4	104.6	122.8	-18.2	-50.0	○	-393.529
2	0.500	32.9	19.4	99.8	113.5	-13.7	-50.0	○	-295.560
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

28

Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



29

3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side --> River Side]

Span1 Name of Span: [Land Side]

Num ber	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]

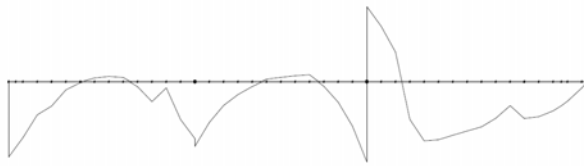
Num ber	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	6.3	-6.2	160.2	146.6	13.6	19.0	○	297.584
2	0.500	6.3	-4.1	158.5	149.9	8.6	19.0	○	187.615
3	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

30

Displacement Diagram



Reaction Force of Ground



Reaction Force



32

Span3 Name of Span: [River Side]

Num ber	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

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2) Calculation Case2 - Load: [Seismic Condition River Side --> Land Side]

Span1 Name of Span: [Land Side]

Num ber	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]

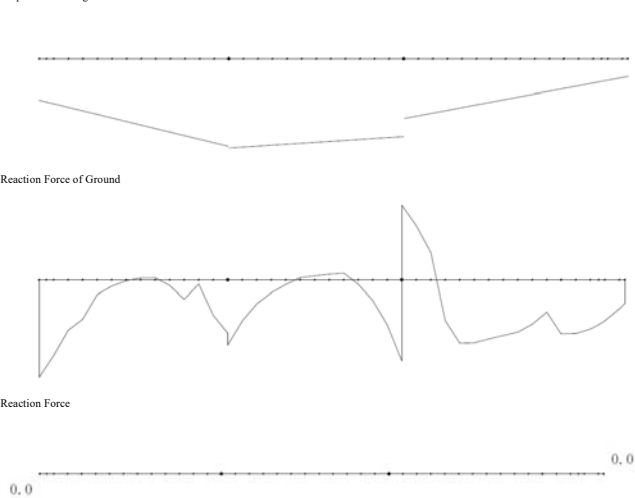
Num ber	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	6.3	-6.2	160.2	146.6	13.6	19.0	○	297.584
2	0.500	6.3	-4.1	158.5	149.9	8.6	19.0	○	187.615
3	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

33

Span3 Name of Span: [River Side]

Num ber	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



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Num ber	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

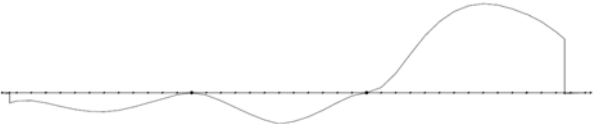
Span2 Name of Span: [Center]

Num ber	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

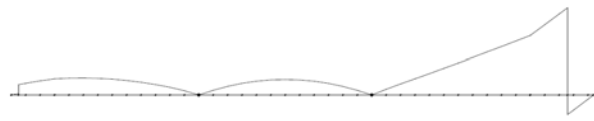
Span3 Name of Span: [River Side]

Num ber	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

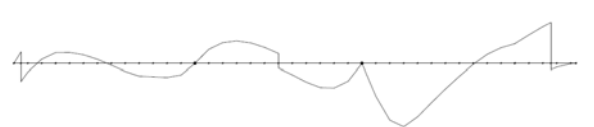
Bending Moment



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

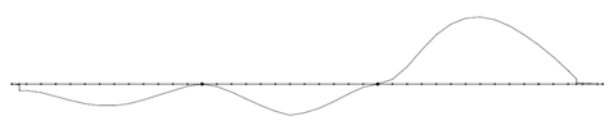
Span2 Name of Span: [Center]

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

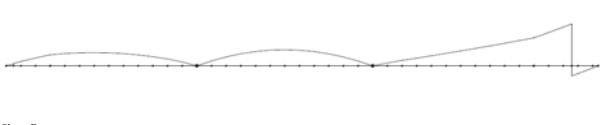
Span3 Name of Span: [River Side]

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

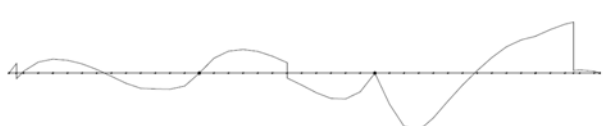
Bending Moment



Axial Force



Shear Force



Span1 Name of Span: [Land Side]

Num ber	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

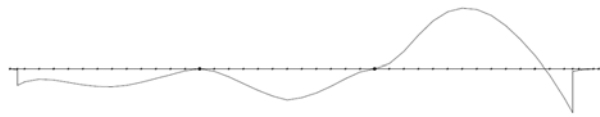
Span2 Name of Span: [Center]

Num ber	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

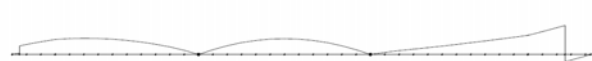
Span3 Name of Span: [River Side]

Num ber	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

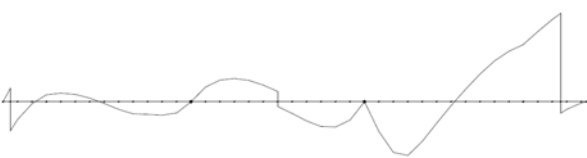
Bending Moment



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
 $\theta = \theta_1 - \theta_2$; - Initial Bending Angle
Thus,
 θ_1 : Angle of Displacement (Left Side) (rad)
 θ_2 : 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)	θ_1 (Degree) (rad)	θ_2 (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)

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3.7 Stress Intensity Analysis

3.7.1 Calculation Condition

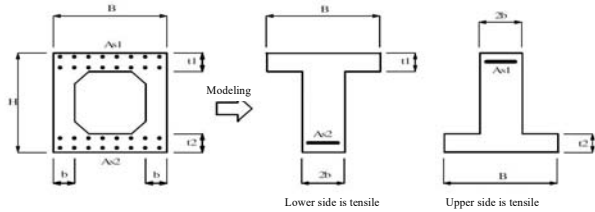
It is considered that double reinforced section which bending moment is acting on. The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.

Position of Neutral Axis

$$x = \frac{n \cdot (A_s \cdot d + A_s' \cdot d') + B \cdot t^2 / 2}{n \cdot (A_s + A_s') + B \cdot t}$$

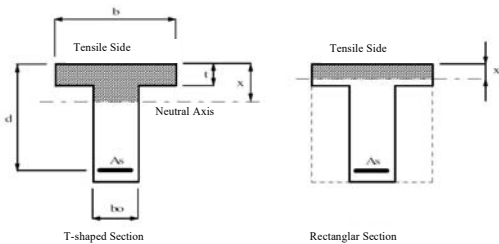
Thus,

- x : Position of Neutral Axis (mm)
- n : Ratio of Young modulus = 9.0
- A_s : Area of Re-bar in tensile side (mm²)
- A_s' : Area of Re-bar in compressive side (mm²)
- 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.



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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	

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 A _s (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side A _s ' (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 A _s (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Tensile Side A _s ' (mm ²)
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

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3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block2

Item		Sym bol	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

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3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition

Span3-Block2

Item		Sym bol	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		900.0	900.0	900.0	900.0
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

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2) Calculation Case2: Seismic Condition River Side →Land Side

Span1-Block1

Item		Sym bol	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	----

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Span1-Block2

Item		Sym bol	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	----

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Span2-Block1

Item		Sym bol	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	----

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Span3-Block1

Item		Sym bol	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	----

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Span3-Block2

Item		Sym bol	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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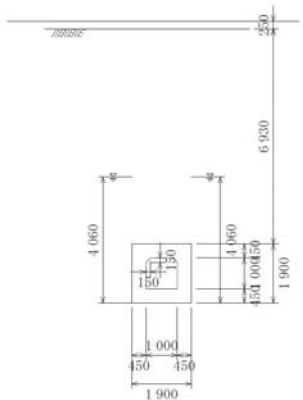
2.2.2.3 SLUICEWAY TYPE C

(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	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	osa	N/mm ²	Normal (General)	140.00
		N/mm ²	Normal (Harsh)	140.00
		N/mm ²	Seismic	186.00
Allow Compressive Strength	osa'	N/mm ²	Normal	140.00
		N/mm ²	Seismic	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		Right Corner	D16	247	
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		Right Sidewall	D13	280	

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		Right Corner	D16	247	
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 A _w (mm ² /m)
Top Slab	100	0.0
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Load

Surchage		(kN/m ²)
Surchage		0.000
Snow Load		0.000

Dead Load (Water Level)		
Case	External Water Level(m)	Internal Water Level(m)
1	4.060	0.000

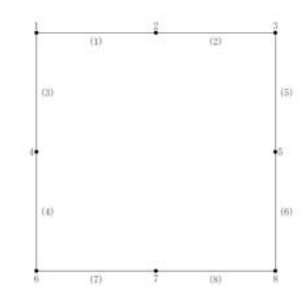
External Water Level: Height from Bottom Surface of Bottom Slab
Internal Water Level: Height from Top Surface of Bottom Slab

Live Load	
Intensity of Distribution Load Q _w (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

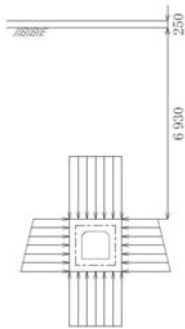
4) Supporting Point

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
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (2) Left Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (3) Right Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level)	$= 1.000 \times 0.250 \times 22.60 = 5.65 \text{ (kN/m}^2\text{)}$
Embankment (Above Water Level)	$= 1.000 \times 4.770 \times 19.00 = 90.63 \text{ (kN/m}^2\text{)}$
Embankment (Below Water Level)	$= 1.000 \times 2.160 \times 10.20 = 22.03 \text{ (kN/m}^2\text{)}$
Water Pressure	$= 2.160 \times 9.80 = 21.17 \text{ (kN/m}^2\text{)}$

$$\Sigma w_d = 139.48 \text{ (kN/m}^2\text{)}$$

(2) Surcharge Load at Road

Surcharge =	0.000 (kN/m ²)
Snow Load =	0.00 (kN/m ²)

$$\Sigma q_d = 0.000 \text{ (kN/m}^2\text{)}$$

(3) Load Acting on Top Slab

Uniformly Distributed Load	$w = 139.48 + 0.00 = 139.48 \text{ (kN/m}^2\text{)}$

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

$$p_i = K_o \times (q_d + \gamma_o \times \gamma_a + Z_u \times \gamma + (Z_o - Z_u) \times \gamma) + (Z_o - Z_u) \times \gamma_w$$

K_o : Coefficient of Earth Pressure at Rest = 0.500

Z_o : Depth of Calculation Point from Embankment Top (m)

(1) Left Side Wall

Symbol	Calculation Point	Z_o (m)	p (kN/m ²)
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	Z_o (m)	p (kN/m ²)
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

$$U = 4.060 \times 1.900 \times 9.80 = 75.60 \text{ (kN/m)}$$

$$w = \frac{-75.60}{1.900} = -39.79 \text{ (kN/m}^2\text{)}$$

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

$$\bar{X} = \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)}$$

$$e = \frac{B}{2} - \bar{X} = 0.000 \text{ (m)}$$

(2) Subgrade Reaction Intensity

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$M_o = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_1 = \frac{\Sigma V}{B} + \frac{6 \times M_o}{B^2} = 122.14 \text{ (kN/m}^2\text{)}$$

$$q_r = \frac{\Sigma V}{B} - \frac{6 \times M_o}{B^2} = 122.14 \text{ (kN/m}^2\text{)}$$

$$q_1^* = q_1 + \frac{q_r - q_1}{B} \times \frac{T}{2} = 122.14 \text{ (kN/m}^2\text{)}$$

$$q_r^* = q_r + \frac{q_1 - q_r}{B} \times \frac{T}{2} = 122.14 \text{ (kN/m}^2\text{)}$$

Thus, T : Thickness of Side Wall

q_1 : Subgrade Reaction Intensity on Left Edge

q_r : Subgrade Reaction Intensity on Right Edge

q_1^* : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

q_r^* : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface $q_L = 10.000 \text{ (kN/m}^2\text{)}$

Load

(1) Vertical Load Effecting Top Slab

$$w_l = q_L = 10.00 \text{ (kN/m}^2\text{)}$$

(2) Horizontal Load Acting on Left Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

(3) Horizontal Load Effecting on Right Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

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

$$\bar{X} = \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)}$$

$$e = \frac{B}{2} - \bar{X} = 0.000 \text{ (m)}$$

(2) Subgrade Reaction Intensity
 $M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$
 $q_l = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$
 $q_r = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$
 $q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$
 $q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$

Thus, T : Thickness of Side Wall
 q_l : Subgrade Reaction Intensity on Left Edge
 q_r : Subgrade Reaction Intensity on Right Edge
 q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
 q_r' : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

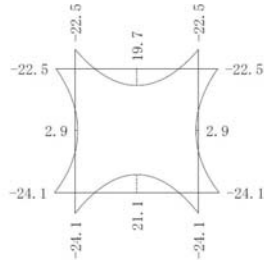
Dead Load + Live Load

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

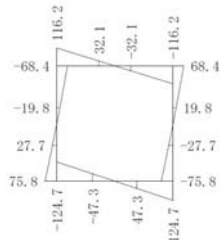
Load Number
13: Member Distribution Load (X Direction)
14: Member Distribution Load (Y Direction)

1.2.4 Calculation Results of Frame Analysis

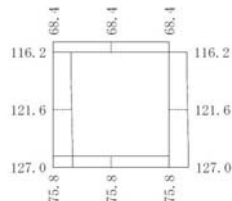
Bending Moment



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	σ_c	N/mm ²	2.03	1.78	2.03
	σ_s	N/mm ²	82.63	72.27	82.63
	σ_s'	N/mm ²	0.00	0.00	0.00
Allowable Stress	σ_{ca}	N/mm ²	8.20	8.20	8.20
	σ_{sa}	N/mm ²	140.00	140.00	140.00
	σ_{sa}'	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+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	-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

$$\tau_m = \frac{S}{b \times d} \leq \tau_a$$

$$b = 1000 \text{ (mm)}$$

Member	Location	S (kN)	d (mm)	τm (N/mm ²)	τa (N/mm ²)	Cases	L (m)
Top Slab	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

1 Calculation of Land Side Breast Wall 1

1.1 Design Conditions 1

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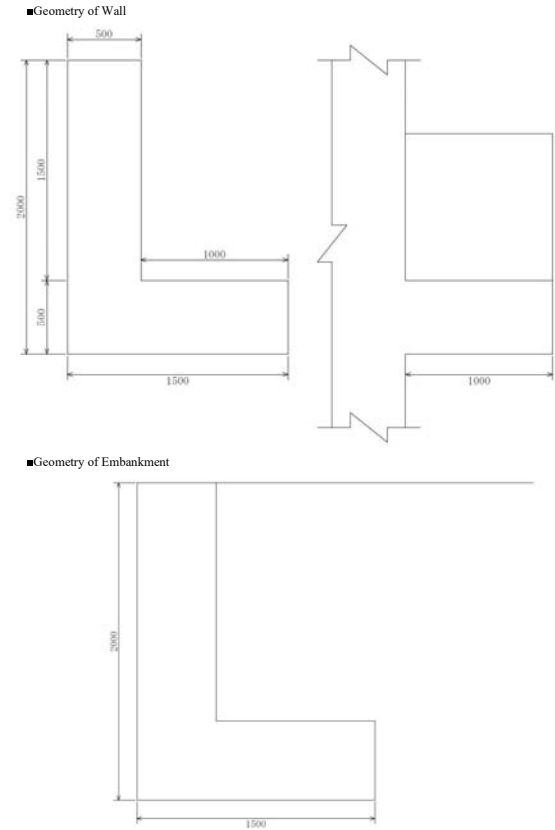
2.2.2.3 SLUICEWAY TYPE C

(3) BREAST WALL - LAND SIDE

1 Calculation of Land Side Breast Wall

1.1 Design Conditions

1.1.1 Dimensions



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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/mm ²	Normal (General)	140.00
		N/mm ²	Normal (Harsh)	140.00
		N/mm ²	Seismic	186.00
Allow Compressive Strength	σsa'	N/mm ²	Normal	140.00
		N/mm ²	Seismic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φ_{res}	°	30
Peak Angle of Internal Friction	φ_{peak}	°	30
Coefficient of Lateral Earth Pressure at-rest	K_o		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 A _w (mm ² /m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

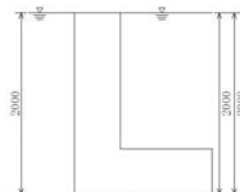
1.1.4 Loads

■Basic Load

1) Water Level

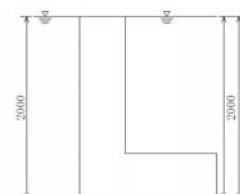
1-1) Normal Condition Number of Cases [1]

<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



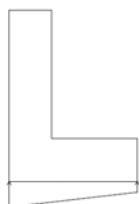
3

4

2) Subgrade Reaction

2-1) Normal <Case 1>

	(kN/m ³), (m)
Toe	95.78
Heel	40.25
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m ³), (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

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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)

※ξ₀(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot wq_0)/B \\ &= (0.000 + 10.00 \times 1.500) / 1.500 \\ &= 10.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 10.000 \times 0.500 = 5.000 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.000 + 5.000 \\ &= 5.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Junction

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 1.500 + 5.000 \\ &= 12.650 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

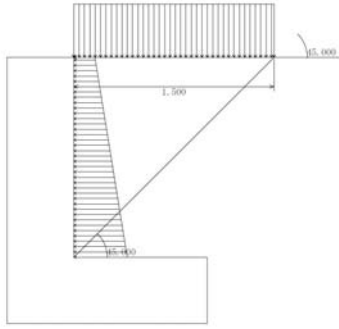
$$\begin{aligned} P &= p_3 \\ &= 12.650 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

- K₀ : Coefficient of Earth Pressure at Rest = 0.50
- B : Converted Load Width (m)
- γ_t : Unit Weight of Soil (Wet) (kN/m³)
- γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)
- γ_w : Unit Weight of Water (kN/m³)
- q₀ : Surcharge (kN/m²)
- w_{q0} : Width of Surcharge (m)
- h₁ : Height above Water Surface (m)
- h₂ : Height under Water Surface (m)

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■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

$$P_h = h \cdot \gamma_w = 1.500 \times 9.80 = 14.700 \text{ (kN/m}^2\text{)}$$

Thus,

h : 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

$$H = B \cdot \gamma_c \cdot kh = 0.500 \times 24.00 \times 0.20 = 2.400$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : 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)	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

$$\cot(\xi_{sa} - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}} \\ = -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \\ \cot(\xi_{sa} - \alpha) = 0.85094$$

Thus,

$$\cot(\xi_{sa} - 0.00^\circ) = \frac{1}{\tan(\xi_{sa})} = 0.85094$$

$$\xi_{sa} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{sa}' - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0'') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0'')}} \\ = -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 19.026^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.026^\circ)}} \\ \cot(\xi_{sa}' - \alpha) = 1.24217$$

Thus,

$$\cot(\xi_{sa}' - 0.00^\circ) = \frac{1}{\tan(\xi_{sa}')} = 1.24217$$

$$\xi_{sa}' = \tan^{-1}\left(\frac{1}{1.24217}\right) = 38.836^\circ$$

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■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{sa} = \frac{\cos^2(\phi - \theta - \theta)}{\cos \theta_0' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0' + \delta_E)} \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0')}{\cos(\theta + \theta_0' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2 \\ = \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2 \\ = 0.4733$$

In case $\phi - \alpha - \theta_0' < 0$, $\sin(\phi - \alpha - \theta_0') = 0$.

$$K_{sa}' = \frac{\cos^2(\phi - \theta_0'' - \theta)}{\cos \theta_0'' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0'' + \delta_E)} \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0'')}{\cos(\theta + \theta_0'' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2 \\ = \frac{\cos^2(30.00^\circ - 19.026^\circ - 0.00^\circ)}{\cos(19.026^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 19.026^\circ + 0.00^\circ)} \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.026^\circ)}{\cos(0.00^\circ + 19.026^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2 \\ = 0.6214$$

In case $\phi - \alpha - \theta_0'' < 0$, $\sin(\phi - \alpha - \theta_0'') = 0$.

Weight of Embankment W $\gamma = 0.000$ (kN/m)

$$\text{Converted Load } q0' = \frac{W + q0 \cdot wq0}{B} \\ = \frac{0.000 + 5.00 \times 1.863}{1.863} \\ = 5.000 \text{ (kN/m}^2\text{)}$$

Earth Pressure at the Top

$$P1 = q0' \cdot K_{sa} = 5.000 \times 0.4733 = 2.366 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$P2 = K_{sa} \cdot \gamma_c \cdot h1 + p1 \\ = 0.4733 \times 19.00 \times 0.000 + 2.366 \\ = 2.366 \text{ (kN/m}^2\text{)}$$

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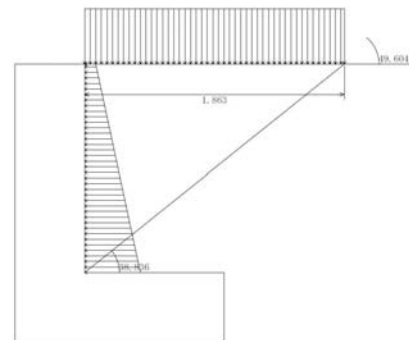
Earth Pressure at Junction

$$P3 = K_{sa} \cdot (\gamma_{sat} - \gamma_w) \cdot h2 + p2 \\ = 0.6214 \times (20.00 - 9.80) \times 1.500 + 2.366 \\ = 11.874 \text{ (kN/m}^2\text{)}$$

Design Earth Pressure

$$P_{HE} = P3 \cdot \cos \delta = 11.874 \times \cos(0.00^\circ) \\ = 11.874 \text{ (kN/m}^2\text{)}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h \cdot \gamma_w = 1.500 \times 9.80 = 14.700 \text{ (kN/m}^2\text{)}$$

Thus,

h : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

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1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P(kN/m ²)	l(m)	P·l/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) = 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(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) = 14.49	
Shear Force	S(kN/m)	Σ(P·l) = 28.97	

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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

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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

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1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$Sw = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

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



$$Pw1 = (h1 \cdot \gamma_1 + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.00$$

$$Pw2 = (h1 \cdot \gamma_1 + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.00$$

Thus,

Pw1 : Weight 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)

γ₁ : 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/m ²)
Base	77.27
Edge	40.25

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1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unit (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



$$S_w = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

Thus,

S_w : Weight of Wall (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



$$P_{w1} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.00$$

$$P_{w2} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.00$$

Thus,

P_{w1} : Weight of Embankment at basis (kN/m²)

P_{w2} : Weight of Embankment at edge (kN/m²)

H_1 : Height of Embankment above water (m)

H_2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

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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)	Unit (kN/m ²)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

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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 (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)	$\Sigma(P \cdot L/2) = 22.43$		
Shear Force	S (kN/m)	$\Sigma(P \cdot L)$	= 44.87

1-2) Edge

	P (kN/m ²)	L (m)	P×L/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)	$\Sigma(P \cdot L/2) = 3.93$		
Shear Force	S (kN/m)	$\Sigma(P \cdot L)$	= 7.85

2) Seismic Condition-1

2-1) Base

	P (kN/m ²)	L (m)	P×L/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)	$\Sigma(P \cdot L/2) = 16.54$		
Shear Force	S (kN/m)	$\Sigma(P \cdot L)$	= 33.08

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2-2) Edge

	P (kN/m ²)	L (m)	P×L/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)	$\Sigma(P \cdot L/2) = -0.35$		
Shear Force	S (kN/m)	$\Sigma(P \cdot L)$	= -0.71

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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	mm	385.0	385.0
	As1	mm ²	794.4	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	mm	385.0	90.0
	As1	mm ²	794.4	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	mm	385.0	385.0
	As1	mm ²	794.4	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
	τa	N/mm ²	0.360	0.360
Allowable Value	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	mm	385.0	90.0
	As1	mm ²	794.4	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

1 Calculation of River Side Breast Wall.....1

1.1 Design Conditions 1

1.1.1 Dimensions.....1

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1.3 Calculation of Heel Slab.....14

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1.3.2 Summary of Cross Sectional Force.....17

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2.2.2.3 SLUICEWAY TYPE C

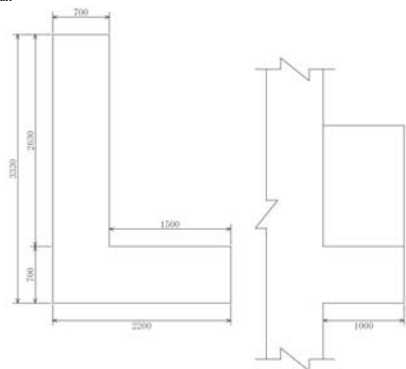
(4) BREAST WALL - RIVER SIDE

1 Calculation of River Side Breast Wall

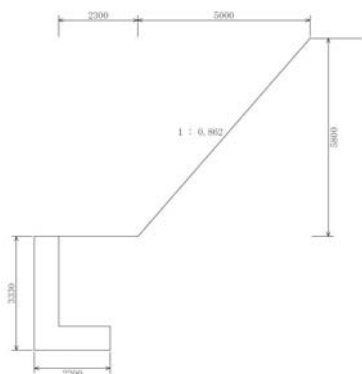
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	osa	N/mm ²	Normal (General)	140.00
		N/mm ²	Normal (Harsh)	140.00
		N/mm ²	Seismic	186.00
Allow Compressive Strength	osa'	N/mm ²	Normal	140.00
		N/mm ²	Seismic	186.00

■Soil

Backfill Angle of Internal Friction	ϕ	°	30.00
Residual Angle of Internal Friction	ϕ_{res}	°	30
Peak Angle of Internal Friction	ϕ_{peak}	°	30
Coefficient of Lateral Earth Pressure at-rest	K_o		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 A _w (mm ² /m)
Side Wall	100.0	0.0
Bottom Slab	100.0	0.0

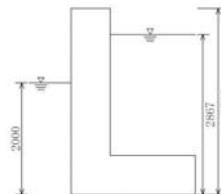
1.1.4 Loads

■Basic Load

1) Water Level

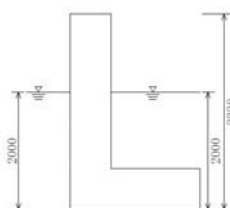
1-1) Normal Condition Number of Cases [1]

<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



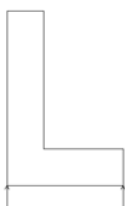
3

4

2) Subgrade Reaction

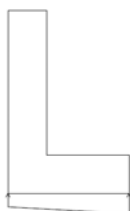
2-1) Normal <Case 1>

	(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

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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)

※ξ₀(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

Converted Load q0' = (W + q0 + wq0)/B
= (80.446 + 10.00 + 1.130) / 2.630
= 34.884 (kN/m²)

Earth Pressure at the Top

p1 = q0' · Ko = 34.884 × 0.500 = 17.442 (kN/m²)

Earth Pressure at Water Level

p2 = Ko · γ_t · h1 + p1
= 0.500 × 19.00 × 0.463 + 17.442
= 21.841 (kN/m²)

Earth Pressure at Junction

p3 = Ko · (γ_{sat} - γ_w) · h2 + p2
= 0.500 × (20.00 - 9.80) × 2.167 + 21.841
= 32.892 (kN/m²)

Design Earth Pressure

P = p3
= 32.892 (kN/m²)

Thus,

K₀ : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γ_t : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

q₀ : Surcharge (kN/m²)

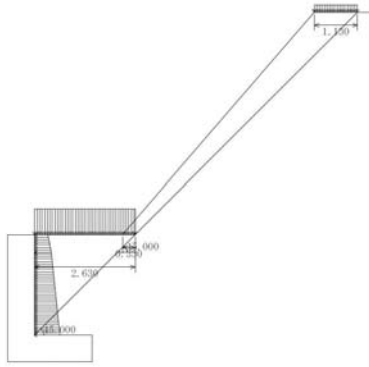
w_{q0} : Width of Surcharge (m)

h₁ : Height above Water Surface (m)

h₂ : Height under Water Surface (m)

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■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

$$P_h = h \cdot \gamma_w = 2.167 \times 9.80 = 21.237 \text{ (kN/m}^2\text{)}$$

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

$$H = B \cdot \gamma_c \cdot kh = 0.700 \times 24.00 \times 0.20 = 3.360$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : 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

$$h_1 = 1.330 \text{ (m)}$$

Embankment Height under the water level surface

$$h_2 = 1.300 \text{ (m)}$$

Angle between the vertical wall and vertical plane

$$\theta = 0.00 \text{ (degree)}$$

Unit Weight of Soil (Wet)

$$\gamma_t = 19.00 \text{ (kN/m}^3\text{)}$$

Unit Weight of Soil (Saturated)

$$\gamma_{sat} = 20.00 \text{ (kN/m}^3\text{)}$$

Unit Weight of Water

$$\gamma_w = 9.80 \text{ (kN/m}^3\text{)}$$

Surcharge

$$q_0 = 5.00 \text{ (kN/m}^2\text{)}$$

Load width of Surcharge

$$wq_0 = 0.037 \text{ (m)}$$

Width of Converted Load

$$B = 2.401 \text{ (m)}$$

Internal Friction Angle of Soil

$$\phi = 30.00 \text{ (degree)}$$

Angle between Ground Surface and Horizontal Plane

$$\alpha = 0.00 \text{ (degree)}$$

Friction Angle (Soil and Concrete)

$$\delta_E = 0.00 \text{ (degree)}$$

Design Horizontal Seismic Coefficient

$$kh = 0.20 \text{ (degree)}$$

Apparent Horizontal Seismic Coefficient underwater

$$kh = 0.259 \text{ (degree)}$$

Compound Angle in Seismic Condition

$$\theta_0 = \tan^{-1}(kh) = 11.310 \text{ (degree)}$$

Compound Angle in Seismic Condition underwater

$$\theta_0 = \tan^{-1}(kh) = 14.496 \text{ (degree)}$$

■Active Angle of Rupture in Seismic Condition

$$\begin{aligned} \cot(\xi_{sa} - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \\ \cot(\xi_{sa} - \alpha) &= 0.85094 \end{aligned}$$

Thus,

$$\cot(\xi_{sa} - 0.00^\circ) = \frac{1}{\tan(\xi_{sa})} = 0.85094$$

$$\xi_{sa} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\begin{aligned} \cot(\xi_{sa}' - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 14.496^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 14.496^\circ)}} \\ \cot(\xi_{sa}' - \alpha) &= 0.97654 \end{aligned}$$

Thus,

$$\cot(\xi_{sa}' - 0.00^\circ) = \frac{1}{\tan(\xi_{sa}')} = 0.97654$$

$$\xi_{sa}' = \tan^{-1}\left(\frac{1}{0.97654}\right) = 45.680^\circ$$

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■Coefficient of Active Earth Pressure in Seismic Condition

$$\begin{aligned} K_{sa} &= \frac{\cos^2(\phi - \theta - \theta_0)}{\cos \theta_{sa} \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0 + \delta_E)} \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta_E) \cdot \cos(\theta - \alpha)}} \right] \\ &= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \\ &\quad \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right] \\ &= 0.4733 \end{aligned}$$

In case $\phi - \alpha - \theta_0 < 0$, $\sin(\phi - \alpha - \theta_0) = 0$.

$$\begin{aligned} K_{sa}' &= \frac{\cos^2(\phi - \theta_{sa}' - \theta)}{\cos \theta_{sa}' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_{sa}' + \delta_E)} \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_{sa}')}{\cos(\theta + \theta_{sa}' + \delta_E) \cdot \cos(\theta - \alpha)}} \right] \\ &= \frac{\cos^2(30.00^\circ - 14.496^\circ - 0.00^\circ)}{\cos(14.496^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 14.496^\circ + 0.00^\circ)} \\ &\quad \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 14.496^\circ)}{\cos(0.00^\circ + 14.496^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right] \\ &= 0.5266 \end{aligned}$$

In case $\phi - \alpha - \theta_{sa}' < 0$, $\sin(\phi - \alpha - \theta_{sa}') = 0$.

$$\text{Weight of Embankment } W = 7.601 \text{ (kN/m)}$$

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot wq_0) / B \\ &= (7.601 + 5.00 \times 0.037) / 2.401 \\ &= 3.242 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$P_1 = q_0' \cdot K_{sa} = 3.242 \times 0.4733 = 1.534 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} P_2 &= K_{sa} \cdot \gamma_c \cdot h_1 + p_1 \\ &= 0.4733 \times 19.00 \times 1.330 + 1.534 \\ &= 13.494 \text{ (kN/m}^2\text{)} \end{aligned}$$

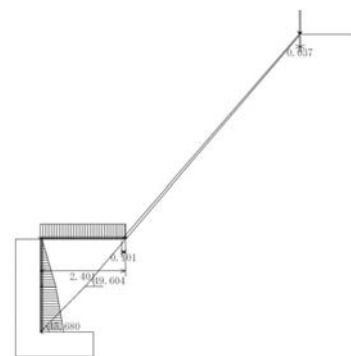
Earth Pressure at Junction

$$\begin{aligned} P_3 &= K_{sa} \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.5266 \times (20.00 - 9.80) \times 1.300 + 13.494 \\ &= 20.476 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P_{IE} &= P_3 \cdot \cos \delta = 46.159 \times \cos(0.00^\circ) \\ &= 46.159 \text{ (kN/m}^2\text{)} \end{aligned}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h \cdot \gamma_w = 1.300 \times 9.80 = 12.740 \text{ (kN/m}^2\text{)}$$

Thus,

hh : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

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1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P(kN/m ²)	l(m)	P·l/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·l/2) =	27.06
Shear Force	S(kN/m)	Σ(P·l) =	54.13

2) Seismic Condition-1

	P(kN/m ²)	l(m)	P·l/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·l/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	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	27.06
Re-bar	d1	mm	610.0
	Asl	mm ²	794.4
Required Area of Re-bar	Back	mm ²	327.1
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm ²	1.08
	σs	N/mm ²	58.62
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	436.1
	inp	mm ²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	18.29
Re-bar	d1	mm	610.0
	Asl	mm ²	794.4
Required Area of Re-bar	Back	mm ²	164.9
Neutral Axis	X	m	0.087
	σc	N/mm ²	0.73
Stress Intensity	σs	N/mm ²	39.61
	σca	N/mm ²	12.30
Allowable Value	σsa	N/mm ²	186.00
Minimum Area of Re-Bar	min	mm ²	
	req	mm ²	219.8
	inp	mm ²	794.4

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2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	54.13
Re-bar	d1	mm	610.0
	Asl	mm ²	794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm ²	0.089
Allowable Value	τa	N/mm ²	0.360
	τa2	N/mm ²	1.600

■Seismic Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	36.58
Re-bar	d1	mm	610.0
	Asl	mm ²	794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm ²	0.060
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



$$Sw = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

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



$$Pw1 = (h1 \cdot \gamma_1 + h2 \cdot \gamma_{sat}) = 0.463 \times 19.00 + 2.167 \times 20.00 = 52.137$$

$$Pw2 = (h1 \cdot \gamma_1 + h2 \cdot \gamma_{sat}) = 0.463 \times 19.00 + 2.167 \times 20.00 = 52.137$$

Thus,

Pw1 : Weight 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)

γ₁ : 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/m ³)
Base	70.40
Edge	72.12

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1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unit (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



$$S_w = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

Thus,

S_w : Weight of Wall (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 1.330 \times 19.00 + 1.300 \times 20.00 = 51.270$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 1.330 \times 19.00 + 1.300 \times 20.00 = 51.270$$

Thus,

$Pw1$: Weight 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)

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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)	Unit (kN/m ²)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

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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)	$\Sigma(P \times l^2/2) = 11.88$		
Shear Force	S(kN/m)	$\Sigma(P \times l)$	=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)	$\Sigma(P \times l^2/2) = 15.64$		
Shear Force	S(kN/m)	$\Sigma(P \times l)$	= 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)	$\Sigma(P \times l^2/2) = -1.17$		
Shear Force	S(kN/m)	$\Sigma(P \times l)$	= -2.34

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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)	$\Sigma(P \times l^2/2) = 5.71$		
Shear Force	S(kN/m)	$\Sigma(P \times l)$	= 11.41

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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 Asl	mm mm ²	585.0 794.4	585.0 794.4
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 Asl	mm mm ²	90.0 794.4	585.0 794.4
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 Asl	mm mm ²	585.0 794.4	585.0 794.4
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
	τa	N/mm ²	0.360	0.360
Allowable Value	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 Asl	mm mm ²	90.0 794.4	585.0 794.4
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

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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

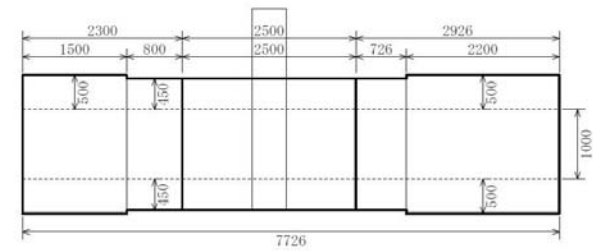
Residual Settlement	: 300.0 (mm)	
Residual Settlement for Rigid Support		: 50.0 (mm)
Relative Displacement	Base Width	: 1.0 (%)
		± : 50.0 (mm)

4) Type of Joint : Flexible Joint

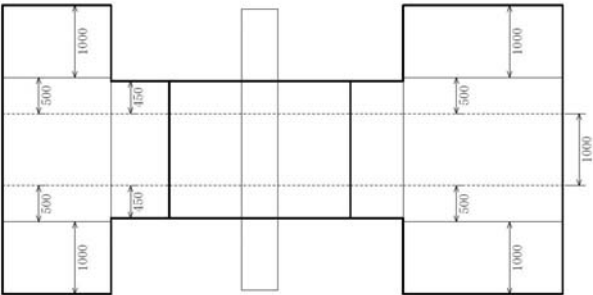
5) Allowable Opening : 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

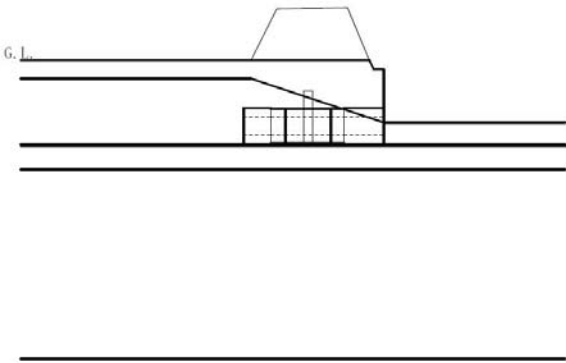
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Levee 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

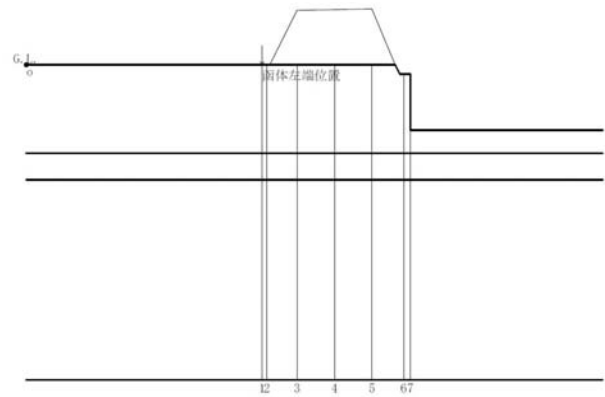
Span No	Block No	Flange			Reinforcing Bar			
		Portion	b (mm)	t (mm)	Outside Diameter@Pitch (Number)	Cover (mm)	Inside Diameter@Pitch (Number)	Cover (mm)
1	1	Top Slab	2000.0	500.0	D16@250(6)	90.0	D16@250(8)	90.0
	1	Bottom Slab	2000.0	500.0	D16@250(6)	115.0	D16@250(8)	90.0
2	2	Top Slab	1900.0	450.0	D16@250(6)	90.0	D16@250(8)	90.0
	2	Bottom Slab	1900.0	450.0	D16@250(6)	115.0	D16@250(8)	90.0
3	3	Top Slab	1900.0	450.0	D16@250(6)	90.0	D16@250(8)	90.0
	3	Bottom Slab	1900.0	450.0	D16@250(6)	115.0	D16@250(8)	90.0
4	4	Top Slab	2000.0	500.0	D25@250(6)	90.0	D25@250(8)	90.0
	4	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

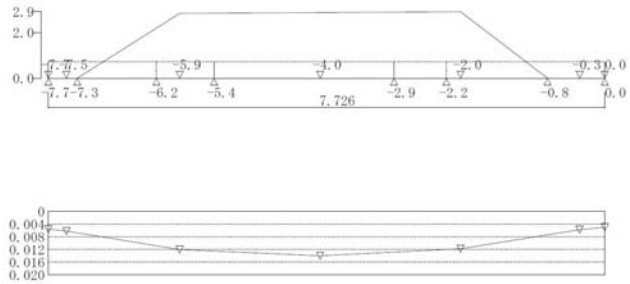
2.1.1 Settlement Calculation Points

Settlement 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 Summary 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

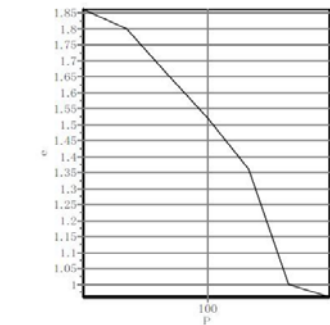


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

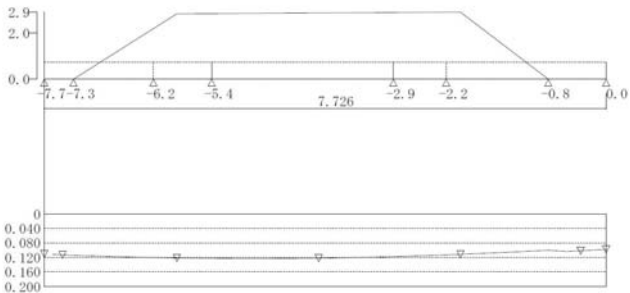
No	Name	Layer	Depth (m)	Unit Weight (W _{sat}) (kN/m ³)	Unit Weight (Saturated) (kN/m ³)	Pre-Consolidation Stress q ₀ (kN/m ²)	Elastic Modulus Es (kN/m ²)
1	Adobe BL	Sand	4.622	17.500	18.500	0.0	6900.0
2	As	Sand	6.019	17.500	18.500	0.0	6900.0
3	Dc1	Clay	16.449	17.500	18.500	0.0	15700.0

No	Concolidation Pressure P(kN/m ²)	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 Summary 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

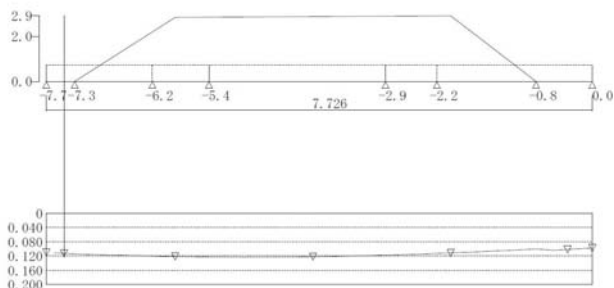


2.3 Residual Settlement

2.3.1 Summary of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Value	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 Longitudinal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B} \cdot \frac{d^4 w}{dx^4} + k_v (w - w_g) = q \text{ (Swag)}$$

$$\frac{EA}{U} \cdot \frac{d^2 u}{dx^2} + k_s (u - u_g) = p \text{ (Displacement in axial direction of Box Culvert)}$$

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/cm²) {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/cm²) {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}

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3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{eq} = \frac{\log \frac{(B+2h_{n-1} \cdot \tan \theta) \cdot L}{(L+2h_{n-1} \cdot \tan \theta) \cdot B}}{\sum \frac{1}{E_i} \log \frac{(B+2h_i \cdot \tan \theta) \cdot (L+2h_{i-1} \cdot \tan \theta)}{(L+2h_i \cdot \tan \theta) \cdot (B+2h_{i-1} \cdot \tan \theta)}}$$

In case of B=L

$$E_{eq} = \frac{-\frac{1}{B+2h_{n-1} \cdot \tan \theta} + \frac{1}{B}}{\sum \frac{1}{E_i} \left(\frac{1}{B+2h_i \cdot \tan \theta} + \frac{1}{B+2h_{i-1} \cdot \tan \theta} \right)}$$

Thus

- E_{eq} : 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/m²)
- θ : Angle of Load Dispersion ($\theta=30^\circ$)

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

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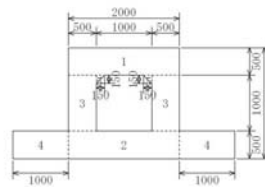
Span3-Block2 River Side

B	4.000 (m)		
L	2.926 (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	42290.6 kN/m ²		

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

Span1-Block1 Land Side

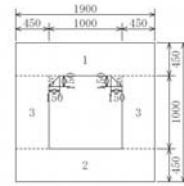


Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ³)	Ioi (m ⁴)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.023	1.450	0.0326	0.0473	0.00003
Total	4.023		3.2826	4.2348	0.14586

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.2826 / 4.023 = 0.8161 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 4.2348 + 0.14586 - 0.6660 \cdot 4.023 = 1.70183 \text{ (m}^4\text{)}$$

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

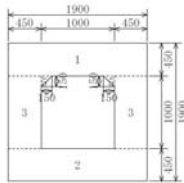
$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.633 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.633 = 1.00722 \text{ (m}^4\text{)}$$

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Span2-Block1 Center

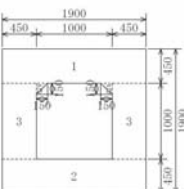


Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ³)	Ioi (m ⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.633 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.633 = 1.00722 \text{ (m}^4\text{)}$$

Span3-Block1 River Side



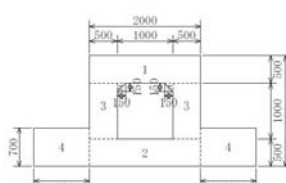
Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ³)	Ioi (m ⁴)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.633 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.633 = 1.00722 \text{ (m}^4\text{)}$$

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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	0.023	1.450	0.0326	0.0473	0.00003
Total	4.423		3.5226	4.3438	0.18219

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.5226 / 4.423 = 0.7965 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 4.3438 + 0.18219 - 0.6344 \cdot 4.423 = 1.72015 \text{ (m}^4\text{)}$$

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3.2.3 Table of Modulus of Subgrade Reaction

Coefficient of Lateral Shear Reaction of Soil

$$k_v = \lambda \cdot k_v$$

Thus,

k_s : 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)

k_v : 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 ²)	k_s (kN/m ²)	$k_v \cdot B$ (kN/m ²)	$k_s \cdot B$ (kN/m ²)
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/m ²)	k_s (kN/m ²)	$k_v \cdot B$ (kN/m ²)	$k_s \cdot B$ (kN/m ²)
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/m ²)	$k_s \cdot B$ (kN/m ²)
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/m ²)	$k_s \cdot B$ (kN/m ²)
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

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3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

$$W = (A1 + A2 + A3) \cdot \gamma_c \text{ (kN/m)}$$

A1: Cross Sectional Area (Excluding Hunch) (m²)

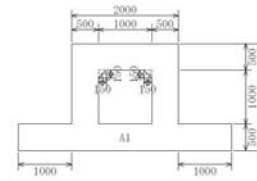
A2: Area of Upper Side Hunch (m²)

A3: Area of Lower Side Hunch (m²)

γ_c : Unit Weight (Concrete) (kN/m³)

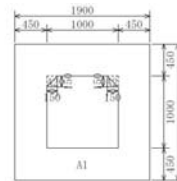
Span No. 1-1 Land Side

$$W = (4.000 + 0.023 + 0.000) \cdot 24.000 = 96.540 \text{ (kN/m)}$$



Span No. 1-2 Land Side

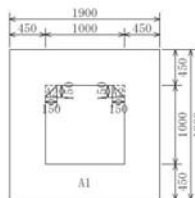
$$W = (2.610 + 0.023 + 0.000) \cdot 24.000 = 63.180 \text{ (kN/m)}$$



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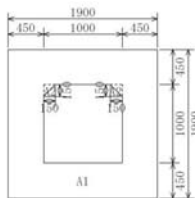
Span No. 2-1 Center

$$W = (2.610 + 0.023 + 0.000) \cdot 24.000 = 63.180 \text{ (kN/m)}$$



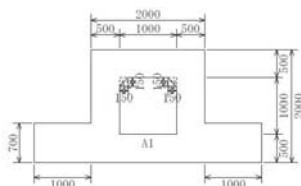
Span No. 3-1 River Side

$$W = (2.610 + 0.023 + 0.000) \cdot 24.000 = 63.180 \text{ (kN/m)}$$



Span No. 3-2 River Side

$$W = (4.400 + 0.023 + 0.000) \cdot 24.000 = 106.140 \text{ (kN/m)}$$



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2) Seepage Cutoff Wall Body Weight

$$A1 = X1 \cdot L2$$

$$A2 = L1 \cdot Y1 \cdot 2$$

$$W = (A1 + A2) \cdot B \cdot \gamma_c \text{ (kN)}$$

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)

γ_c : Unit Weight (Concrete) (kN/m³)

SpanNo.2-SpanDistance from Base Point (1.250)

$$A1 = 3.900 \cdot 1.000$$

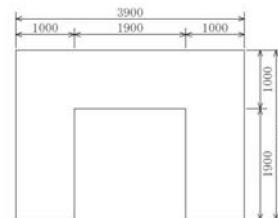
$$= 3.900 \text{ (m}^2\text{)}$$

$$A2 = 1.000 \cdot 1.900 \cdot 2$$

$$= 3.800 \text{ (m}^2\text{)}$$

$$W = (3.900 + 3.800) \cdot 0.500 \cdot 24.00$$

$$= 92.400 \text{ (kN)}$$



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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)	-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/m ²)	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/m ²)	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



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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/m ²)	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/m ²)	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/m ²)	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



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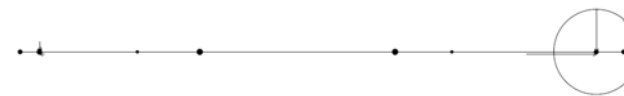
3.3.3 Point Load from Breast Walls

1) Normal Condition (Case Number: 1)

Case of Normal Condition 1

Name of Normal Load: [Gate Piers and Breast Walls (Normal) 1]

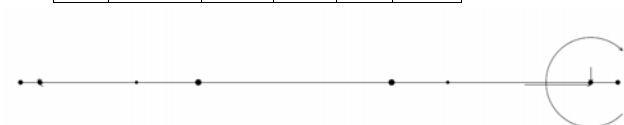
Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN·m)
1	Gate Structure	5.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-40.40	93.20	-47.97
3	Right Breast Wall	7.376	622.05	385.92	-759.30



2) Seismic Condition (Total Number: 2)

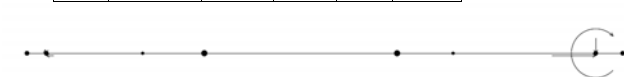
Case of Seismic Condition 1 [Land Side →River Side]

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 Seismic 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



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3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data 1	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 Data 1	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	Engaging Load (Dead Load)1	Gate Structure · Breast Wall (Dead Load)1	1.0000
6	Engaging 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 Data 1	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	Engaging Load (Dead Load)2	Seismic Load	1.0000
6	Engaging Load (Dead Load)2	Gate Structure · Breast Wall (Dead Load)2	1.0000

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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]

Num ber	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

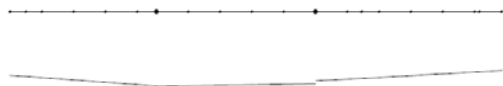
Span2 Name of Span: [Center]

Num ber	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]

Num ber	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



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2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Num ber	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]

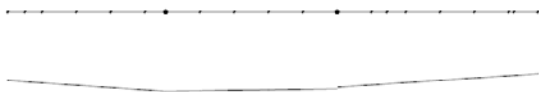
Num ber	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	-0.5	-3.4	139.4	135.4	3.9	19.0	○	209.709
2	0.500	-0.5	-2.2	138.5	136.6	1.9	19.0	○	99.529
3	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]

Num ber	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

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Displacement Diagram



Reaction Force of Ground



Reaction Force



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3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Num ber	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]

Num ber	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]

Num ber	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

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Bending Moment



Axial Force



Shear Force



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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

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Bending Moment



Axial Force



Shear Force



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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

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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,

θ_1 : Angle of Displacement (Left Side) (rad)

θ_2 : 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)	θ_1 (Degree) (rad)	θ_2 (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	

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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)	θ_1 (Degree) (rad)	θ_2 (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)	θ_1 (Degree) (rad)	θ_2 (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

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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	

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3.7 Stress Intensity Analysis

3.7.1 Calculation Condition

It is considered that double reinforced section which bending moment is acting on.

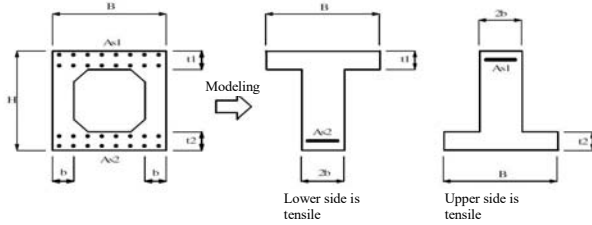
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.

Position of Neutral Axis

$$x = \frac{n \cdot (A_s \cdot d + A_s' \cdot d') + B \cdot t / 2}{n \cdot (A_s + A_s') + B \cdot t}$$

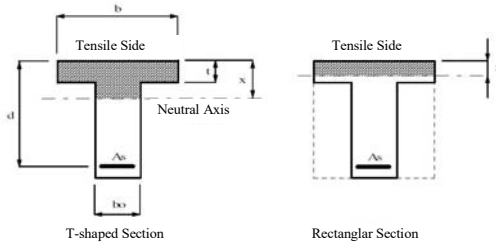
Thus,

- x : Position of Neutral Axis (mm)
- n : Ratio of Young modulus = 9.0
- A_s : Area of Re-bar in tensile side (mm²)
- A_s' : Area of Re-bar in compressive side (mm²)
- 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.



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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 A _s (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side A _s ' (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

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3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1

Item	Sym bol	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
	Inside of Top Slab	d2 As2	mm	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
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar	A _s	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	σ _c	N/mm ²	0.32	----	0.32	0.02
	σ _s	N/mm ²	24.46	----	24.46	1.78
	σ _s '	N/mm ²	-1.59	----	-1.59	-0.12
	σ _{ca}	N/mm ²	8.20	8.20	8.20	8.20
Allowable Stress Intensity	σ _{sa}	N/mm ²	140.00	140.00	140.00	140.00
	σ _{sa} '	N/mm ²	-140.00	-140.00	-140.00	-140.00
	min	mm ²	----	----	----	----
	req	mm ²	623.6	----	623.6	44.3
Minimum Area of Re-Bar	inp	mm ²	2780.4	----	2780.4	2780.4

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Calculation Case1: Normal Condition

Span1-Block2

Item	Sym bol	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
	Inside of Top Slab	d2 As2	mm	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
	Outside of Bottom Inside	d4 As4	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar	A _s	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	σ _c	N/mm ²	0.07	----	0.07	----
	σ _s	N/mm ²	5.23	----	5.23	----
	σ _s '	N/mm ²	-0.36	----	-0.36	----
	σ _{ca}	N/mm ²	8.20	8.20	8.20	8.20
Allowable Stress Intensity	σ _{sa}	N/mm ²	140.00	140.00	140.00	140.00
	σ _{sa} '	N/mm ²	-140.00	-140.00	-140.00	-140.00
	min	mm ²	----	----	----	----
	req	mm ²	131.4	----	131.4	----
Minimum Area of Re-Bar	inp	mm ²	2780.4	----	2780.4	----

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Calculation Case1: Normal Condition

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block2

Item		Sym bol	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

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3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Sym bol	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	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	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	----

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Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side →River Side

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side →River Side

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition

Span3-Block2

Item		Sym bol	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

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2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Sym bol	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		Sym bol	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	----

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Span2-Block1

Item		Sym bol	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		Sym bol	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	----

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Span3-Block2

Item		Sym bol	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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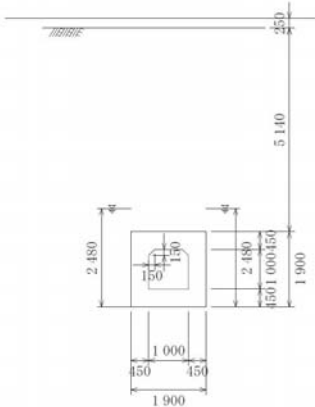
2.2.2.4 SLUICeway TYPE F

(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	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil(Wet)	γ_t	kN/m ³	19.00
Soil(Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		9.0	9.0
Expansion Coefficient *10 ⁻⁶	α	/°C	9.00	9.00

■Steel Reinforcement

Material			SD295	
	Sidewall		Harsh Environment	
Normal	Bottom Slab		Harsh Environment	
Allow Tensile Strength	σ_{sa}	N/mm ²	Normal (General)	140.00
		N/mm ²	Normal (Harsh)	140.00
		N/mm ²	Seismic	186.00
Allow Compressive Strength	σ_{sa}'	N/mm ²	Normal	140.00
		N/mm ²	Seismic	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
—	—	—		—	—	—	

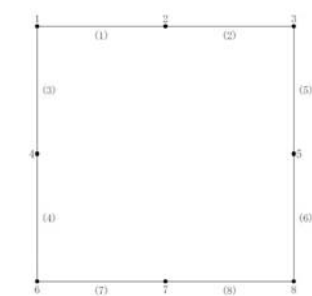
Cover					
Location		Cover(mm)		Location	
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Midwall		—	—		—

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

1.2 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

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

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 Slab	7	6	7	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slab	8	7	8	4.500000E-001	7.593750E-003	2.310000E+007

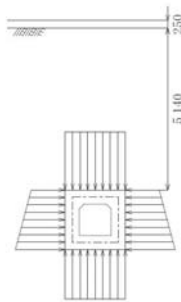
4) Supporting Point

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
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
(2) Left Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
(3) Right Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level)	$= 1.000 \times 0.250 \times 22.60 = 5.65 \text{ (kN/m}^2\text{)}$
Embankment (Above Water Level)	$= 1.000 \times 4.560 \times 18.00 = 82.08 \text{ (kN/m}^2\text{)}$
Embankment (Below Water Level)	$= 1.000 \times 0.580 \times 9.20 = 5.34 \text{ (kN/m}^2\text{)}$
Water Pressure	$= 0.580 \times 9.80 = 5.68 \text{ (kN/m}^2\text{)}$

$\Sigma w_d = 98.75 \text{ (kN/m}^2\text{)}$

(2) Surcharge Load at Road

Surcharge =	0.000 (kN/m ²)
Snow Load =	0.00 (kN/m ²)

$\Sigma q_d = 0.000 \text{ (kN/m}^2\text{)}$

(3) Load Acting on Top Slab

Uniformly Distributed Load	$w = 98.75 + 0.00 = 98.75 \text{ (kN/m}^2\text{)}$

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

$p_i = K_o \times (q_d + Y_o \times \gamma_a + Z_u \times \gamma + (Z_o - Z_u) \times \gamma') + (Z_o - Z_u) \times \gamma_w$

K_o : Coefficient of Earth Pressure at Rest = 0.500

Z_o : Depth of Calculation Point from Embankment Top (m)

(1) Left Side Wall

Symbol	Calculation Point	Z_o (m)	p (kN/m ²)
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	Z_o (m)	p (kN/m ²)
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

$U = 2.480 \times 1.900 \times 9.80 = 46.18 \text{ (kN/m)}$

$w = \frac{-46.18}{1.900} = -24.30 \text{ (kN/m}^2\text{)}$

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

$\bar{X} = \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)}$

$e = \frac{B}{2} - \bar{X} = 0.000 \text{ (m)}$

(2) Subgrade Reaction Intensity

$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$

$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$

$q_l = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 96.90 \text{ (kN/m}^2\text{)}$

$q_r = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 96.90 \text{ (kN/m}^2\text{)}$

$q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 96.90 \text{ (kN/m}^2\text{)}$

$q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 96.90 \text{ (kN/m}^2\text{)}$

Thus, T: Thickness of Side Wall

q_l : Subgrade Reaction Intensity on Left Edge

q_r : Subgrade Reaction Intensity on Right Edge

q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

q_r' : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface $q_L = 10.00 \text{ (kN/m}^2\text{)}$

Load

(1) Vertical Load Effecting Top Slab

$w_l = q_L = 10.00 \text{ (kN/m}^2\text{)}$

(2) Horizontal Load Acting on Left Side Wall

Converted Uniformly Distributed Load

$w_l = 10.00 \text{ (kN/m}^2\text{)}$

$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$

(3) Horizontal Load Effecting on Right Side Wall

Converted Uniformly Distributed Load

$w_l = 10.00 \text{ (kN/m}^2\text{)}$

$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$

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

$\bar{X} = \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)}$

$e = \frac{B}{2} - \bar{X} = 0.000 \text{ (m)}$

$$(2) \text{ Subgrade Reaction Intensity}$$

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_l' = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_r' = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

Thus, T : Thickness of Side Wall
 q_l : Subgrade Reaction Intensity on Left Edge
 q_r : Subgrade Reaction Intensity on Right Edge
 q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
 q_r' : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

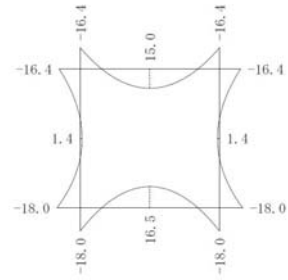
Dead Load + Live Load

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

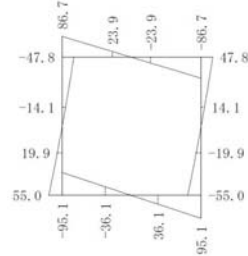
Load Number
13: Member Distribution Load (X Direction)
14: Member Distribution Load (Y Direction)

1.2.4 Calculation Results of Frame Analysis

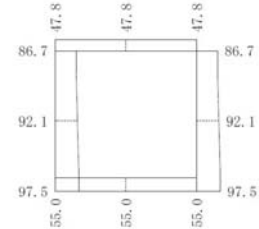
Bending Moment



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	-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	oc	N/mm ²	1.49	1.37	1.49
	os	N/mm ²	61.02	55.88	60.31
	os'	N/mm ²	0.00	0.00	0.00
Allowable Stress	oca	N/mm ²	8.20	8.20	8.20
	osa	N/mm ²	140.00	140.00	140.00
	osa'	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+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	-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	oc	N/mm ²	1.03	0.25	1.11
	os	N/mm ²	9.07	0.00	9.17
	os'	N/mm ²	0.00	-1.58	0.00
Allowable Stress	oca	N/mm ²	8.20	8.20	8.20
	osa	N/mm ²	140.00	140.00	140.00
	osa'	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

$$\tau_m = \frac{S}{b \times d} \leq \tau_a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm2)	τa (N/mm2)	Cases	L (m)
Top Slab	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

1 Calculation of Land Side Breast Wall 1

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1.3.1 Load 14

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2.2.2.4 SLUICEWAY TYPE F

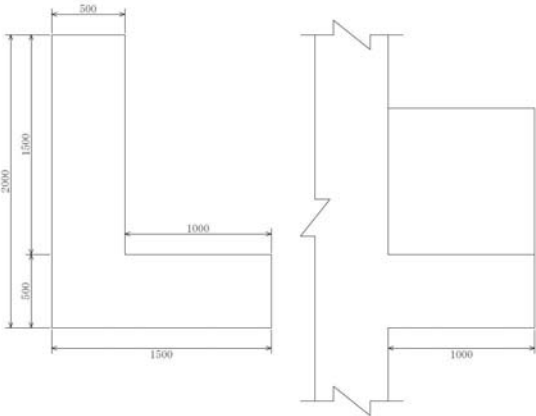
(3) BREAST WALL - LAND SIDE

1 Calculation of Land Side Breast Wall

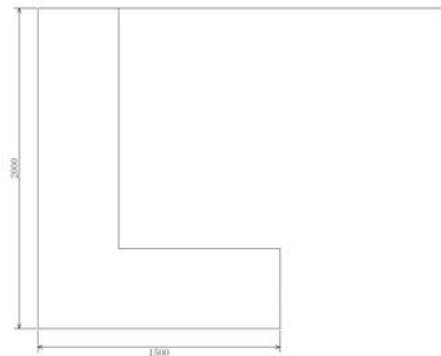
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	osa	N/mm ²	Normal (General)	140.00
		N/mm ²	Normal (Harsh)	140.00
		N/mm ²	Seismic	186.00
Allow Compressive Strength	osa'	N/mm ²	Normal	140.00
		N/mm ²	Seismic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φ_{res}	°	30
Peak Angle of Internal Friction	φ_{peak}	°	30
Coefficient of Lateral Earth Pressure at-rest	K_o		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

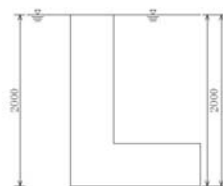
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

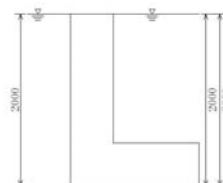
	(m)
Toe	2.000
Heel	2.000



1-2) Seismic Condition Number of Cases [1]

<Case 1>

	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front



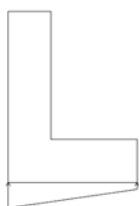
3

4

2) Subgrade Reaction

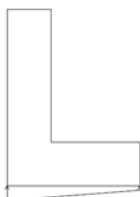
2-1) Normal <Case 1>

	(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)

$\times \xi_{s1}$ (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 + wq_0)/B \\ &= (0.000 + 10.00 \times 1.500) / 1.500 \\ &= 10.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 10.000 \times 0.500 = 5.000 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.000 + 5.000 \\ &= 5.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Junction

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 1.500 + 5.000 \\ &= 12.650 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P &= p_3 \\ &= 12.650 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.5

B : Converted Load Width (m)

γ_t : 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)

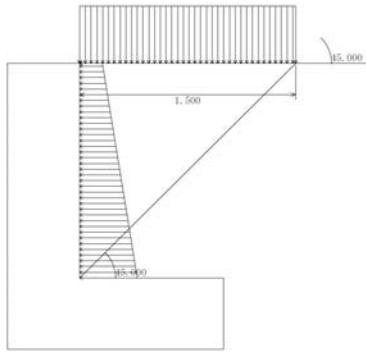
h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

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■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

$$P_h = h \cdot \gamma_w = 1.500 \times 9.80 = 14.700 \text{ (kN/m}^2\text{)}$$

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

$$H = B \cdot \gamma_c \cdot kh = 0.500 \times 24.00 \times 0.20 = 2.400$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : Unit Weight of Concrete (kN/m³)

Kh : Design Horizontal Seismic Coefficient

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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

$$\cot(\xi_{sa} - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0)}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}}$$

$$\cot(\xi_{sa} - \alpha) = 0.85094$$

Thus,

$$\cot(\xi_{sa} - 0.00^\circ) = \frac{1}{\tan(\xi_{sa})} = 0.85094$$

$$\xi_{sa} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{sa}' - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}}$$

$$= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 19.026^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.026^\circ)}}$$

$$\cot(\xi_{sa}' - \alpha) = 1.24217$$

Thus,

$$\cot(\xi_{sa}' - 0.00^\circ) = \frac{1}{\tan(\xi_{sa}')} = 1.24217$$

$$\xi_{sa}' = \tan^{-1}\left(\frac{1}{1.24217}\right) = 38.836^\circ$$

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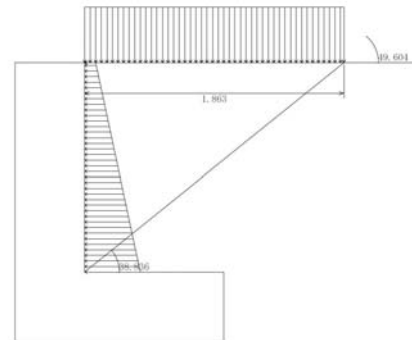
$$= 11.874 \text{ (kN/m}^2\text{)}$$

Design Earth Pressure

$$P_{HE} = P_3 \cdot \cos\delta = 11.874 \times \cos(0.00^\circ)$$

$$= 11.874 \text{ (kN/m}^2\text{)}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h \cdot \gamma_w = 1.500 \times 9.80 = 14.700 \text{ (kN/m}^2\text{)}$$

Thus,

hh : Height from the base of Vertical Wall to Water Surface at Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi - \theta - \theta_0)}{\cos\theta \cdot \cos^2\theta \cdot \cos(\theta + \theta_0 + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta_E) \cdot \cos(\theta - \alpha)}} \right]}$$

$$= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)}$$

$$\times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]$$

$$= 0.4733$$

In case $\phi - \alpha - \theta_0 < 0$, $\sin(\phi - \alpha - \theta_0) = 0$.

$$K_{EA}' = \frac{\cos^2(\phi - \theta_0' - \theta)}{\cos\theta \cdot \cos^2\theta \cdot \cos(\theta + \theta_0' + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0')}{\cos(\theta + \theta_0' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]}$$

$$= \frac{\cos^2(30.00^\circ - 19.026^\circ - 0.00^\circ)}{\cos(19.026^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 19.026^\circ + 0.00^\circ)}$$

$$\times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.026^\circ)}{\cos(0.00^\circ + 19.026^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]$$

$$= 0.6214$$

In case $\phi - \alpha - \theta_0' < 0$, $\sin(\phi - \alpha - \theta_0') = 0$.

Weight of Embankment W = 0.000 (kN/m)

$$\text{Converted Load } q0' = \frac{(W + q0 \cdot wq0)}{B}$$

$$= \frac{(0.000 + 5.00 \times 1.863)}{1.863}$$

$$= 5.000 \text{ (kN/m}^2\text{)}$$

Earth Pressure at the Top

$$P1 = q0' \cdot K_{EA} = 5.000 \times 0.4733 = 2.366 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$P2 = K_{EA} \cdot \gamma_w \cdot h1 + p1$$

$$= 0.4733 \times 19.00 \times 0.000 + 2.366$$

$$= 2.366 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Junction

$$P3 = K_{EA} \cdot (\gamma_{sat} - \gamma_w) \cdot h2 + p2$$

$$= 0.6214 \times (20.00 - 9.80) \times 1.500 + 2.366$$

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1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m ²)	L (m)	P·l/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) = 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 (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) = 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	mm	410.0
	As1	mm ²	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	mm	410.0
	As1	mm ²	794.4
Required Area of Re-bar	Back	mm ²	195.7
Neutral Axis	X	m	0.070
	σc	N/mm ²	1.07
Stress Intensity	σs	N/mm ²	47.15
	σca	N/mm ²	12.30
Allowable Value	σsa	N/mm ²	186.00
Minimum Area of Re-Bar	min	mm ²	
	req	mm ²	261.0
	inp	mm ²	794.4

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2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	27.35
Re-bar	d1	mm	410.0
	As1	mm ²	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

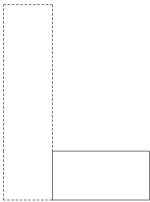
	Symbol	Unit	Junction
Shear Force	S	kN	28.97
Re-bar	d1	mm	410.0
	As1	mm ²	794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm ²	0.071
Allowable Value	τa	N/mm ²	0.540
	τa2	N/mm ²	2.400

1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$Sw = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

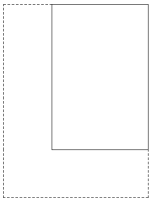
Thus,

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



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

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)

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/m ²)
Base	71.47
Edge	25.88

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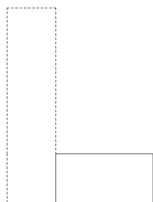
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1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unit (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



$$S_w = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

Thus,

S_w : Weight of Wall (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



$$P_{w1} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

$$P_{w2} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

Thus,

P_{w1} : Weight of Embankment at basis (kN/m²)

P_{w2} : 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)

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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)	Unit (kN/m ²)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

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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 (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)	$\Sigma(P \cdot L/2) = 19.54$		
Shear Force S (kN/m)	$\Sigma(P \cdot L) = 39.07$		

1-2) Edge

	P (kN/m ²)	L (m)	P×L/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)	$\Sigma(P \cdot L/2) = -3.26$		
Shear Force S (kN/m)	$\Sigma(P \cdot L) = -6.52$		

2) Seismic Condition-1

2-1) Base

	P (kN/m ²)	L (m)	P×L/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)	$\Sigma(P \cdot L/2) = 6.11$		
Shear Force S (kN/m)	$\Sigma(P \cdot L) = 12.23$		

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2-2) Edge

	P (kN/m ²)	L (m)	P×L/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)	$\Sigma(P \cdot L/2) = -6.33$		
Shear Force S (kN/m)	$\Sigma(P \cdot L) = -12.66$		

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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	mm	385.0	90.0
	As1	mm ²	1548.4	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	mm	385.0	90.0
	As1	mm ²	1548.4	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	mm	385.0	90.0
	As1	mm ²	1548.4	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
	τa	N/mm ²	0.360	0.360
Allowable Value	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	mm	385.0	90.0
	As1	mm ²	1548.4	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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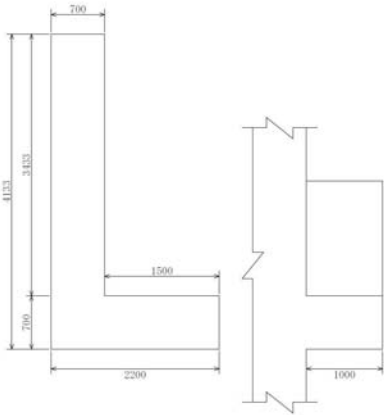
1.3.3 Stress Intensity Calculation.....20

1 Calculation of River Side Breast Wall

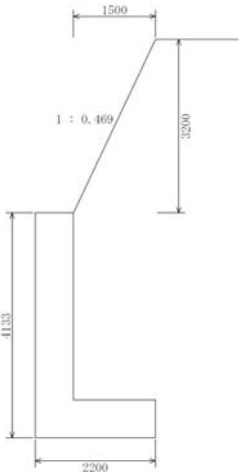
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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/mm ² Normal (General)	140.00
		N/mm ² Normal (Harsh)	140.00
		N/mm ² Seismic	186.00
Allow Compressive Strength	σsa'	N/mm ² Normal	140.00
		N/mm ² Seismic	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	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 (mm ² /m)
Side Wall	100.0	0.0
Bottom Slab	100.0	0.0

3

4

1.1.4 Loads

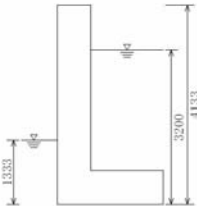
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

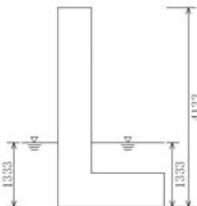
	(m)
Toe	1.333
Heel	3.200



1-2) Seismic Condition Number of Cases [1]

<Case 1>

	(m)
Toe	1.333
Heel	1.333
Direction	Back → Front

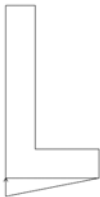


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2) Subgrade Reaction

2-1) Normal <Case 1>

	(kN/m ²), (m)
Toe	354.08
Heel	0.00
Load Width	2.200



2-2) Seismic <Case 1>

	(kN/m ²), (m)
Toe	171.95
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

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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_A (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot \gamma_w) / B \\ &= (260.406 + 10.00 \times 5.133) / 3.433 \\ &= 90.806 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 90.806 \times 0.500 = 45.403 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.933 + 45.403 \\ &= 54.266 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Junction

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 2.500 + 54.266 \\ &= 67.016 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P &= p_3 \\ &= 67.016 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γ_t : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

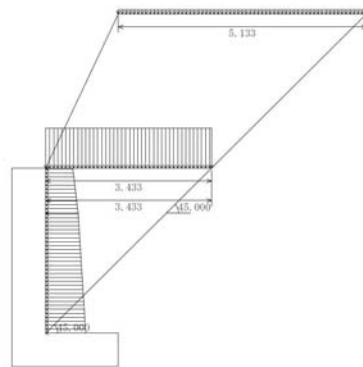
q_0 : Surcharge (kN/m²)

w_{q_0} : 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

$$P_h = h_h \cdot \gamma_w = 2.500 \times 9.80 = 24.500 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : 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

$$H = B \cdot \gamma_c \cdot k_h = 0.700 \times 24.00 \times 0.20 = 3.360$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : Unit Weight of Concrete (kN/m³)

k_h : Design Horizontal Seismic Coefficient

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h_1	= 2.800	(m)
Embankment Height under the water level surface	h_2	= 0.633	(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	q_0	= 5.00	(kN/m ²)
Load width of Surcharge	w_{q_0}	= 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	k_h	= 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	$\theta_w = \tan^{-1}(kh')$	= 12.363	(degree)

■Active Angle of Rupture in Seismic Condition

$$\begin{aligned} \cot(\xi_{EA} - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_s) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_s)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \end{aligned}$$

$$\cot(\xi_{EA} - \alpha) = 0.85094$$

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

$$\begin{aligned} \cot(\xi_{EA} - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_s) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_s)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 12.363^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 12.363^\circ)}} \end{aligned}$$

$$\cot(\xi_{EA} - \alpha) = 0.88870$$

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

$$\begin{aligned} K_{EA} &= \frac{\cos^2(\phi - \theta_s - \theta)}{\cos \theta_s \cdot \cos^2 \theta \cdot \cos(\theta + \theta_s + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_s)}{\cos(\theta + \theta_s + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2} \\ &= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \\ &\quad \times \frac{1}{\left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2} \\ &= 0.4733 \end{aligned}$$

In case $\phi - \alpha - \theta_s < 0$, $\sin(\phi - \alpha - \theta_s) = 0$.

$$\begin{aligned} K_{EA} &= \frac{\cos^2(\phi - \theta_s' - \theta)}{\cos \theta_s' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_s' + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_s')}{\cos(\theta + \theta_s' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2} \\ &= \frac{\cos^2(30.00^\circ - 12.363^\circ - 0.00^\circ)}{\cos(12.363^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 12.363^\circ + 0.00^\circ)} \\ &\quad \times \frac{1}{\left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 12.363^\circ)}{\cos(0.00^\circ + 12.363^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2} \\ &= 0.4900 \end{aligned}$$

In case $\phi - \alpha - \theta_s' < 0$, $\sin(\phi - \alpha - \theta_s') = 0$.

Weight of Embankment $W = 216.247$ (kN/m)

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot \gamma_w) / B \\ &= (216.247 + 5.00 \times 4.168) / 2.945 \\ &= 80.500 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$P_1 = q_0' \cdot K_{EA} = 80.500 \times 0.4733 = 38.098 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} P_2 &= K_{EA} \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.4733 \times 19.00 \times 2.900 + 38.098 \\ &= 63.276 \text{ (kN/m}^2\text{)} \end{aligned}$$

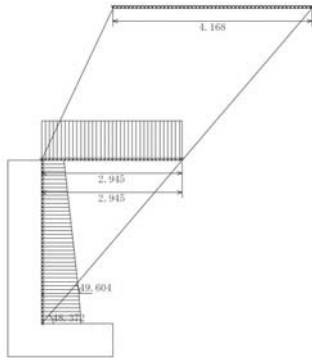
Earth Pressure at Junction

$$\begin{aligned} P_3 &= K_{EA} \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.4900 \times (20.00 - 9.80) \times 0.633 + 63.276 \\ &= 66.439 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$P_{1E} = P_3 \cdot \cos \delta = 66.439 \times \cos(0.00^\circ) = 66.439 \text{ (kN/m}^2\text{)}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h_h \cdot \gamma_w = 0.633 \times 9.80 = 6.203 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m ²)	L (m)	P · L/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) Σ(P · L/2) = 45.76			
Shear Force	S (kN/m)	Σ(P · L) = 91.52	

2) Seismic Condition-1

	P (kN/m ²)	L (m)	P · L/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) Σ(P · L/2) = 38.00			
Shear Force	S (kN/m)	Σ(P · L) = 76.00	

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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	mm	610.0
	As1	mm ²	1548.4
Required Area of Re-bar	Back	mm ²	558.2
Neutral Axis	X	m	0.117
	ec	N/mm ²	1.37
Stress Intensity	os	N/mm ²	51.76
	oca	N/mm ²	8.20
Allowable Value	osa	N/mm ²	140.00
	min	mm ²	1220.0
Minimum Area of Re-Bar	inp	mm ²	1548.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	38.00
Re-bar	d1	mm	610.0
	As1	mm ²	1548.4
Required Area of Re-bar	Back	mm ²	346.0
Neutral Axis	X	m	0.117
	ec	N/mm ²	1.14
Stress Intensity	os	N/mm ²	42.98
	oca	N/mm ²	12.30
Allowable Value	osa	N/mm ²	186.00
	min	mm ²	1220.0
Minimum Area of Re-Bar	inp	mm ²	1548.4

2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	91.52
Re-bar	d1	mm	610.0
	As1	mm ²	1548.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	tm	N/mm ²	0.150
Allowable Value	ta	N/mm ²	0.360
	ta2	N/mm ²	1.600

■Seismic Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	76.00
Re-bar	d1	mm	610.0
	As1	mm ²	1548.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	tm	N/mm ²	0.125
Allowable Value	ta	N/mm ²	0.540
	ta2	N/mm ²	2.400

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1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$S_w = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

Thus,

S_w : 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



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.933 \times 19.00 + 2.500 \times 20.00 = 67.727$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 4.133 \times 19.00 + 2.500 \times 20.00 = 128.527$$

Thus,

$Pw1$: Weight 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)

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$Pw2$: 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	117.24
Edge	0.00

2-4 Uplift Force

	Calculating Formula Height of Water Level × Unit Weight of Water (γ_w)	Unit (kN/m ²)
Base	1.333×9.80	13.063
Edge	1.333×9.80	13.063

1-3) Subgrade Reaction Force

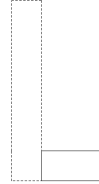
	Intensity of subgrade reaction (kN/m ²)
Base	241.42
Edge	0.00

1-4) Uplift Force

	Calculating Formula Height of Water Level × Unit Weight of Water (γ_w)	Unit (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



$$S_w = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

Thus,

S_w : Weight of Wall (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 2.800 \times 19.00 + 0.633 \times 20.00 = 65.860$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 6.000 \times 19.00 + 0.633 \times 20.00 = 126.660$$

Thus,

$Pw1$: Weight of Embankment at basis (kN/m²)

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1.3.2 Summary of Cross-Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m ²)	L (m)	$P \cdot l^2/2$ (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)	$\Sigma(P \cdot l^2/2) = 87.89$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 175.78$		

1-2) Edge

	P (kN/m ²)	L (m)	$P \cdot l^2/2$ (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)	$\Sigma(P \cdot l^2/2) = -56.98$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = -113.97$		

2) Seismic Condition-1

2-1) Base

	P (kN/m ²)	L (m)	$P \cdot l^2/2$ (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)	$\Sigma(P \cdot l^2/2) = 23.82$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 47.64$		

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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	

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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	mm	585.0	90.0
	As1	mm ²	1548.4	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	mm	585.0	90.0
	As1	mm ²	1548.4	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

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(2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	175.78	-113.97
Re-bar	d1	mm	585.0	90.0
	As1	mm ²	1548.4	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
	τa	N/mm ²	0.360	0.360
Allowable Value	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	mm	585.0	90.0
	As1	mm ²	1548.4	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

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2.2.2.5 SLUICEWAY TYPE H

(1) BOX - LONGITUDINAL

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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)

The diagram shows a cross-section of a road. At the bottom is a thick black line representing the ground level. Above it is a layer of hatched material representing the subgrade. On top of the subgrade is a road surface, shown as a horizontal line. A trapezoidal embankment structure is built on the road surface. The embankment has a sloped left side and a vertical right side. A horizontal line labeled G_{I} is shown to the left of the embankment, representing a ground level or a reference line.

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

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

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

Span No	Block No	Flange			Reinforcing Bar			
		Portion	b (mm)	t (mm)	Outside Diameter@Pitch (Number)	Cover (mm)	Inside 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

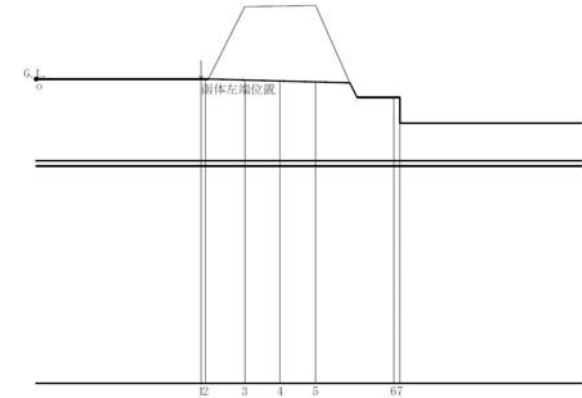
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2 Settlement and Lateral Displacement

2.1 Immediate Settlement

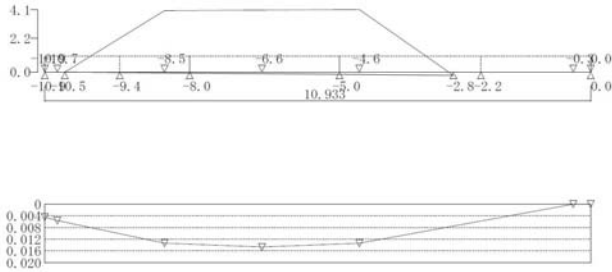
2.1.1 Settlement Calculation Points

Settlement 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 Summary 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

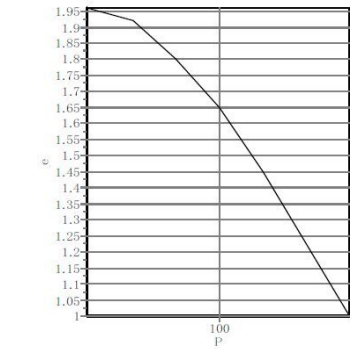


2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

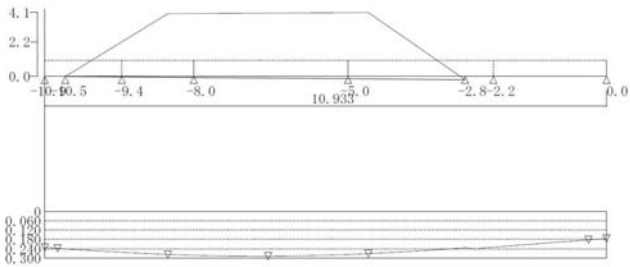
No	Name	Layer	Depth (m)	Unit Weight (W _{sat}) (kN/m ³)	Unit Weight (Saturated) (kN/m ³)	Pre-Consolidation Stress q ₀ (kN/m ²)	Elastic Modulus Es (kN/m ²)
1	Adobe BL	Sand	4.512	17.500	18.500	0.0	6900.0
2	As	Sand	4.812	17.500	18.500	0.0	6900.0
3	Dc1	Clay	16.762	17.500	18.500	0.0	15700.0

No	Concolidation Pressure P(kN/m ²)	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 Summary 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

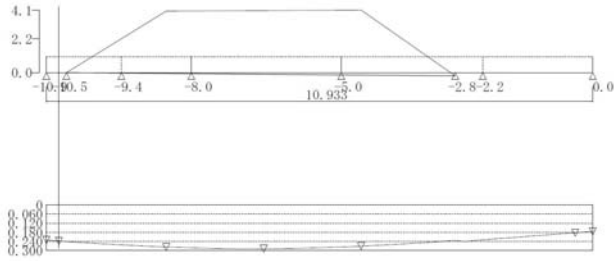


2.3 Residual Settlement

2.3.1 Summary of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Value	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 Longitudinal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B} \cdot \frac{d^4 w}{dx^4} + k_v (w - w_g) = q \text{ (Swag)}$$

$$\frac{EA}{U} \cdot \frac{d^2 u}{dx^2} + k_s (u - u_g) = p \text{ (Displacement in axial direction of Box Culvert)}$$

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/cm²) {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/cm²) {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}

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3.2 Coefficient of Subgrade Reaction

3.2.1 Deformation Modulus

Calculation of Converted Modulus of Deformation

In case of B≠L

$$E_{om} = \frac{\log \frac{(B+2h_n \cdot \tan \theta) \cdot L}{(L+2h_{n-1} \cdot \tan \theta) \cdot B}}{\sum \frac{1}{E_i} \log \frac{(B+2h_n \cdot \tan \theta) \cdot (L+2h_{n-1} \cdot \tan \theta)}{(L+2h_{n-1} \cdot \tan \theta) \cdot (B+2h_{n-1} \cdot \tan \theta)}}$$

In case of B=L

$$E_{om} = \frac{\frac{1}{B+2h_n \cdot \tan \theta} + \frac{1}{B}}{\sum \frac{1}{E_i} \left(\frac{1}{B+2h_n \cdot \tan \theta} + \frac{1}{B+2h_{n-1} \cdot \tan \theta} \right)}$$

Thus

- E_{om} : 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/m²)
- θ : Angle of Load Dispersion ($\theta=30^\circ$)

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/m ²)		

※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/m ²)		

※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/m ²)		

※Layer and Depth is the values from the subgrade

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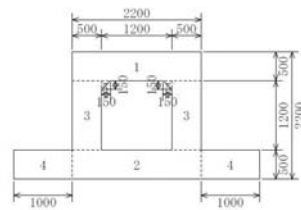
Span3-Block2 River Side

B	4.200 (m)		
L	5.033 (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	58127.6 (kN/m2)		

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

Span1-Block1 Land Side

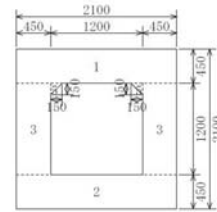


Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ³)	I _{oi} (m ⁴)
1	1.100	1.950	2.1450	4.1828	0.02292
2	1.100	0.250	0.2750	0.0688	0.02292
3	1.200	1.100	1.3200	1.4520	0.14400
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.023	1.650	0.0371	0.0613	0.00003
Total	4.423		4.0271	5.8273	0.21069

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 4.0271 / 4.423 = 0.9106 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_{i2}) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 5.8273 + 0.21069 - 0.8292 \cdot 4.423 = 2.37085 \text{ (m}^4\text{)}$$

Span1-Block2 Land Side



Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ³)	I _{oi} (m ⁴)
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

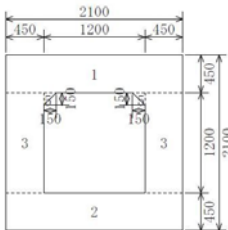
$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.1545 / 2.993 = 1.0541 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_{i2}) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 4.6184 + 0.16152 - 1.1112 \cdot 2.993 = 1.45466 \text{ (m}^4\text{)}$$

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Span2-Block1 Center

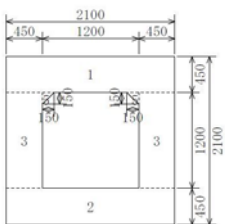


Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ³)	I _{oi} (m ⁴)
1	0.945	1.875	1.7719	3.3223	0.01595
2	0.945	0.225	0.2126	0.0478	0.01595
3	1.080	1.050	1.1340	1.1907	0.12960
5	0.023	1.600	0.0360	0.0576	0.00003
Total	2.993		3.1545	4.6184	0.16152

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.1545 / 2.993 = 1.0541 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_{i2}) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 4.6184 + 0.16152 - 1.1112 \cdot 2.993 = 1.45466 \text{ (m}^4\text{)}$$

Span3-Block1 River Side



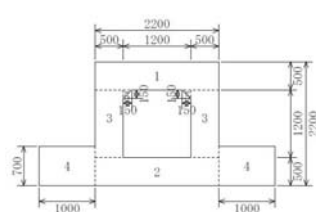
Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ³)	I _{oi} (m ⁴)
1	0.945	1.875	1.7719	3.3223	0.01595
2	0.945	0.225	0.2126	0.0478	0.01595
3	1.080	1.050	1.1340	1.1907	0.12960
5	0.023	1.600	0.0360	0.0576	0.00003
Total	2.993		3.1545	4.6184	0.16152

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.1545 / 2.993 = 1.0541 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_{i2}) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 4.6184 + 0.16152 - 1.1112 \cdot 2.993 = 1.45466 \text{ (m}^4\text{)}$$

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Span3-Block2 River Side



Position	A _i (m ²)	Y _i (m)	A _i ·Y _i (m ³)	A _i ·Y _i ² (m ³)	I _{oi} (m ⁴)
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

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 4.2671 / 4.823 = 0.8848 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_{i2}) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 5.9363 + 0.24703 - 0.7829 \cdot 4.823 = 2.40758 \text{ (m}^4\text{)}$$

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3.2.3 Table of Modulus of Subgrade Reaction

Coefficient of Lateral Shear Reaction of Soil

$$k_v = \lambda \cdot k_v$$

Thus,

k_s : 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)

k_v : 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	-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/m ³)	k_s (kN/m ³)	$k_v \cdot B$ (kN/m ²)	$k_s \cdot B$ (kN/m ²)
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/m ²)	$k_s \cdot B$ (kN/m ²)
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/m ²)	$k_s \cdot B$ (kN/m ²)
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

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3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

$$W = (A1 + A2 + A3) \cdot \gamma_c \quad (\text{kN/m})$$

A1: Cross Sectional Area (Excluding Hunch) (m²)

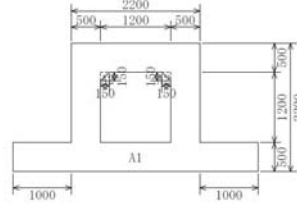
A2: Area of Upper Side Hunch (m²)

A3: Area of Lower Side Hunch (m²)

γ_c : Unit Weight (Concrete) (kN/m³)

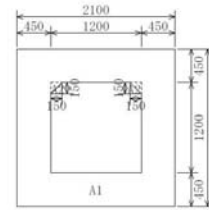
Span No. 1-1 Land Side

$$W = (4.400 + 0.023 + 0.000) \cdot 24.000 = 106.140 \quad (\text{kN/m})$$



Span No. 1-2 Land Side

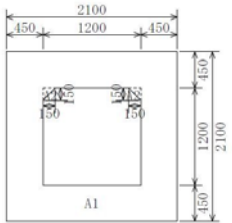
$$W = (2.970 + 0.023 + 0.000) \cdot 24.000 = 71.820 \quad (\text{kN/m})$$



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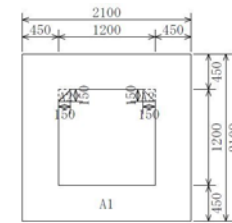
Span No. 2-1 Center

$$W = (2.970 + 0.023 + 0.000) \cdot 24.000 = 71.820 \quad (\text{kN/m})$$



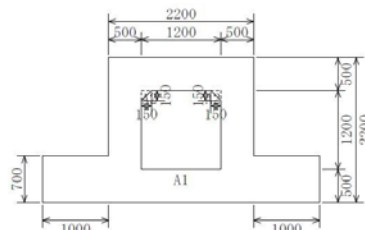
Span No. 3-1 River Side

$$W = (2.970 + 0.023 + 0.000) \cdot 24.000 = 71.820 \quad (\text{kN/m})$$



Span No. 3-2 River Side

$$W = (4.800 + 0.023 + 0.000) \cdot 24.000 = 115.740 \quad (\text{kN/m})$$



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2) Seepage Cutoff Wall Body Weight

$$A1 = X1 \cdot L2$$

$$A2 = L1 \cdot Y1 \cdot 2$$

$$W = (A1 + A2) \cdot B \cdot \gamma_c \quad (\text{kN})$$

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)

γ_c : Unit Weight (Concrete) (kN/m³)

SpanNo.2-SpanDistance from Base Point (1.450)

$$A1 = 4.100 \cdot 1.000$$

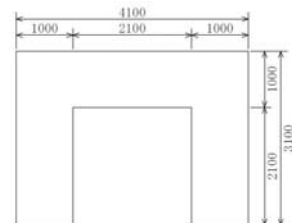
$$= 4.100 \quad (\text{m}^2)$$

$$A2 = 1.000 \cdot 2.100 \cdot 2$$

$$= 4.200 \quad (\text{m}^2)$$

$$W = (4.100 + 4.200) \cdot 0.500 \cdot 24.00$$

$$= 99.600 \quad (\text{kN})$$



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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)	-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

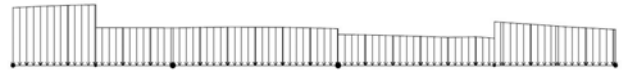
Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m ²)	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

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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-(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/m ²)	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

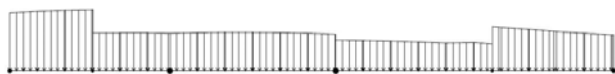
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Span2 Name of Span: [Center]

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-(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/m ²)	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



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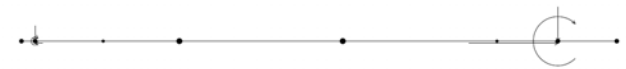
3.3.3 Point Load from Breast Walls

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 Condition 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 Seismic 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



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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	○
2	0.250	-7.4	-7.6	242.8	238.4	4.4	42.0	○
3	0.500	-7.4	-7.5	243.7	241.5	2.2	42.0	○
4	1.000	-7.4	-6.9	245.4	245.5	0.0	-50.0	○
5	1.500	-7.4	-6.3	247.2	247.8	-0.6	-50.0	○
6	2.000	-7.4	-5.6	248.9	248.6	0.3	21.0	○
7	2.500	-7.4	-4.9	250.7	248.1	2.5	21.0	○
8	2.900	-7.4	-3.8	252.1	246.2	5.8	21.0	○

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	○
2	0.500	0.2	-2.5	252.6	250.4	2.2	21.0	○
3	1.000	0.2	-1.2	251.7	252.4	-0.7	-50.0	○
4	1.500	0.2	0.2	250.8	252.1	-1.3	-50.0	○
5	2.000	0.2	1.5	249.9	250.6	-0.6	-50.0	○
6	2.500	0.2	2.8	249.0	246.8	2.2	21.0	○
7	3.000	0.2	4.1	248.1	240.8	7.3	21.0	○

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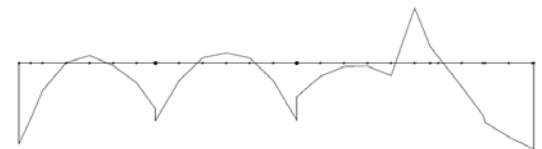
Span3 Name of Span: [River Side]

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	○
2	0.500	15.4	5.3	239.5	237.5	2.0	21.0	○
3	1.000	15.4	6.0	233.2	232.7	0.5	21.0	○
4	1.500	15.4	6.6	226.9	226.4	0.5	21.0	○
5	2.000	15.4	7.3	220.6	218.6	1.9	21.0	○
6	2.500	15.4	7.6	214.2	222.6	-8.3	-50.0	○
7	2.833	15.4	7.6	210.0	211.5	-1.5	-50.0	○
8	3.000	15.4	7.6	207.9	208.5	-0.6	-50.0	○
9	3.500	15.4	7.5	201.6	199.4	2.2	42.0	○
10	3.950	15.4	7.5	195.9	191.0	4.9	42.0	○
11	4.000	15.4	7.5	195.2	189.7	5.6	42.0	○
12	4.500	15.4	7.4	188.9	182.0	6.9	42.0	○
13	5.000	15.4	7.4	182.6	174.6	8.0	42.0	○
14	5.033	15.4	7.4	182.2	174.1	8.1	42.0	○

Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



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3.4.2 Seismic Condition

1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]									
Num ber	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

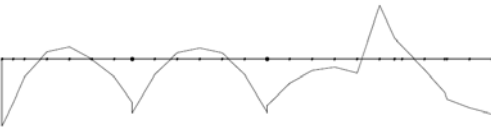
Span2 Name of Span: [Center]									
Num ber	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	0.2	-3.8	253.4	246.2	7.2	21.0	○	558.064
2	0.500	0.2	-2.5	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

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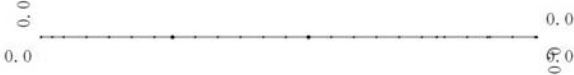
Displacement Diagram



Reaction Force of Ground



Reaction Force



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Span3 Name of Span: [River Side]

Num ber	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

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2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]									
Num ber	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]									
Num ber	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

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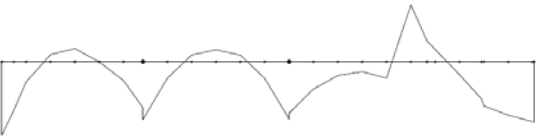
Span3 Name of Span: [River Side]

Num ber	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]

Num ber	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]

Num ber	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]

Num ber	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

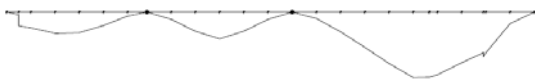
Span2 Name of Span: [Center]

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

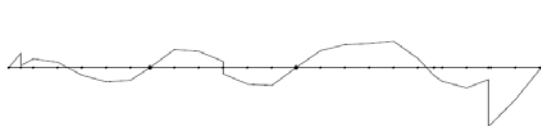
Bending Moment



Axial Force



Shear Force



Span1 Name of Span: [Land Side]

Num ber	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

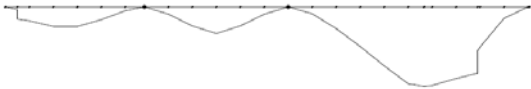
Span2 Name of Span: [Center]

Num ber	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]

Num ber	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

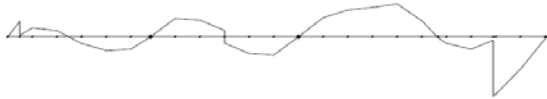
Bending Moment



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
 $\theta = \theta_1 - \theta_2$ - Initial Bending Angle
Thus,
01: Angle of Displacement (Left Side) (rad)
02: Angle of Displacement (Right Side) (rad)
0: 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)	θ_1 (Degree) (rad)	θ_2 (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

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3.7 Stress Intensity Analysis

3.7.1 Calculation Condition

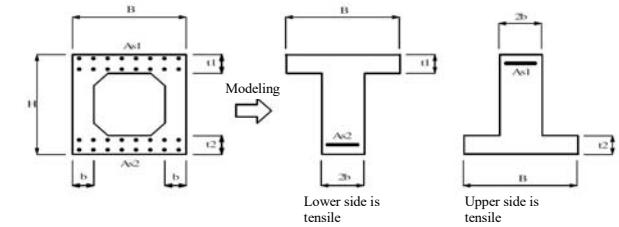
It is considered that double reinforced section which bending moment is acting on.
The position of neutral axis of T- shaped section is calculated and the section for stress calculation is decided.

Position of Neutral Axis

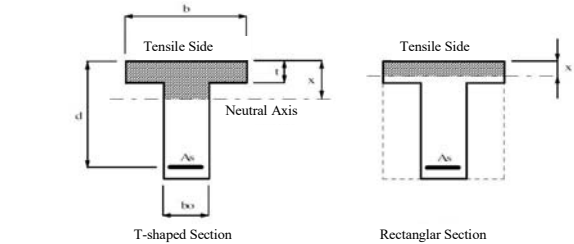
$$x = \frac{n \cdot (A_s \cdot d + A_s' \cdot d') + B \cdot t^2 / 2}{n \cdot (A_s + A_s') + B \cdot t}$$

Thus,

- x : Position of Neutral Axis (mm)
- n : Ratio of Young modulus = 9.0
- A_s : Area of Re-bar in tensile side (mm²)
- A_s' : Area of Re-bar in compressive side (mm²)
- 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.



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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	

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Calculation Condition (In Case Bottom Slab is Tensile)

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

Span Block	Width B (m)	Height H (m)	Effective Height d (m)	Area of Re-bar in Tensile Side A _s (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side A _s ' (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)

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

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

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3.7.2 Normal Condition

1) Calculation Case1 : Normal Condition

Span1-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block2

Item		Sym bol	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

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3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition

Span3-Block2

Item		Sym bol	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

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2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Sym bol	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	900.0	900.0	900.0	900.0
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	----

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Span1-Block2

Item		Sym bol	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	----

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Span2-Block1

Item		Sym bol	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	12.30
	σsa'	N/mm ²	186.00	186.00	186.00	186.00	186.00
	σsa'	N/mm ²	-186.00	-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		Sym bol	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	12.30
	σsa'	N/mm ²	186.00	186.00	186.00	186.00	186.00
	σsa'	N/mm ²	-186.00	-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		Sym bol	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	12.30
	σsa'	N/mm ²	186.00	186.00	186.00	186.00	186.00
	σsa'	N/mm ²	-186.00	-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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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
—	—	—		—	—	—	

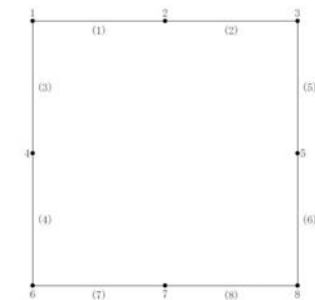
Cover					
Location		Cover(mm)		Location	
Top Slab	Upper	90.0	Right Wall	Outside	90.0
	Lower	90.0		Inside	90.0
Left Wall	Outside	90.0	Bottom Slab	Upper	90.0
	Inside	90.0		Lower	115.0
Midwall		90.0	—		—

Diagonal Tensile Reinforcement		
Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm ² /m)
Top Slab	100	0.0
Side Wall	100	0.0
Bottom Slab	100	0.0

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

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	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/m ²)	10.000

3) Member Material and Sectional Characteristics

Member	Num ber	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 Slab	7	6	7	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slab	8	7	8	4.500000E-001	7.593750E-003	2.310000E+007

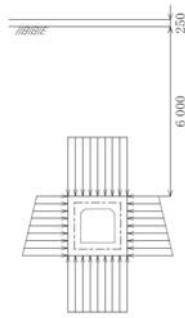
4) Supporting Point

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
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (2) Left Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (3) Right Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$

Surcharge Load

(1) Pavement and Embankment

Pavement (Above Water Level)	$= 1.000 \times 0.250 \times 22.60 = 5.65 \text{ (kN/m}^2\text{)}$
Embankment (Above Water Level)	$= 1.000 \times 5.200 \times 18.00 = 93.60 \text{ (kN/m}^2\text{)}$
$\Sigma w_d = 114.45 \text{ (kN/m}^2\text{)}$	

(2) Surcharge Load at Road

Surcharge =	$10.000 \text{ (kN/m}^2\text{)}$
Snow Load =	$0.00 \text{ (kN/m}^2\text{)}$
$\Sigma q_d = 10.000 \text{ (kN/m}^2\text{)}$	

(3) Load Acting on Top Slab

Uniformly Distributed Load	$w = 114.45 + 10.00 = 124.45 \text{ (kN/m}^2\text{)}$

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

$$p_i = K_o \times (q_d + \gamma_o \times \gamma_a + Z_u \times \gamma + (Z_o - Z_u) \times \gamma') + (Z_o - Z_u) \times \gamma_w$$

K_o : Coefficient of Earth Pressure at Rest = 0.500
 Z_o : Depth of Calculation Point from Embankment Top (m)

(1) Left Side Wall

Symbol	Calculation Point	Z_o (m)	p (kN/m ²)
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	Z_o (m)	p (kN/m ²)
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

$$U = 2.900 \times 2.100 \times 9.80 = 59.68 \text{ (kN/m)}$$
$$w = \frac{-59.68}{2.100} = -28.42 \text{ (kN/m}^2\text{)}$$

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		170.66		0.985	168.08
	Right Side Wall		-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

$$\bar{X} = \frac{\Sigma V}{\Sigma V} = 1.050 \text{ (m)}$$
$$e = \frac{B}{2} - \bar{X} = 0.000 \text{ (m)}$$

(2) Subgrade Reaction Intensity

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$M_o = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_l = \frac{\Sigma V}{B} + \frac{6 \times M_o}{B^2} = 119.43 \text{ (kN/m}^2\text{)}$$

$$q_r = \frac{\Sigma V}{B} - \frac{6 \times M_o}{B^2} = 119.43 \text{ (kN/m}^2\text{)}$$

$$q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 119.43 \text{ (kN/m}^2\text{)}$$

$$q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 119.43 \text{ (kN/m}^2\text{)}$$

Thus, T : Thickness of Side Wall

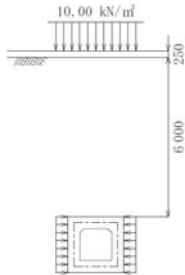
q_l : Subgrade Reaction Intensity on Left Edge

q_r : Subgrade Reaction Intensity on Right Edge

q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

q_r' : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Live Load (Case-1)



Live Load Intensity on Road Surface $q_L = 10.000 \text{ (kN/m}^2\text{)}$

Load

(1) Vertical Load Effecting Top Slab

$$w_l = q_L = 10.00 \text{ (kN/m}^2\text{)}$$

(2) Horizontal Load Acting on Left Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

(3) Horizontal Load Effecting on Right Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

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

$$\bar{X} = \frac{\Sigma V}{\Sigma V} = 1.050 \text{ (m)}$$
$$e = \frac{B}{2} - \bar{X} = 0.000 \text{ (m)}$$

$$(2) \text{ Subgrade Reaction Intensity}$$

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_l = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_r = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

Thus, T : Thickness of Side Wall
 q_l : Subgrade Reaction Intensity on Left Edge
 q_r : Subgrade Reaction Intensity on Right Edge
 q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
 q_r' : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

1.2.3 FRAME LOAD

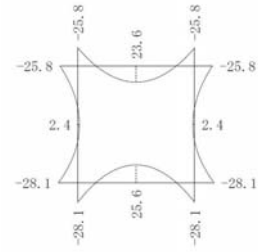
Dead Load + Live Load

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

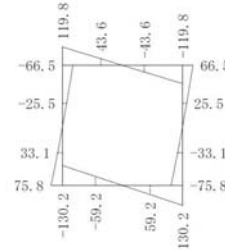
Load Number
13:MemberDistribution Load(X Direction)
14:MemberDistribution Load(Y Direction)

1.2.4 Calculation Results of Frame Analysis

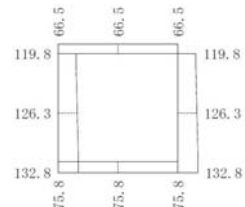
Bending Moment



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	-25.842	23.589	-25.842
Axial Force	N	0.000	0.000	0.000
Section Width	b	1.000	1.000	1.000
Section Height	h	0.450	0.450	0.450
Outside Cover	d1	90.0	90.0	90.0
Inside Cover	d2	90.0	90.0	90.0
Required Area of Re-Bar	External	540.0	0.0	540.0
	Internal	0.0	491.8	0.0
Re-Bar	External	D16 @ 250 D @ 794.4	D16 @ 250 D @ 794.4	D16 @ 247 D @ 804.0
	Internal	D16 @ 250 D @ 794.4	D16 @ 250 D @ 794.4	D16 @ 250 D @ 794.4
Neutral Axis	X	0.065	0.065	0.065
Stress Intensity	oc	N/mm ² 2.35	2.15	2.34
	os	N/mm ² 96.15	87.77	95.02
	os'	N/mm ² 0.00	0.00	0.00
Allowable Stress	oca	N/mm ² 8.20	8.20	8.20
	osa	N/mm ² 140.00	140.00	140.00
	osa'	N/mm ² -186.00	-186.00	-186.00
Minimum Re-Bar Sectional Area	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+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 -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	D16 @ 250 D @ 794.4	D16 @ 250 D @ 794.4	D16 @ 250 D @ 794.4
	Internal	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	oc	N/mm ² 1.75	0.35	1.89
	os	N/mm ² 20.78	0.00	21.56
	os'	N/mm ² 0.00	-2.10	0.00
Allowable Stress	oca	N/mm ² 8.20	8.20	8.20
	osa	N/mm ² 140.00	140.00	140.00
	osa'	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	Ext ermal	mm ²	34.1	0.0	29.5
	Inter nal	mm ²	0.0	0.0	0.0
Re-Bar	Ext ermal	mm ²	D16 @ 247 D—@— 804.0	D16 @ 250 D—@— 794.4	D16 @ 250 D—@— 794.4
	Inter nal	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

$$\tau_m = \frac{S}{b \times d} \leq \tau_a$$

$$b = 1000 \text{ (mm)}$$

Member	Location	S (kN)	d (mm)	τm (N/mm2)	τa (N/mm2)	Cases	L (m)
Top Slab	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

1 Calculation of Land Side Breast Wall 1

1.1 Design Conditions 1

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2.2.2.5 SLUICEWAY TYPE H

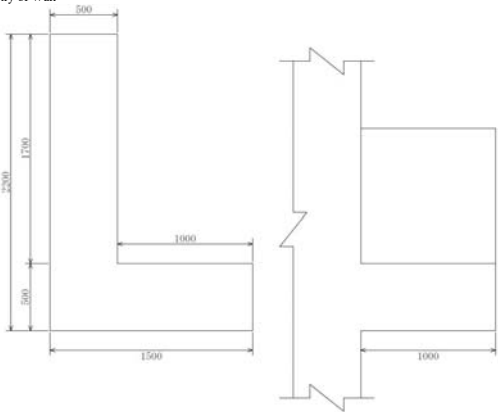
(3) BREAST WALL - LAND SIDE

1 Calculation of Land Side Breast Wall

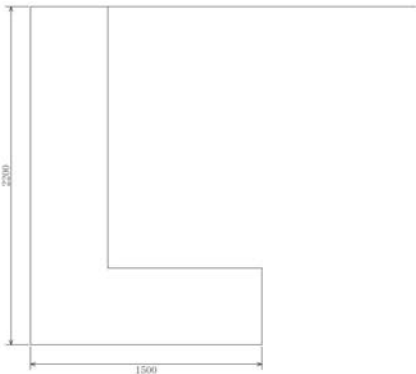
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil(Wet)	γ_t	kN/m ³	19.00
Soil(Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	σ_{sa}	N/mm ² Normal (General)	140.00
		N/mm ² Normal (Harsh)	140.00
		N/mm ² Seismic	186.00
Allow Compressive Strength	$\sigma_{sa'}$	N/mm ² Normal	140.00
		N/mm ² Seismic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φ_{res}	°	30
Peak Angle of Internal Friction	φ_{peak}	°	30
Coefficient of Lateral Earth Pressure at rest	K_o		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

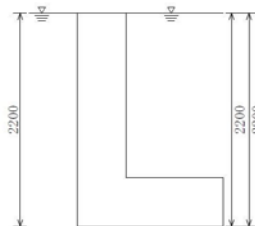
1.1.4 Loads

■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

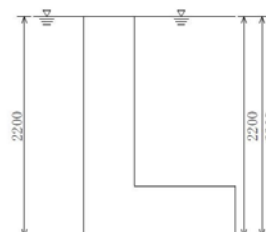
<Case 1>	
	(m)
Toe	2.200
Heel	2.200



1-2) Seismic Condition Number of Cases [1]

<Case 1>

	(m)
Toe	2.200
Heel	2.200
Direction	Back → Front



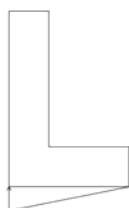
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2) Subgrade Reaction

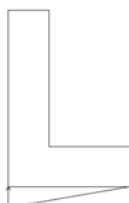
2-1) Normal <Case 1>

	(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)

※ξ₀(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 + w_q) / B \\ &= (0.000 + 10.00 \times 1.700) / 1.700 \\ &= 10.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 10.000 \times 0.500 = 5.000 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_t \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.000 + 5.000 \\ &= 5.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Junction

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 1.700 + 5.000 \\ &= 13.670 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P &= p_3 \\ &= 13.670 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

K₀ : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γ_t : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

q₀ : Surcharge (kN/m²)

w_{q0} : Width of Surcharge (m)

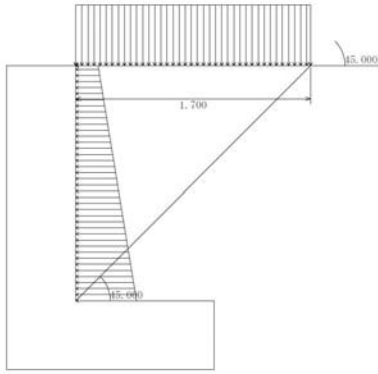
h₁ : Height above Water Surface (m)

h₂ : Height under Water Surface (m)

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■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.700 \times 9.80 = 16.660 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : 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

$$H = B \cdot \gamma_c \cdot kh = 0.500 \times 24.00 \times 0.20 = 2.400$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : Unit Weight of Concrete (kN/m³)

kh : Design Horizontal Seismic Coefficient

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2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h_1	=	0.302	(m)
Embankment Height under the water level surface	h_2	=	1.700	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_s	=	19.00	(kN/m ³)
Unit Weight of Soil (Dry)	γ_{sd}	=	20.00	(kN/m ³)
Unit Weight of Water	γ_w	=	9.80	(kN/m ³)
Surcharge	q_0	=	5.00	(kN/m ²)
Load width of Surcharge	wq_0	=	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

$$\cot(\xi_{sa} - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}} \\ = -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \\ \cot(\xi_{sa} - \alpha) = 0.85094$$

Thus,

$$\cot(\xi_{sa} - 0.00^\circ) = \frac{1}{\tan(\xi_{sa})} = 0.85094$$

$$\xi_{sa} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.804^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\cot(\xi_{sa}' - \alpha) = -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}} \\ = -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 19.247^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.247^\circ)}} \\ \cot(\xi_{sa}' - \alpha) = 1.25932$$

Thus,

$$\cot(\xi_{sa}' - 0.00^\circ) = \frac{1}{\tan(\xi_{sa}')} = 1.25932$$

$$\xi_{sa}' = \tan^{-1}\left(\frac{1}{1.25932}\right) = 38.452^\circ$$

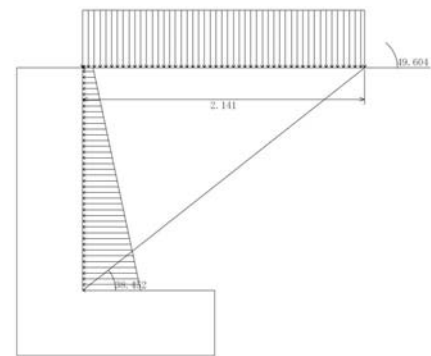
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$$= 0.6268 \times (20.00 - 9.80) \times 1.700 + 2.366 \\ = 13.236 \text{ (kN/m}^2\text{)}$$

Design Earth Pressure

$$P_{HE} = P_3 \cdot \cos\delta = 13.236 \times \cos(0.00^\circ) \\ = 13.236 \text{ (kN/m}^2\text{)}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.700 \times 9.80 = 16.660 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

■Coefficient of Active Earth Pressure in Seismic Condition

$$K_{EA} = \frac{\cos^2(\phi - \theta_0 - \theta)}{\cos\theta_0' \cdot \cos^2\theta \cdot \cos(\theta + \theta_0' + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0')}{\cos(\theta + \theta_0' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]} \\ = \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \\ \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right] \\ = 0.4733$$

In case $\phi - \alpha - \theta_0' < 0$, $\sin(\phi - \alpha - \theta_0') = 0$.

$$K_{EA}' = \frac{\cos^2(\phi - \theta_0' - \theta)}{\cos\theta_0' \cdot \cos^2\theta \cdot \cos(\theta + \theta_0' + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0')}{\cos(\theta + \theta_0' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]} \\ = \frac{\cos^2(30.00^\circ - 19.247^\circ - 0.00^\circ)}{\cos(19.247^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 19.247^\circ + 0.00^\circ)} \\ \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.247^\circ)}{\cos(0.00^\circ + 19.247^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right] \\ = 0.6268$$

In case $\phi - \alpha - \theta_0' < 0$, $\sin(\phi - \alpha - \theta_0') = 0$.

Weight of Embankment W $W = 0.000 \text{ (kN/m)}$

$$\text{Converted Load } q_0' \quad q_0' = (W + q_0 \cdot wq_0) / B \\ = (0.000 + 5.00 \times 2.141) / 2.141 \\ = 5.000 \text{ (kN/m}^2\text{)}$$

Earth Pressure at the Top

$$P_1 = q_0' \cdot K_{EA} = 5.000 \times 0.4733 = 2.366 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$P_2 = K_{EA} \cdot \gamma_s \cdot h_1 + p_1 \\ = 0.4733 \times 19.00 \times 0.000 + 2.366 \\ = 2.366 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Junction

$$P_3 = K_{EA} \cdot (\gamma_{sat} \gamma_w) \cdot h_2 + p_2$$

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1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m ²)	L (m)	P·l/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 · l/2) = 15.17	
Shear Force	S (kN/m)	Σ(P · l) = 30.33	

2) Seismic Condition-1

	P (kN/m ²)	L (m)	P·l/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 · l/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	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	15.17
Re-bar	d1 As1	mm ²	410.0 794.4
Required Area of Re-bar	Back	mm ²	273.7
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm ²	1.12
	σs	N/mm ²	49.36
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	364.9
	inp	mm ²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	16.15
Re-bar	d1 As1	mm ²	410.0 794.4
Required Area of Re-bar	Back	mm ²	218.5
Neutral Axis	X	m	0.070
Stress Intensity	σc	N/mm ²	1.20
	σs	N/mm ²	52.56
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	291.4
	inp	mm ²	794.4

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2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	30.33
Re-bar	d1 As1	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	0.074
Allowable Value	τa	N/mm ²	0.360
	τa2	N/mm ²	1.600

■Seismic Condition-1

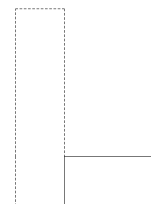
	Symbol	Unit	Junction
Shear Force	S	kN	32.30
Re-bar	d1 As1	mm ²	410.0 794.4
Effective Height	d	mm	410.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm ²	0.079
Allowable Value	τa	N/mm ²	0.540
	τa2	N/mm ²	2.400

1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$Sw = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

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



$$Pw1 = (h1 \cdot \gamma_c + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.700 \times 20.00 = 34.000$$

$$Pw2 = (h1 \cdot \gamma_c + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.700 \times 20.00 = 34.000$$

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_s : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

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1-3) Subgrade Reaction Force

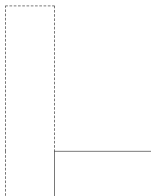
	Intensity of subgrade reaction (kN/m ²)
Base	127.17
Edge	0.00

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ _w)	Unit (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



$$Sw = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

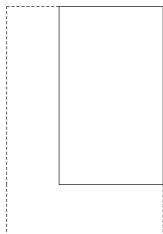
Thus,

Sw : Weight of Wall (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



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$$Pw1 = (h1 \cdot \gamma_c + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.700 \times 20.00 = 34.000$$

$$Pw2 = (h1 \cdot \gamma_c + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.700 \times 20.00 = 34.000$$

Thus,

Pw1 : Weight 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 under water (m)

γ_c : 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	110.50
Edge	0.00

2-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ _w)	Unit (kN/m ²)
Base	2.200× 9.80	21.560
Edge	2.200× 9.80	21.560

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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 (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 × L/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 (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 × L/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 (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 × L/2) = 40.53			
Shear Force S (kN/m) Σ(P × L) = 81.06			

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2-2) Edge

	P(kN/m ²)	l(m)	P×l/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) = -14.72			
Shear Force S(kN/m) Σ(P×l) = -29.44			

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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	mm	385.0	90.0
	Asl	mm ²	1146.0	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	mm	385.0	90.0
	Asl	mm ²	1146.0	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	mm	385.0	90.0
	Asl	mm ²	1146.0	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
	τa	N/mm ²	0.360	0.360
Allowable Value	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	mm	385.0	90.0
	Asl	mm ²	1146.0	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	0.211	0.072
	τa	N/mm ²	0.540	0.540
Allowable Value	τa2	N/mm ²	2.400	2.400

1 Calculation of River Side Breast Wall.....1

1.1 Design Condition 1

1.1.1 Dimensions.....1

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1.3.1 Load 15

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2.2.2.5 SLUICeway TYPE H

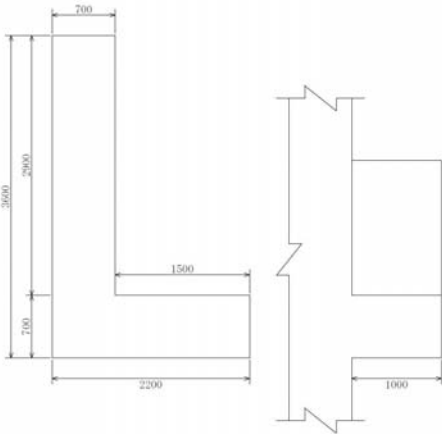
(4) BREAST WALL - RIVER SIDE

1 Calculation of River Side Breast Wall

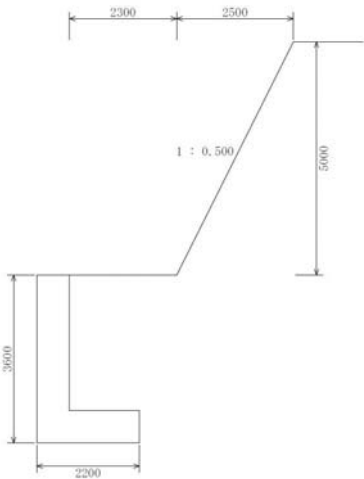
1.1 Design Condition

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



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)

$\times \xi_{\alpha}$ (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot wq_0) / B \\ &= (175.750 + 10.00 \times 3.100) / 2.900 \\ &= 71.293 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 71.293 \times 0.500 = 35.647 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 1.100 + 35.647 \\ &= 36.597 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Bottom Surface of Base

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 2.800 + 36.597 \\ &= 50.877 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P &= p_3 \\ &= 50.877 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γ_t : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

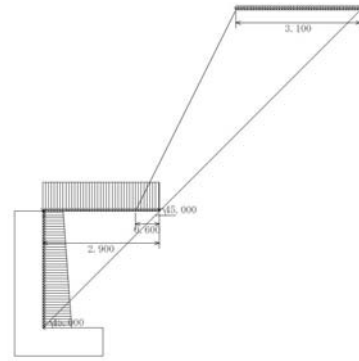
q_0 : Surcharge (kN/m²)

w_{q_0} : 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

$$P_h = h_h \cdot \gamma_w = 2.800 \times 9.80 = 27.440 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : 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

$$H = B \cdot \gamma_c \cdot kh = 0.700 \times 24.00 \times 0.20 = 3.360$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : 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

$h_1 = 1.500$ (m)

Embankment Height under the water level surface

$h_2 = 1.400$ (m)

Angle between the vertical wall and vertical plane

$\theta = 0.00$ (degree)

Unit Weight of Soil (Wet)

$\gamma_t = 19.00$ (kN/m³)

Unit Weight of Soil (Dry)

$\gamma_{sat} = 20.00$ (kN/m³)

Unit Weight of Water

$\gamma_w = 9.80$ (kN/m³)

Surcharge

$q_0 = 5.00$ (kN/m²)

Load width of Surcharge

$wq_0 = 2.095$ (m)

Width of Converted Load

B = 2.640 (m)

Internal Friction Angle of Soil

$\phi = 30.00$ (degree)

Angle between Ground Surface and Horizontal Plane

$\alpha = 0.00$ (degree)

Friction Angle (Soil and Concrete)

$\delta_0 = 0.00$ (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

$$\begin{aligned} \cot(\xi_{\alpha} - \alpha) &= -\tan(\phi + \delta_0 + \theta - \alpha) + \sec(\phi + \delta_0 + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_0 + \theta_0') \cdot \sin(\phi + \delta_0)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \end{aligned}$$

$$\cot(\xi_{\alpha} - \alpha) = 0.85094$$

Thus,

$$\cot(\xi_{\alpha} - 0.00^\circ) = \frac{1}{\tan(\xi_{\alpha})} = 0.85094$$

$$\xi_{\alpha} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\begin{aligned} \cot(\xi_{\alpha'} - \alpha) &= -\tan(\phi + \delta_0 + \theta - \alpha) + \sec(\phi + \delta_0 + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_0 + \theta_0') \cdot \sin(\phi + \delta_0)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 14.436^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 14.436^\circ)}} \end{aligned}$$

$$\cot(\xi_{\alpha'} - \alpha) = 0.97385$$

Thus,

$$\cot(\xi_{\alpha'} - 0.00^\circ) = \frac{1}{\tan(\xi_{\alpha'})} = 0.97385$$

$$\xi_{\alpha'} = \tan^{-1}\left(\frac{1}{0.97385}\right) = 45.759^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$\begin{aligned} K_{EA} &= \frac{\cos^2(\phi - \theta_0 - \theta)}{\cos \theta_0' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0' + \delta_0) \left[1 + \sqrt{\frac{\sin(\phi + \delta_0) \cdot \sin(\phi - \alpha - \theta_0')}{\cos(\theta + \theta_0' + \delta_0) \cdot \cos(\theta - \alpha)}} \right]^2} \\ &= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \\ &\quad \times \frac{1}{\left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2} \\ &= 0.4733 \end{aligned}$$

In case $\phi - \alpha - \theta_0 < 0$, $\sin(\phi - \alpha - \theta_0) = 0$.

$$\begin{aligned} K_{EA'} &= \frac{\cos^2(\phi - \theta_0' - \theta)}{\cos \theta_0' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0' + \delta_0) \left[1 + \sqrt{\frac{\sin(\phi + \delta_0) \cdot \sin(\phi - \alpha - \theta_0')}{\cos(\theta + \theta_0' + \delta_0) \cdot \cos(\theta - \alpha)}} \right]^2} \\ &= \frac{\cos^2(30.00^\circ - 14.436^\circ - 0.00^\circ)}{\cos(14.436^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 14.436^\circ + 0.00^\circ)} \\ &\quad \times \frac{1}{\left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 14.436^\circ)}{\cos(0.00^\circ + 14.436^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2} \\ &= 0.5255 \end{aligned}$$

In case $\phi - \alpha - \theta_0' < 0$, $\sin(\phi - \alpha - \theta_0') = 0$.

Weight of Embankment $W = 115.630$ (kN/m)

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot wq_0) / B \\ &= (115.630 + 5.00 \times 2.095) / 2.640 \\ &= 47.770 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$P_1 = q_0' \cdot K_{EA} = 47.770 \times 0.4733 = 22.608 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} P_2 &= K_{EA} \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.4733 \times 19.00 \times 1.500 + 22.608 \\ &= 36.096 \text{ (kN/m}^2\text{)} \end{aligned}$$

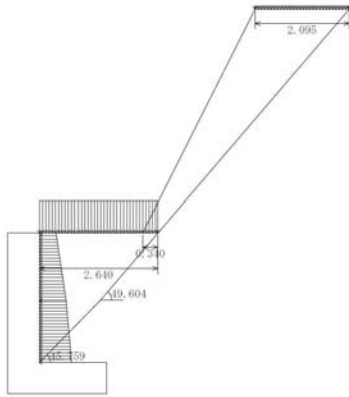
Earth Pressure at Junction

$$\begin{aligned} P_3 &= K_{EA} \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.5255 \times (20.00 - 9.80) \times 1.400 + 36.096 \\ &= 43.600 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$P_{1E} = P_3 \cdot \cos\theta = 43.600 \times \cos(0.00^\circ) = 43.600 \text{ (kN/m}^2\text{)}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.400 \times 9.80 = 13.720 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P(kN/m ²)	l(m)	P·l/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) = 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(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) = 30.34	
Shear Force	S(kN/m)	Σ(P·l) = 60.68	

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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	d1	mm	610.0
	As1	mm ²	794.4
Required Area of Re-bar	Back	mm ²	476.3
Neutral Axis	X	m	0.087
	ec	N/mm ²	1.56
Stress Intensity	os	N/mm ²	84.82
	oca	N/mm ²	8.20
Allowable Value	osa	N/mm ²	140.00
	min	mm ²	
Minimum Area of Re-Bar	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	d1	mm	610.0
	As1	mm ²	794.4
Required Area of Re-bar	Back	mm ²	275.3
Neutral Axis	X	m	0.087
	ec	N/mm ²	1.21
Stress Intensity	os	N/mm ²	65.72
	oca	N/mm ²	12.30
Allowable Value	osa	N/mm ²	186.00
	min	mm ²	
Minimum Area of Re-Bar	req	mm ²	367.1
	inp	mm ²	794.4

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2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	78.32
Re-bar	d1	mm	610.0
	As1	mm ²	794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	tm	N/mm ²	0.128
Allowable Value	ta	N/mm ²	0.360
	ta2	N/mm ²	1.600

■Seismic Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	60.68
Re-bar	d1	mm	610.0
	As1	mm ²	794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	tm	N/mm ²	0.099
Allowable Value	ta	N/mm ²	0.540
	ta2	N/mm ²	2.400

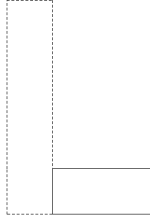
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1.3 Calculation of Bottom Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$S_w = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

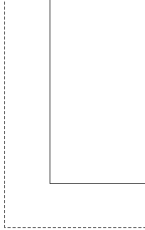
Thus,

S_w : 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



$$P_{w1} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 0.100 \times 19.00 + 2.800 \times 20.00 = 57.900$$

$$P_{w2} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 0.100 \times 19.00 + 2.800 \times 20.00 = 57.900$$

Thus,

P_{w1} : Weight of Embankment at basis (kN/m²)

P_{w2} : Weight of Embankment at edge (kN/m²)

H_1 : Height of Embankment above water (m)

H_2 : Height of Embankment underwater (m)

γ_t : Wet Unit Weight of Soil (kN/m³)

γ_{sat} : Unit Weight of Soil underwater (kN/m³)

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Thus,

P_{w1} : Weight of Embankment at basis (kN/m²)

P_{w2} : Weight of Embankment at edge (kN/m²)

H_1 : Height of Embankment above water (m)

H_2 : 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	97.45
Edge	79.15

2-4 Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unit (kN/m ²)
Base	2.100×9.80	20.580
Edge	2.100×9.80	20.580

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)	Unit (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



$$S_w = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

Thus,

S_w : 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



$$P_{w1} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 1.500 \times 19.00 + 1.400 \times 20.00 = 56.500$$

$$P_{w2} = (h_1 \cdot \gamma_t + h_2 \cdot \gamma_{sat}) = 1.500 \times 19.00 + 1.400 \times 20.00 = 56.500$$

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1.3.2 Summary of Cross Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m ²)	L (m)	$P \cdot l^2/2$ (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)	$\Sigma(P \cdot l^2/2) = 39.54$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 79.08$		

1-2) Edge

	P (kN/m ²)	L (m)	$P \cdot l^2/2$ (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)	$\Sigma(P \cdot l^2/2) = 14.99$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 29.97$		

2) Seismic Condition-1

2-1) Base

	P (kN/m ²)	L (m)	$P \cdot l^2/2$ (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)	$\Sigma(P \cdot l^2/2) = 22.37$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 44.73$		

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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	-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•L ² /2) = 13.22			
Shear Force	S (kN/m)	Σ (P•L) = 26.43	

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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	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	39.54	14.99
Re-bar	d1	mm	585.0	585.0
	As1	mm ²	1146.0	1146.0
Required Area of Re-bar	Lower		502.3	187.5
Neutral Axis	X	m	0.100	0.100
Stress Intensity	σc	N/mm ²	1.43	0.54
	σs	N/mm ²	62.55	23.71
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	669.8	250.1
	inp	mm ²	1146.0	1146.0

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	22.37	13.22
Re-bar	d1	mm	585.0	585.0
	As1	mm ²	1146.0	1146.0
Required Area of Re-bar	Lower		211.0	123.9
Neutral Axis	X	m	0.100	0.100
Stress Intensity	σc	N/mm ²	0.81	0.48
	σs	N/mm ²	35.38	20.91
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	281.3	165.2
	inp	mm ²	1146.0	1146.0

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(2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	79.08	29.97
Re-bar	d1	mm	585.0	585.0
	As1	mm ²	1146.0	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/mm ²	0.135	0.051
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	44.73	26.43
Re-bar	d1	mm	585.0	585.0
	As1	mm ²	1146.0	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/mm ²	0.076	0.045
Allowable Value	τa	N/mm ²	0.540	0.540
	τa2	N/mm ²	2.400	2.400

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2.2.2.6 SLUICEWAY TYPE I

(1) BOX - LONGITUDINAL

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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

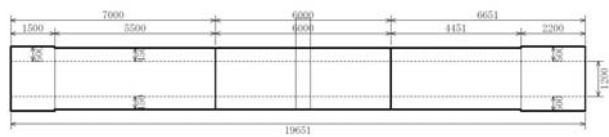
Residual Settlement	: 300.0 (mm)	
Residual Settlement for Rigid Support		: 50.0 (mm)
Relative Displacement	Base Width	: 1.0 (%)
		± : 50.0 (mm)

4) Type of Joint : Flexible Joint

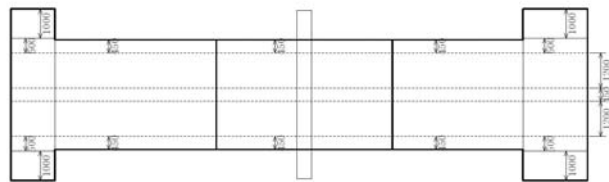
5) Allowable Opening : 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

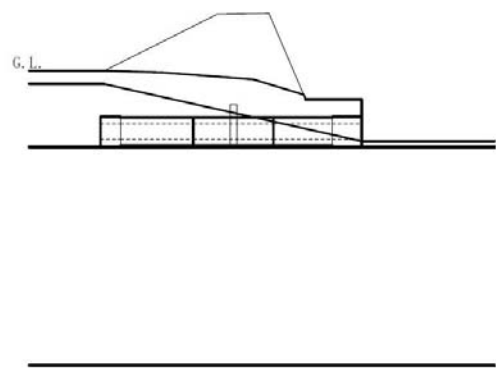
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Levee 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

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 Upper 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

1.2.2 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

Main Re-bar

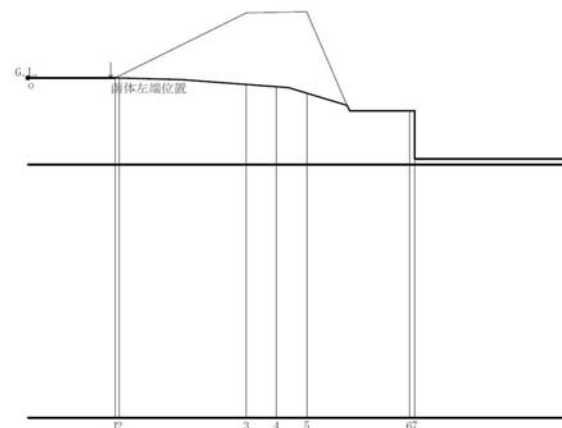
Span No	Block No	Flange		Reinforcing Bar				
		Portion	b (mm)	t (mm)	Outside		Inside	
					Diameter@Pitch (Number)	Cover (mm)	Diameter@Pitch (Number)	Cover (mm)
1	1	Top Slab	3850.0	500.0	D16@250 (15)	90.0	D16@250 (17)	90.0
		Bottom Slab	3850.0	500.0	D16@250 (15)	115.0	D16@250 (17)	90.0
	2	Top Slab	3750.0	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	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

2.1 Immediate Settlement

2.1.1 Settlement Calculation Points

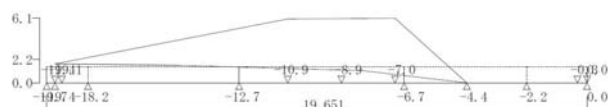
Settlement Calculation Points

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 Summary 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

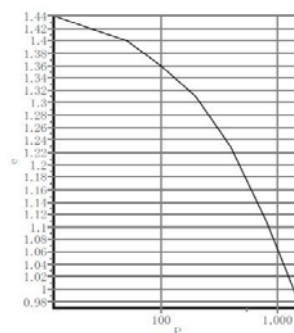


2.2.1 Ground Condition and e-logP Curb

2.2.1 Ground Condition and e-logP Curb

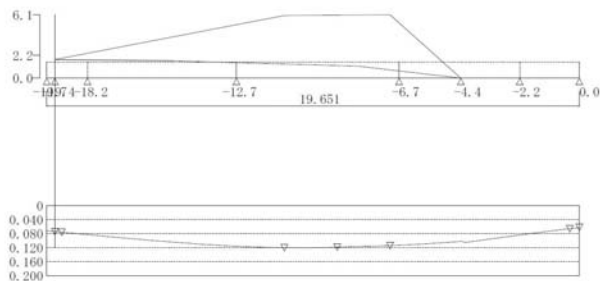
No	Name	Layer	Depth (m)	Unit Weight (W _{et}) (kN/m ³)	Unit Weight (Saturated) (kN/m ³)	Pre-Consolidation Stress (q ₀) (kN/m ²)	Elastic Modulus E _s (kN/m ²)
1	Adobe BL	Sand	5.662	17.500	18.500	0.0	6900.0
2	Dc4	Clay	22.112	17.500	18.500	0.0	15700.0

No	Consolidation Pressure P(kN/m ²)	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 Summary 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

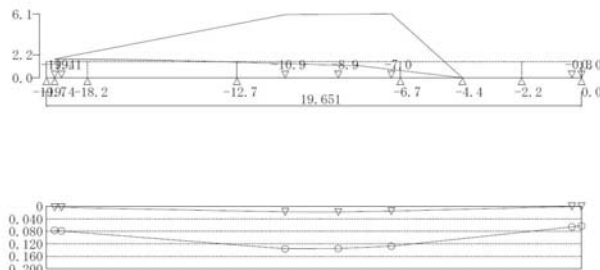


2.3 Residual Settlement

2.3.1 Summary of Results

No	Calculation Point (m)	Name	Immediate Settlement (mm)	Consolidation Settlement (mm)	Camber Bedding (mm)	Residual Settlement (mm)	Allowable Value	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

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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.

$$\frac{EI}{B} \cdot \frac{d^4 w}{dx^4} + k_s (w - w_g) = q \quad (\text{Swag})$$

$$\frac{EA}{U} \cdot \frac{d^2 u}{dx^2} + k_s (u - u_g) = p \quad (\text{Displacement in axial direction of Box Culvert})$$

Thus,

- w : Displacement of Box Culvert (Swag : cm {m})
- w_g : Displacement of the Ground (Residual Settlement: cm {m})
- k_s : 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 $B \neq L$

$$E_{om} = \frac{\log \frac{(B+2h_n \cdot \tan \theta) \cdot L}{(L+2h_n \cdot \tan \theta) \cdot B}}{\sum \frac{1}{E} \log \frac{(B+2h_n \cdot \tan \theta) \cdot (L+2h_{n+1} \cdot \tan \theta)}{(L+2h_n \cdot \tan \theta) \cdot (B+2h_{n+1} \cdot \tan \theta)}}$$

In case of $B=L$

$$E_{om} = \frac{\frac{1}{B+2h_n \cdot \tan \theta} + \frac{1}{B}}{\sum \frac{1}{E} \left(\frac{1}{B+2h_n \cdot \tan \theta} + \frac{1}{B+2h_{n+1} \cdot \tan \theta} \right)}$$

Thus

- E_{om} : 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/m²)
- θ : Angle of Load Dispersion ($\theta=30^\circ$)

Span1-Block1 Land Side

B	5.850 (m)		
L	7.000 (m)		
h _n	17.550 (m)		
Layer	Layer Thickness (m)	Depth (m)	E _i (kN/m ²)
1	17.550	17.550	62800.0
Total	17.550		
E _{om}	62800.0 (kN/m ²)		

※Layer Thickness and Depths are the values based on subgrade Surface.

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Span1-Block2 Land Side

B	3.750 (m)		
L	7.000 (m)		
hn	12.600 (m)		
Layer	Layer Thickness (m)	Depth (m)	Ei (kN/m ²)
1	12.600	12.600	62800.0
Total	12.600		
Eom	62800.0 (kN/m ²)		

※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/m ²)
1	11.250	11.250	62800.0
Total	11.250		
Eom	62800.0 (kN/m ²)		

※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/m ²)
1	11.250	11.250	62800.0
Total	11.250		
Eom	62800.0 (kN/m ²)		

※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/m ²)
1	17.550	17.550	62800.0
Total	17.550		
Eom	62800.0 (kN/m ²)		

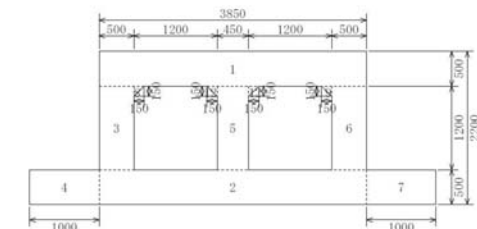
※Layer and Depth is the values from the subgrade

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3.2.2 Dimensions of Box Culvert

Span1-Block1 Land Side

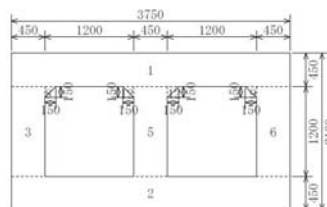


Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ³)	Ioi (m ³)
1	1.925	1.950	3.7538	7.3198	0.04010
2	1.925	0.250	0.4813	0.1203	0.04010
3	0.600	1.100	0.6600	0.7260	0.07200
4	0.500	0.250	0.1250	0.0313	0.01042
5	0.540	1.100	0.5940	0.6534	0.06480
6	0.600	1.100	0.6600	0.7260	0.07200
7	0.500	0.250	0.1250	0.0313	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

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 6.4733 / 6.635 = 0.9756 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 9.7305 + 0.30990 - 0.9518 \cdot 6.635 = 3.72499 \text{ (m}^4\text{)}$$

Span1-Block2 Land Side



Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ³)	Ioi (m ³)
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

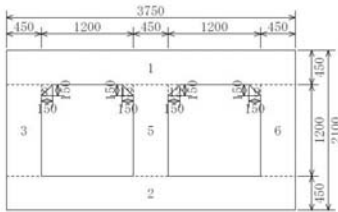
$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 5.3168 / 5.040 = 1.0549 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 7.9193 + 0.25141 - 1.1128 \cdot 5.040 = 2.56201 \text{ (m}^4\text{)}$$

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Span2-Block1 Center



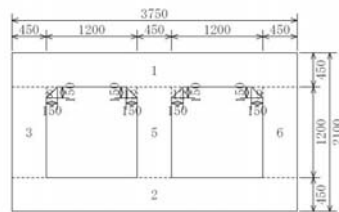
Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ³)	Ioi (m ⁴)
1	1.688	1.875	3.1641	5.9326	0.02848
2	1.688	0.225	0.3797	0.0854	0.02848
3	0.540	1.050	0.5670	0.5954	0.06480
5	0.540	1.050	0.5670	0.5954	0.06480
6	0.540	1.050	0.5670	0.5954	0.06480
8	0.011	1.600	0.0180	0.0288	0.00001
9	0.011	1.600	0.0180	0.0288	0.00001
12	0.023	1.600	0.0360	0.0576	0.00003
Total	5.040		5.3168	7.9193	0.25141

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 5.3168 / 5.040 = 1.0549 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 7.9193 + 0.25141 - 1.1128 \cdot 5.040 = 2.56201 \text{ (m}^4\text{)}$$

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Span3-Block1 River Side



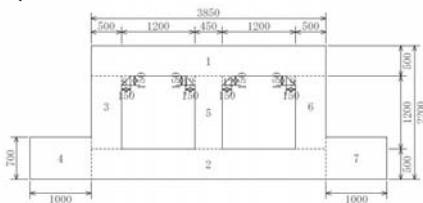
Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ³)	Ioi (m ⁴)
1	1.688	1.875	3.1641	5.9326	0.02848
2	1.688	0.225	0.3797	0.0854	0.02848
3	0.540	1.050	0.5670	0.5954	0.06480
5	0.540	1.050	0.5670	0.5954	0.06480
6	0.540	1.050	0.5670	0.5954	0.06480
8	0.011	1.600	0.0180	0.0288	0.00001
9	0.011	1.600	0.0180	0.0288	0.00001
12	0.023	1.600	0.0360	0.0576	0.00003
Total	5.040		5.3168	7.9193	0.25141

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 5.3168 / 5.040 = 1.0549 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 7.9193 + 0.25141 - 1.1128 \cdot 5.040 = 2.56201 \text{ (m}^4\text{)}$$

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Span3-Block2 River Side



Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (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

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 6.7133 / 7.035 = 0.9543 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma I_{oi} - Y_g^2 \cdot \Sigma A_i = 9.8395 + 0.34623 - 0.9106 \cdot 7.035 = 3.77955 \text{ (m}^4\text{)}$$

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3.2.3 Table of Modulus of Subgrade Reaction

Coefficient of Lateral Shear Reaction of Soil

$$k_c = \lambda \cdot k_v$$

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/m ³)	ks (kN/m ³)	kv·B (kN/m ²)	ks·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)	kv (kN/m ³)	ks (kN/m ³)	kv·B (kN/m ²)	ks·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)	kv·B (kN/m ²)	ks·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	kv·B (kN/m ²)	ks·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

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3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

$$W = (A1 + A2 + A3 + A4 + A5 + A6 + A7) \cdot \gamma_c \quad (\text{kN/m})$$

A1: Cross Sectional Area (Excluding Haunch) (m²)

A2: Area of Left Side Wall Upper Haunch (m²)

A3: Area of Left Side Wall Lower Haunch (m²)

A4: Area of Right Side Wall Upper Haunch (m²)

A5: Area of Right Side Wall Lower Haunch (m²)

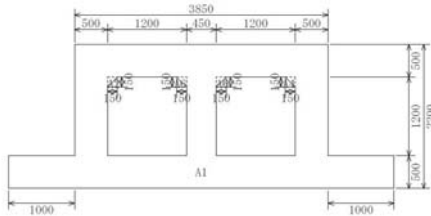
A6: Area of Center Wall Upper Haunch (m²)

A7: Area of Center Wall Lower Haunch (m²)

γ_c : Unit Weight (Concrete) (kN/m³)

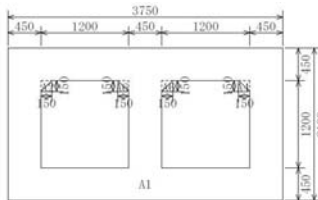
Span No. 1-1 Land Side

$$W = (6.590 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000) \cdot 24.000 = 159.240 \quad (\text{kN/m})$$



Span No. 1-2 Land Side

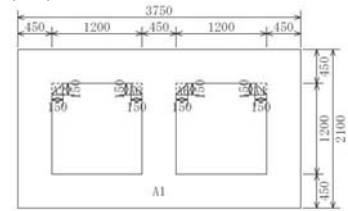
$$W = (4.995 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000) \cdot 24.000 = 120.960 \quad (\text{kN/m})$$



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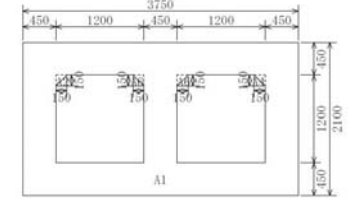
Span No. 2-1 Center

$$W = (4.995 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000) \cdot 24.000 = 120.960 \quad (\text{kN/m})$$



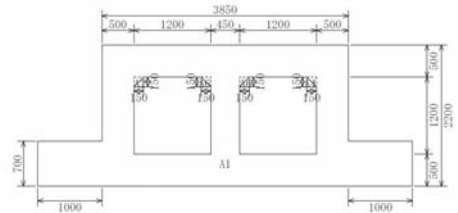
Span No. 3-1 River Side

$$W = (4.995 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000) \cdot 24.000 = 120.960 \quad (\text{kN/m})$$



Span No. 3-2 River Side

$$W = (6.990 + 0.011 + 0.000 + 0.011 + 0.000 + 0.023 + 0.000) \cdot 24.000 = 168.840 \quad (\text{kN/m})$$



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2) Seepage Cutoff Wall Body Weight

$$A1 = X1 \cdot L2$$

$$A2 = L1 \cdot Y1 \cdot 2$$

$$W = (A1 + A2) \cdot B \cdot \gamma_c \quad (\text{kN})$$

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 (m²)

A2: Left Wall Area (m²)

A3: Right Wall Area (m²)

B: Thickness (m)

γ_c : Unit Weight (Concrete) (kN/m³)

SpanNo.2-SpanDistance from Base Point (2.000)

$$A1 = 5.750 \cdot 1.000$$

$$= 5.750 \quad (\text{m}^2)$$

$$A2 = 1.000 \cdot 2.100$$

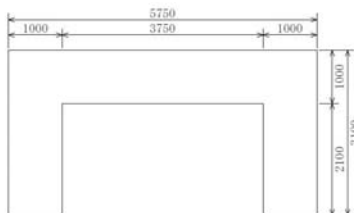
$$= 2.100 \quad (\text{m}^2)$$

$$A3 = 1.000 \cdot 2.100$$

$$= 2.100 \quad (\text{m}^2)$$

$$W = (5.750 + 2.100 + 2.100) \cdot 0.500 \cdot 24.00$$

$$= 119.400 \quad (\text{kN})$$



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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	-13655.229
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-(23)	-9.151~-8.651	3.750	99001.6	135.4	134.5	-13399.987	-13320.325
1-(24)	-8.651~-8.151	3.750	99001.6	134.5	133.7	-13320.325	-13240.942
1-(25)	-8.151~-7.651	3.750	99001.6	133.7	133.0	-13240.942	-13165.527
1-(26)	-7.651~-7.151	3.750	99001.6	133.0	129.3	-13165.527	-12799.317
1-(27)	-7.151~-6.651	3.750	99001.6	129.3	123.9	-12799.317	-12268.537

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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-(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



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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/m ²)	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

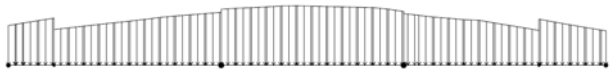
Span2 Name of Span: [Center]

Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m ²)	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

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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-(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



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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 Condition 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 Seismic 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



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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)l	Gate Structure •Breast Wall (Normal)l	1.0000
6	Arbitrary Load(Normal)l	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)l	Surcharge in Seismic Condition	1.0000
6	Ingaging Load(Dead Load)l	Gate Structure •Breast Wall (Dead Load)l	1.0000
7	Ingaging Load(Seismic)l	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)l	Surcharge in Seismic Condition	1.0000

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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	○
2	0.250	-11.5	-12.7	79.3	75.9	3.4	50.0	○
3	0.500	-11.5	-12.6	81.3	78.2	3.1	50.0	○
4	1.000	-11.5	-12.3	85.3	82.9	2.4	50.0	○
5	1.500	-11.5	-12.0	89.3	87.3	2.0	37.5	○
6	2.000	-11.5	-11.8	93.3	91.6	1.7	37.5	○
7	2.500	-11.5	-11.5	97.3	95.8	1.4	37.5	○
8	3.000	-11.5	-11.2	101.3	100.0	1.3	37.5	○
9	3.500	-11.5	-11.0	105.3	104.1	1.2	37.5	○
10	4.000	-11.5	-10.7	109.3	108.1	1.2	37.5	○
11	4.500	-11.5	-10.4	113.2	112.3	1.0	37.5	○
12	5.000	-11.5	-9.6	117.2	116.9	0.3	37.5	○
13	5.500	-11.5	-8.6	121.2	120.5	0.7	37.5	○
14	6.000	-11.5	-7.6	125.2	123.4	1.8	37.5	○
15	6.500	-11.5	-6.6	129.2	126.6	2.7	37.5	○
16	7.000	-11.5	-5.6	133.2	129.3	4.0	37.5	○

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	○
2	0.500	1.7	-4.6	136.4	131.5	4.9	37.5	○
3	1.000	1.7	-3.6	136.1	133.0	3.2	37.5	○
4	1.500	1.7	-2.6	135.9	134.7	1.2	37.5	○
5	2.000	1.7	-1.4	135.7	136.7	-1.0	-50.0	○
6	2.500	1.7	0.0	135.4	137.0	-1.6	-50.0	○
7	3.000	1.7	1.5	135.2	136.2	-1.0	-50.0	○
8	3.500	1.7	2.9	134.9	135.4	-0.4	-50.0	○
9	4.000	1.7	4.3	134.7	134.5	0.1	37.5	○
10	4.500	1.7	5.7	134.4	133.7	0.7	37.5	○
11	5.000	1.7	7.2	134.2	133.0	1.2	37.5	○
12	5.500	1.7	8.8	134.0	129.3	4.7	37.5	○
13	6.000	1.7	9.8	133.7	123.9	9.8	37.5	○

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Span3 Name of Span: [River Side]

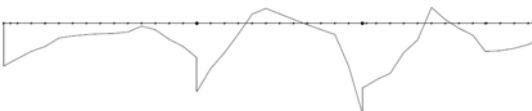
Number	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)				Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge
1	0.000	16.2	9.8	131.2	123.9	7.3	37.5	○
2	0.140	16.2	10.0	129.8	122.7	7.0	37.5	○
3	0.500	16.2	10.5	126.1	119.8	6.3	37.5	○
4	1.000	16.2	11.2	121.0	115.4	5.6	37.5	○
5	1.500	16.2	12.0	116.0	112.7	3.3	37.5	○
6	2.000	16.2	12.7	110.9	109.0	1.9	37.5	○
7	2.500	16.2	13.1	105.8	107.6	-1.8	-50.0	○
8	3.000	16.2	13.0	100.7	101.1	-0.4	-50.0	○
9	3.500	16.2	12.9	95.7	95.1	0.6	37.5	○
10	4.000	16.2	12.8	90.6	89.2	1.3	37.5	○
11	4.451	16.2	12.8	86.0	83.6	2.4	37.5	○
12	4.500	16.2	12.8	85.5	83.1	2.4	50.0	○
13	5.000	16.2	12.7	80.4	78.1	2.3	50.0	○
14	5.500	16.2	12.6	75.3	73.2	2.1	50.0	○
15	6.000	16.2	12.5	70.3	68.5	1.8	50.0	○
16	6.500	16.2	12.4	65.2	63.9	1.3	50.0	○
17	6.651	16.2	12.4	63.7	62.6	1.1	50.0	○

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Displacement Diagram



Reaction Diagram of Ground



Reaction Force Diagram



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3.4.2 Seismic Condition

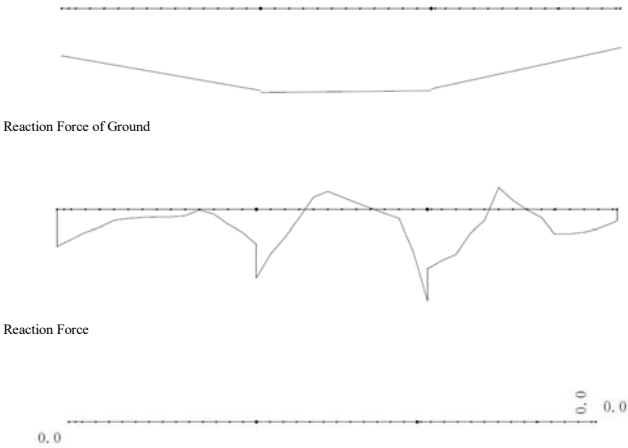
1) Calculation Case1 - Load: [Seismic Condition Land Side → River Side]

Span1 Name of Span: [Land Side]									
Num ber	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]									
Num ber	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

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Displacement Diagram



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Span3 Name of Span: [River Side]

Num ber	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

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2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]									
Num ber	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

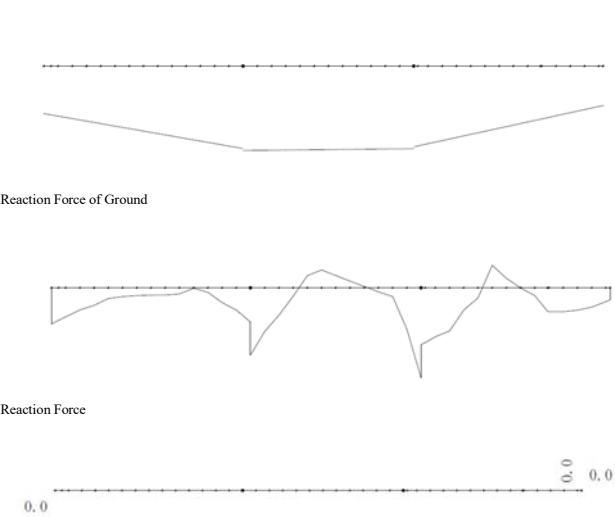
Span2 Name of Span: [Center]									
Num ber	Distance X(m)	Longitudinal Direction Displacement(mm)		Vertical Direction Displacement (mm)					Reaction Force of Ground (kN/m)
		Box Culvert	Ground	Box Culvert	Ground	Relative	Allowable	Judge	
1	0.000	1.7	-5.6	136.3	129.3	7.1	37.5	○	702.355
2	0.500	1.7	-4.6	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

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Span3 Name of Span: [River Side]

Num ber	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]

Num ber	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

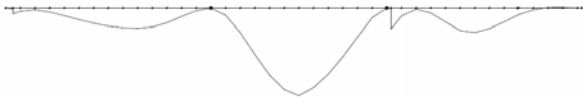
Span2 Name of Span: [Center]

Num ber	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

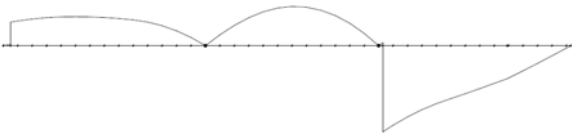
Span3 Name of Span: [River Side]

Num ber	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

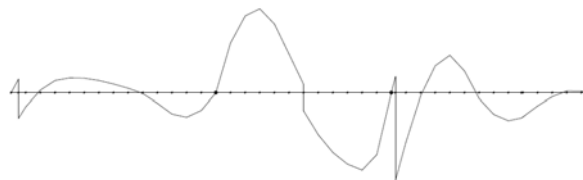
Bending Moment



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

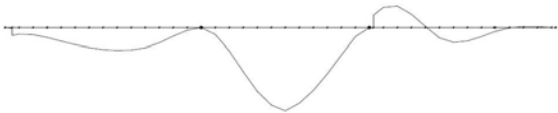
Span2 Name of Span: [Center]

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

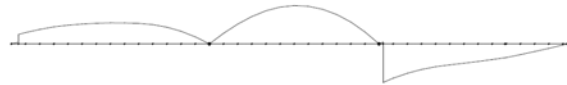
Span3 Name of Span: [River Side]

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

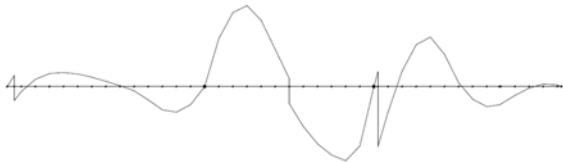
Bending Moment



Axial Force



Shear Force



Span1 Name of Span: [Land Side]

Num ber	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

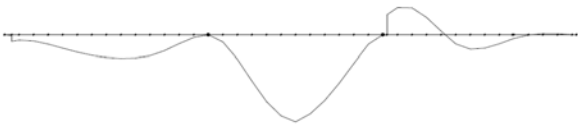
Span2 Name of Span: [Center]

Num ber	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

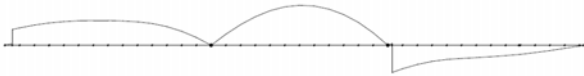
Span3 Name of Span: [River Side]

Num ber	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

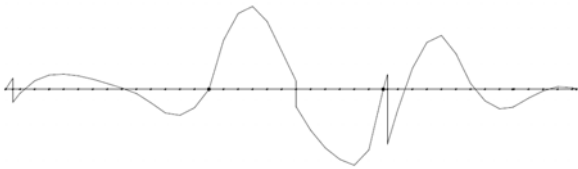
Bending Moment



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
 $\theta = \theta_1 - \theta_2$ - Initial Bending Angle
Thus,
01: Angle of Displacement (Left Side) (rad)
02: Angle of Displacement (Right Side) (rad)
0: 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)	01(Degree) (rad)	02(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)	$\theta 1$ (Degree) (rad)	$\theta 2$ (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)	$\theta 1$ (Degree) (rad)	$\theta 2$ (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

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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	

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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

$$x = \frac{n \cdot (A_s \cdot d + A_s' \cdot d') + B \cdot t^2 / 2}{n \cdot (A_s + A_s') + B \cdot t}$$

Thus,

x : Position of Neutral Axis (mm)

n : Ratio of Young modulus = 9.0

A_s : Area of Re-bar in tensile side (mm²)

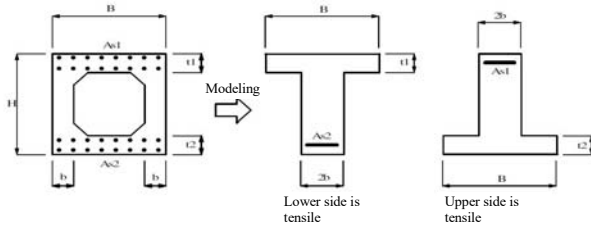
A_s' : Area of Re-bar in compressive side (mm²)

d : Effective Height of Beam (mm)

d' : Distance from the compressive edge of concrete to the centric of Re-bar (mm)

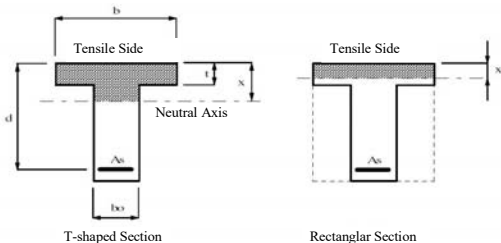
B : Width of Flange (mm)

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.



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Calculation Condition (In Case Bottom Slab is Tensile)

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 A _s (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side A _s ' (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)

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

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3.7.2 Normal Condition

1) Calculation Case1 : Normal Condition

Span1-Block1

Item		Sym bol	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		48.465	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	----

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Calculation Case1: Normal Condition

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Normal Condition

Span3-Block1

Item		Sym bol	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

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Calculation Case1: Normal Condition

Span3-Block2

Item		Sym bol	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

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3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Sym bol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Sym bol	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

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Calculation Case1: Seismic Condition

Span3-Block2

Item		Sym bol	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

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2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Sym bol	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	----

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Span1-Block2

Item		Sym bol	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	----

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Span2-Block1

Item		Sym bol	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		Sym bol	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		Sym bol	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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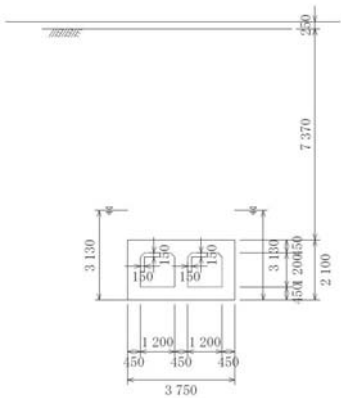
2.2.2.6 SLUICEWAY TYPE I

(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	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	σ_{sa}	N/mm ²	Normal (General)	140.00
		N/mm ²	Normal (Harsh)	140.00
		N/mm ²	Seismic	186.00
Allow Compressive Strength	σ_{sa}'	N/mm ²	Normal	140.00
		N/mm ²	Seismic	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	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 (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
Middle Sidewall	D13 —	250 —	506.8	Middle Sidewall	— —	— —	—

Outside of Top Slab	Diameter	Pitch	Area (mm²)	Inside of Top Slab	Diameter	Pitch	Area (mm²)
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

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	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/m²)	10.000

■ Cover

Location	Cover(mm)	Location	Cover(mm)
Top Slab	Upper 90.0 Lower 90.0	Right Wall	Outside 90.0 Inside 90.0
Left Wall	Outside 90.0 Inside 90.0	Bottom Slab	Upper 90.0 Lower 115.0
Midwall	90.0		—

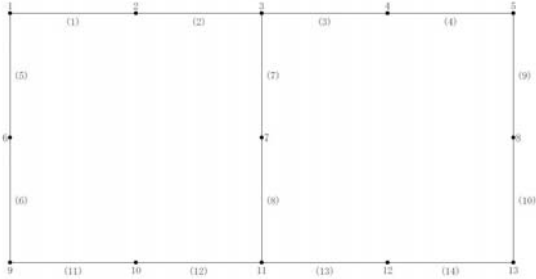
■ Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement Aw (mm²/m)
Top Slab	100	0.0
Left Sidewall	100	0.0
Medium Sidewall	100	100.0
Middle Sidewall	100	0.0
Bottom Slab	100	0.0

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

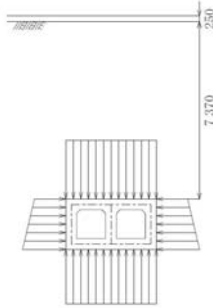
4) Supporting Point

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
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (2) Left Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (3) Middle Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (4) Right Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$

Surcharge Load

(1) Pavement and Embankment

$$\begin{aligned} \text{Pavement (Above Water Level)} &= 1.000 \times 0.250 \times 22.60 = 5.65 \text{ (kN/m}^2\text{)} \\ \text{Embankment (Above Water Level)} &= 1.000 \times 6.340 \times 18.00 = 114.12 \text{ (kN/m}^2\text{)} \\ \text{Embankment (Below Water Level)} &= 1.000 \times 1.030 \times 9.20 = 9.48 \text{ (kN/m}^2\text{)} \\ \text{Water Pressure} &= 1.030 \times 9.80 = 10.09 \text{ (kN/m}^2\text{)} \end{aligned}$$

$$\Sigma w_d = 139.34 \text{ (kN/m}^2\text{)}$$

(2) Surcharge Load at Road

$$\begin{aligned} \text{Surcharge} &= 10.000 \text{ (kN/m}^2\text{)} \\ \text{Snow Load} &= 0.00 \text{ (kN/m}^2\text{)} \end{aligned}$$

$$\Sigma q_d = 10.000 \text{ (kN/m}^2\text{)}$$

(3) Load Acting on Top Slab

$$\begin{aligned} \text{Uniformly Distributed Load} \\ w &= 139.34 + 10.00 = 149.34 \text{ (kN/m}^2\text{)} \end{aligned}$$

Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

$$\begin{aligned} p_i &= K_o \times (q_d + Y_o \times \gamma_a + Z_u \times \gamma + (Z_o - Z_u) \times \gamma') + (Z_o - Z_u) \times \gamma_w \\ K_o &: \text{Coefficient of Earth Pressure at Rest} = 0.500 \\ Z_o &: \text{Depth of Calculation Point from Embankment Top (m)} \end{aligned}$$

(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

$$\begin{aligned} U &= 3.130 \times 3.750 \times 9.80 = 115.03 \text{ (kN/m)} \\ w &= \frac{-115.03}{3.750} = -30.67 \text{ (kN/m}^2\text{)} \end{aligned}$$

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

$$\bar{x} = \frac{\Sigma M}{\Sigma V} = 1.875 \text{ (m)}$$

$$e = \frac{B}{2} - \bar{x} = 0.000 \text{ (m)}$$

(2) Subgrade Reaction Intensity

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$M_o = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_l = \frac{\Sigma V}{B} + \frac{6 \times M_o}{B^2} = 140.12 \text{ (kN/m}^2\text{)}$$

$$q_r = \frac{\Sigma V}{B} - \frac{6 \times M_o}{B^2} = 140.12 \text{ (kN/m}^2\text{)}$$

$$q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 140.12 \text{ (kN/m}^2\text{)}$$

$$q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 140.12 \text{ (kN/m}^2\text{)}$$

Thus, T : Thickness of Side Wall

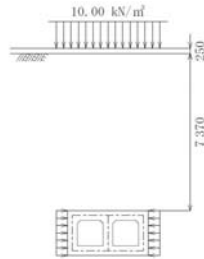
q_l : Subgrade Reaction Intensity on Left Edge

q_r : Subgrade Reaction Intensity on Right Edge

q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

q_r' : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface $q_L = 10.000 \text{ (kN/m}^2\text{)}$

Load

- (1) Vertical Load Effecting Top Slab
 $w_L = q_L = 10.00 \text{ (kN/m}^2\text{)}$
 (2) Horizontal Load Acting on Left Side Wall
 Converted Uniformly Distributed Load
 $w_L = 10.00 \text{ (kN/m}^2\text{)}$
 $p = K_o \times w_L = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$
 (3) Horizontal Load Effecting on Right Side Wall
 Converted Uniformly Distributed Load
 $w_L = 10.00 \text{ (kN/m}^2\text{)}$
 $p = K_o \times w_L = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$

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

$$\bar{X} = \frac{\sum M}{\sum V} = 1.875 \text{ (m)}$$

$$e = \frac{B}{2} - \bar{X} = 0.000 \text{ (m)}$$

$$M_e = \sum V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_l = \frac{\sum V}{B} + \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_r = \frac{\sum V}{B} - \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

$$q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$$

Thus, T : Thickness of Side Wall
 q_l : Subgrade Reaction Intensity on Left Edge
 q_r : Subgrade Reaction Intensity on Right Edge
 q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
 q_r' : 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

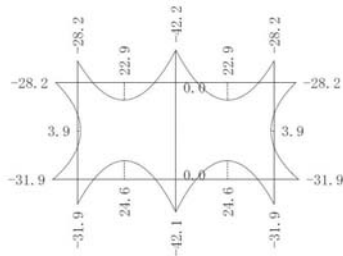
Load Number

13: Member Distribution Load (X Direction)

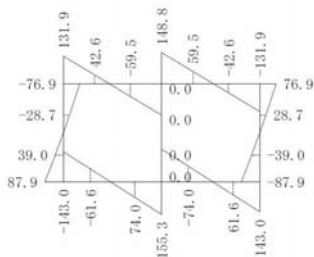
14: Member Distribution Load (Y Direction)

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		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 1146.0	D19 @ 250 1146.0	D19 @ 250 1146.0	D19 @ 250 1146.0	D19 @ 250 1146.0
	Internal	mm²	D16 @ 250 794.4	D16 @ 250 794.4	D16 @ 250 794.4	D16 @ 250 794.4	D16 @ 250 794.4
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		
	rcq	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

$$\tau_m = \frac{S}{b \times d} \leq \tau_a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm2)	τa (N/mm2)	Cases	L (m)
Top Slab	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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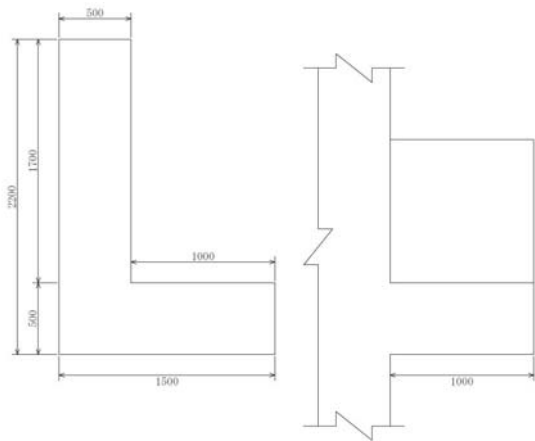
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1 Calculation of Land Side Breast Wall

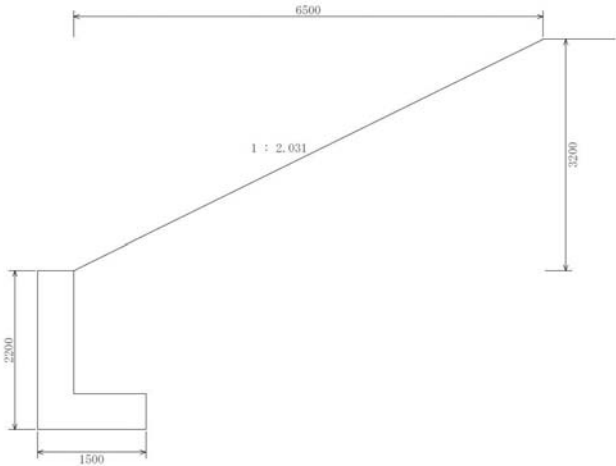
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Critical Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	σ_{sa}	N/mm ² Normal (General)	140.00
		N/mm ² Normal (Harsh)	140.00
		N/mm ² Seismic	186.00
Allow Compressive Strength	σ_{sa}'	N/mm ² Normal	140.00
		N/mm ² Seismic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φ_{res}	○	30
Peak Angle of Internal Friction	φ_{peak}	○	30
Coefficient of Lateral Earth Pressure at-rest	K_0		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 A _w (mm ² /m)
Side Wall	0.0	0.0
Bottom Slab	0.0	0.0

1.1.4 Loads

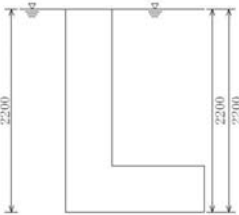
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

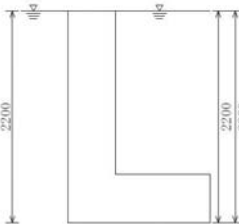
	(m)
Toe	2.200
Heel	2.200



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	78.22
Heel	42.41
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m ²), (m)
Toe	65.24
Heel	31.62
Load Width	0.000

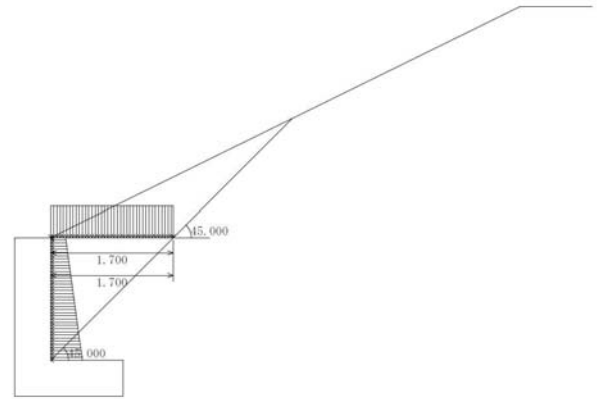


3) Surcharge Load

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) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.700 \cdot 9.80 = 16.660 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : 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

$$H = B \cdot \gamma_c \cdot k_h = 0.500 \times 24.00 \times 0.20 = 2.400$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : Unit Weight of Concrete (kN/m³)

k_h : Design Horizontal Seismic Coefficient

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 $W = 26.623 \text{ (kN/m)}$

ξ_A (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot wq_0) / B \\ &= (26.623 + 10.00 \times 2.300) / 1.700 \\ &= 15.661 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 15.661 \times 0.500 = 7.830 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.000 + 7.830 \\ &= 7.830 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Junction

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 1.700 + 7.830 \\ &= 16.500 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P &= p_3 \\ &= 16.500 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

q_0 : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

wq_0 : Surcharge (kN/m²)

wq_0 : Width of Surcharge (m)

h_1 : Height above Water Surface (m)

h_2 : Height under Water Surface (m)

2-2) Earth Pressure

●Type of Earth Pressure: Active Earth Pressure

Embankment Height above the water level surface	h_1	=	0.000	(m)
Embankment Height under the water level surface	h_2	=	1.700	(m)
Angle between the vertical wall and vertical plane	θ	=	0.00	(degree)
Unit Weight of Soil (Wet)	γ_s	=	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	q_0	=	5.00	(kN/m ²)
Load width of Surcharge	wq_0	=	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)	$\delta_{\bar{c}}$	=	0.00	(degree)
Design Horizontal Seismic Coefficient	k_h	=	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

$$\begin{aligned} \cot(\xi_{sa} - \alpha) &= -\tan(\phi + \delta_s + \theta - \alpha) + \sec(\phi + \delta_s + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_s + \theta_s) \cdot \sin(\phi + \delta_s)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_s)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \end{aligned}$$

$$\cot(\xi_{sa} - \alpha) = 0.85094$$

Thus,

$$\cot(\xi_{sa} - 0.00^\circ) = \frac{1}{\tan(\xi_{sa})} = 0.85094$$

$$\xi_{sa} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Active Angle of Rupture underwater in Seismic Condition

$$\begin{aligned} \cot(\xi_{sa'} - \alpha) &= -\tan(\phi + \delta_s + \theta - \alpha) + \sec(\phi + \delta_s + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_s + \theta_s) \cdot \sin(\phi + \delta_s)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_s)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 16.855^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 16.855^\circ)}} \end{aligned}$$

$$\cot(\xi_{sa'} - \alpha) = 1.09764$$

Thus,

$$\cot(\xi_{sa'} - 0.00^\circ) = \frac{1}{\tan(\xi_{sa'})} = 1.09764$$

$$\xi_{sa'} = \tan^{-1}\left(\frac{1}{1.09764}\right) = 42.335^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$\begin{aligned} K_{ea} &= \frac{\cos^2(\phi - \theta_s - \theta)}{\cos \theta_s \cdot \cos^2 \theta \cdot \cos(\theta + \theta_s + \delta_s) \left[1 + \sqrt{\frac{\sin(\phi + \delta_s) \cdot \sin(\phi - \alpha - \theta_s)}{\cos(\theta + \theta_s + \delta_s) \cdot \cos(\theta - \alpha)}} \right]^2} \\ &= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \\ &\quad \times \frac{1}{\left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2} \\ &= 0.4733 \end{aligned}$$

In case $\phi - \alpha - \theta_s < 0$, $\sin(\phi - \alpha - \theta_s) = 0$.

$$\begin{aligned} K_{ea} &= \frac{\cos^2(\phi - \theta_s - \theta)}{\cos \theta_s \cdot \cos^2 \theta \cdot \cos(\theta + \theta_s + \delta_s) \left[1 + \sqrt{\frac{\sin(\phi + \delta_s) \cdot \sin(\phi - \alpha - \theta_s)}{\cos(\theta + \theta_s + \delta_s) \cdot \cos(\theta - \alpha)}} \right]^2} \\ &= \frac{\cos^2(30.00^\circ - 16.855^\circ - 0.00^\circ)}{\cos(16.855^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 16.855^\circ + 0.00^\circ)} \\ &\quad \times \frac{1}{\left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 16.855^\circ)}{\cos(0.00^\circ + 16.855^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2} \\ &= 0.5726 \end{aligned}$$

In case $\phi - \alpha - \theta_s < 0$, $\sin(\phi - \alpha - \theta_s) = 0$.

Weight of Embankment $W = 28.025 \text{ (kN/m)}$

Converted Load $q_0' = (W + q_0 \cdot wq_0) / B$

$$= (28.025 + 5.00 \times 0.000) / 1.866$$

$$= 15.019 \text{ (kN/m}^2\text{)}$$

Earth Pressure at the Top

$$P_1 = q_0' \cdot K_{ea} = 15.019 \times 0.4733 = 7.108 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$P2 = K_{EA} \cdot \gamma_w \cdot h1 + p1$$

$$= 0.4733 \times 19.00 \times 0.000 + 7.108$$

$$= 7.108 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Junction

$$P3 = K_{EA} \cdot (\gamma_{sat} - \gamma_w) \cdot h2 + p2$$

$$= 0.5726 \times (20.00 - 9.80) \times 1.700 + 7.108$$

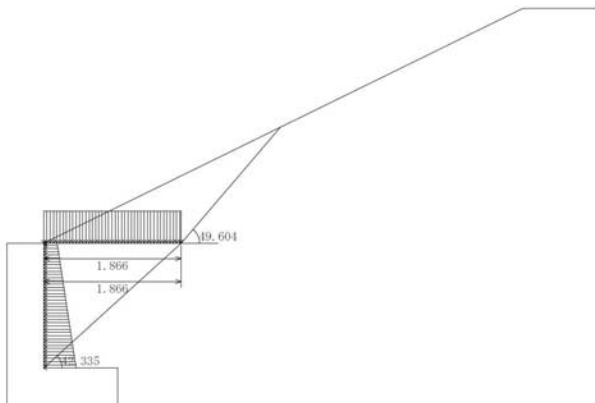
$$= 17.036 \text{ (kN/m}^2\text{)}$$

Design Earth Pressure

$$P_{1E} = P3 \cdot \cos\delta = 17.036 \times \cos(0.00^\circ)$$

$$= 17.036 \text{ (kN/m}^2\text{)}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.700 \times 9.80 = 16.660 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m ²)	L (m)	P·l/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) = 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 (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) = 18.05		
Shear Force S (kN/m)	Σ(P · l) = 36.10		

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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	mm	410.0
	As1	mm ²	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

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2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	33.16
Re-bar	d1	mm	410.0
	As1	mm ²	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	mm	410.0
	As1	mm ²	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

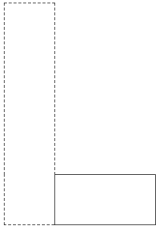
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1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$S_w = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

Thus,

S_w : 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



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sw}) = 0.000 \times 19.00 + 1.700 \times 20.00 = 34.000$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sw}) = 0.492 \times 19.00 + 1.700 \times 20.00 = 43.354$$

Thus,

$Pw1$: Weight 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_{sw} : Unit Weight of Soil underwater (kN/m³)

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1-3) Subgrade Reaction Force

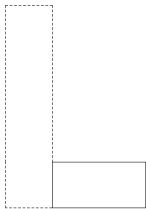
	Intensity of subgrade reaction (kN/m ²)
Base	66.28
Edge	42.41

1-4) Uplift Force

	Calculating Formula Height of Water Level × Unit Weight of Water (γ_w)	Unit (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



$$S_w = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

Thus,

S_w : Weight of Wall (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

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2-2) Weight of the Embankment



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sw}) = 0.000 \times 19.00 + 1.700 \times 20.00 = 34.000$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sw}) = 0.492 \times 19.00 + 1.700 \times 20.00 = 43.354$$

Thus,

$Pw1$: Weight 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_{sw} : Unit Weight of Soil underwater (kN/m³)

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)	Unit (kN/m ²)
Base	2.200 × 9.80	21.560
Edge	2.200 × 9.80	21.560

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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)	$\Sigma(P \cdot l^2/2) = 20.92$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 41.84$		

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)	$\Sigma(P \cdot l^2/2) = 4.31$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 8.62$		

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)	$\Sigma(P \cdot l^2/2) = 14.80$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 29.59$		

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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	-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•l ² /2) = -1.09			
Shear Force	S (kN/m)	Σ(P•l) = -2.17	

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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	20.92	4.31
Re-bar	d1	mm	385.0	385.0
	Asl	mm ²	794.4	794.4
Required Area of Re-bar	Lower	mm ²	405.5	81.6
Neutral Axis	X	m	0.067	0.067
Stress Intensity	σc	N/mm ²	1.71	0.35
	σs	N/mm ²	72.65	14.96
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	540.7	108.7
	inp	mm ²	794.4	794.4

■Seismic Condition-1

	Symbol	Unit	Junction	Edge
Bending Moment	M	kN.m	14.80	-1.09
Re-bar	d1	mm	385.0	90.0
	Asl	mm ²	794.4	794.4
Required Area of Re-bar	Upper	mm ²		14.4
	Lower	mm ²	213.4	
Neutral Axis	X	m	0.067	0.070
Stress Intensity	σc	N/mm ²	1.21	0.08
	σs	N/mm ²	51.38	3.54
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	284.5	19.2
	inp	mm ²	794.4	794.4

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(2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction	Edge
Shear Force	S	kN	41.84	8.62
Re-bar	d1	mm	385.0	385.0
	Asl	mm ²	794.4	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	0.109	0.022
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	29.59	-2.17
Re-bar	d1	mm	385.0	90.0
	Asl	mm ²	794.4	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	0.077	0.005
Allowable Value	τa	N/mm ²	0.540	0.540
	τa2	N/mm ²	2.400	2.400

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2.2.2.6 SLUICeway TYPE I
(4) BREAST WALL - RIVER SIDE

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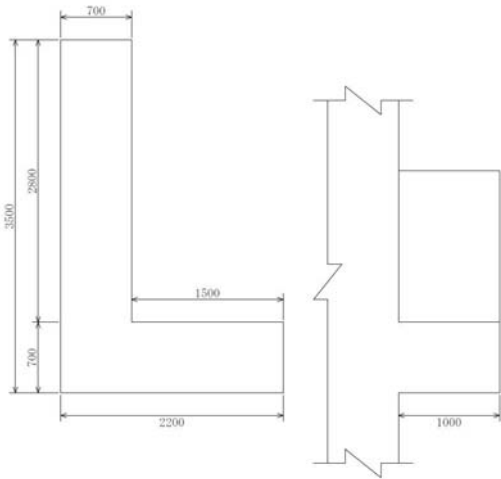
1.3.3 Stress Intensity Calculation.....19

1 Calculation of River Side Breast Wall

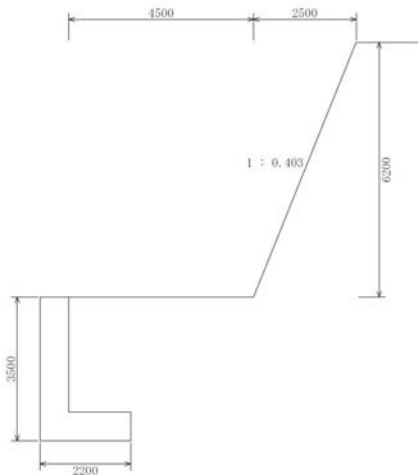
1.1 Design Condition

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Critical Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	σ_{sa}	N/mm ² Normal (General)	140.00
		N/mm ² Normal (Harsh)	140.00
		N/mm ² Seismic	186.00
Allow Compressive Strength	$\sigma_{sa'}$	N/mm ² Normal	140.00
		N/mm ² Seismic	186.00

■Soil

Backfill Angle of Internal Friction	φ	°	30.00
Residual Angle of Internal Friction	φ_{res}	°	30
Peak Angle of Internal Friction	φ_{peak}	°	30
Coefficient of Lateral Earth Pressure at-rest	K_0		0.500

1.1.3 Reinforcement Arrangement

■Main Tensile Reinforcement

	Location	Clear Cover (mm)	Diameter	Pitch (mm)	Amount of Reinforcement (mm ² /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 A _w (mm ² /m)
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Loads

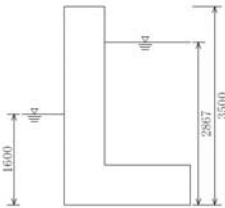
■Basic Load

1)Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

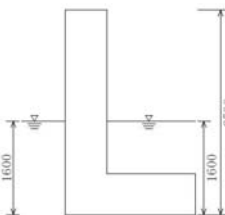
	(m)
Toe	1.600
Heel	2.867



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/m ²), (m)
Toe	161.74
Heel	12.13
Load Width	0.000



2-2) Seismic <Case 1>

	(kN/m ²), (m)
Toe	140.84
Heel	4.72
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_s (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot wq_0) / B \\ &= (0.000 + 10.00 \times 0.000) / 2.800 \\ &= 0.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 0.000 \times 0.500 = 0.000 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.633 + 0.000 \\ &= 6.014 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Bottom Surface of Base

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 2.167 + 6.014 \\ &= 17.065 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P &= p_3 \\ &= 17.065 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γ_t : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

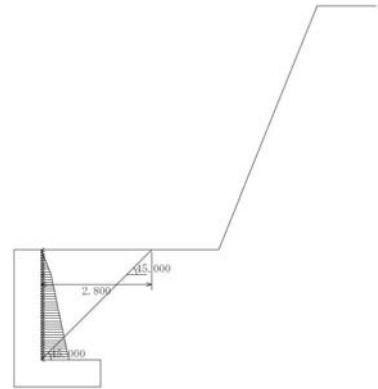
q_0 : Surcharge (kN/m²)

wq_0 : 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

$$P_h = h_h \cdot \gamma_w = 2.167 \times 9.80 = 21.237 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : 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

$$H = B \cdot \gamma_c \cdot kh = 0.700 \times 24.00 \times 0.20 = 3.360$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : 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	h_1	= 1.900	(m)
Angle between the vertical wall and vertical plane	θ	= 0.00	(degree)
Unit Weight of Soil (Wet)	γ_s	= 19.00	(kN/m ³)
Surcharge	q_0	= 5.00	(kN/m ²)
Load width of Surcharge	wq_0	= 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

$$\begin{aligned} \cot(\xi_{sa} - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \\ \cot(\xi_{sa} - \alpha) &= 0.85094 \end{aligned}$$

Thus,

$$\cot(\xi_{sa} - 0.00^\circ) = \frac{1}{\tan(\xi_{sa})} = 0.85094$$

$$\xi_{sa} = \tan^{-1}\left(\frac{1}{0.85094}\right) = 49.604^\circ$$

■Coefficient of Active Earth Pressure in Seismic Condition

$$\begin{aligned} \cot(\xi_{sa}' - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 13.229^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 13.229^\circ)}} \\ \cot(\xi_{sa}' - \alpha) &= 0.92236 \end{aligned}$$

In case $\phi - \alpha - \theta_0 < 0$, $\sin(\phi - \alpha - \theta_0) = 0$.

Weight of Embankment	W	$\gamma = 0.000$ (kN/m)
Converted Load	q_0'	$q_0' = (\gamma + q_0 \cdot wq_0) / B$
		$= (0.000 + 5.00 \times 0.000) / 2.447$
		$= 0.000$ (kN/m ²)

Earth Pressure at the Top

$$P_1 = q_0' \cdot K_{EA} = 0.000 \times 0.4733 = 0.000 \text{ (kN/m}^2\text{)}$$

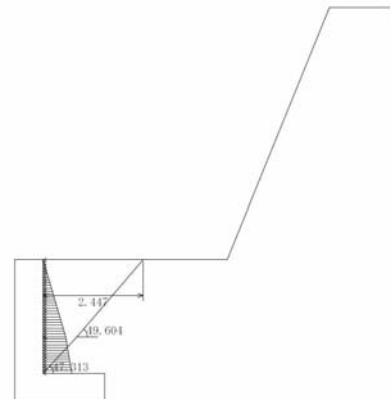
Earth Pressure at Water Level

$$\begin{aligned} P_2 &= K_{EA} \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.4733 \times 19.00 \times 1.900 + 0.000 \\ &= 17.085 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P_{HE} &= P_2 \cdot \cos \delta = 21.715 \times \cos(0.00^\circ) \\ &= 21.715 \text{ (kN/m}^2\text{)} \end{aligned}$$

■Figure of Converted Load Acting on Breast Wall



1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-I

	P (kN/m ²)	L (m)	P·l ² /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·l ² /2) = 19.15	
Shear Force	S (kN/m)	Σ(P·l) = 38.30	

2) Seismic Condition-I

	P (kN/m ²)	L (m)	P·l ² /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·l ² /2) = 16.95		
Shear Force S (kN/m)	Σ(P·l) = 33.89		

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2) Shear Stress Intensity

■Normal Condition-I

	Symbol	Unit	Junction
Shear Force	S	kN	38.30
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	0.063
Allowable Value	τa	N/mm ²	0.360
	τa2	N/mm ²	1.600

■Seismic Condition-I

	Symbol	Unit	Junction
Shear Force	S	kN	33.89
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	0.056
Allowable Value	τa	N/mm ²	0.540
	τa2	N/mm ²	2.400

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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-I

	Symbol	Unit	Junction
Bending Moment	M	kN.m	19.15
Re-bar	d1 As1	mm mm ²	610.0 794.4
Required Area of Re-bar	Back	mm ²	230.3
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm ²	0.76
	σs	N/mm ²	41.48
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	307.1
	inp	mm ²	794.4

■Seismic Condition-I

	Symbol	Unit	Junction
Bending Moment	M	kN.m	16.95
Re-bar	d1 As1	mm mm ²	610.0 794.4
Required Area of Re-bar	Back	mm ²	152.7
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm ²	0.67
	σs	N/mm ²	36.71
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	203.6
	inp	mm ²	794.4

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1.3 Calculation of Bottom Slab

1.3.1 Load

(1) Normal Condition-I

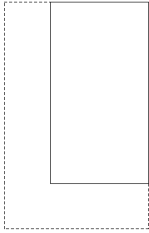
1-1) Self-weight of Wall



$Sw = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$

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



$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.633 \times 19.00 + 2.167 \times 20.00 = 55.367$
 $Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.633 \times 19.00 + 2.167 \times 20.00 = 55.367$

Thus,
Pw1 : Weight 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)

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1-3) Subgrade Reaction Force

	Intensity of subgrade reaction (kN/m ²)
Base	114.14
Edge	12.13

1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ _w)	Unit (kN/m ²)
Base	2.003× 9.80	19.631
Edge	2.867× 9.80	28.097

(2) Seismic Condition-1

2-1) Self-weight of Wall



$$S_w = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

Thus,

S_w : 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



$$P_{w1} = (h_1 \cdot \gamma_c + h_2 \cdot \gamma_{sat}) = 1.900 \times 19.00 + 0.900 \times 20.00 = 54.100$$

$$P_{w2} = (h_1 \cdot \gamma_c + h_2 \cdot \gamma_{sat}) = 1.900 \times 19.00 + 0.900 \times 20.00 = 54.100$$

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Thus,

P_{w1} : Weight of Embankment at basis (kN/m²)

P_{w2} : Weight of Embankment at edge (kN/m²)

H_1 : Height of Embankment above water (m)

H_2 : Height of Embankment underwater (m)

γ_c : 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

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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 (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×l/2) = 30.80		
Shear Force S (kN/m)	Σ(P×l) = 61.60		

1-2) Edge

	P (kN/m ²)	L (m)	P×l/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×l/2) = -15.97		
Shear Force S (kN/m)	Σ(P×l) = -31.94		

2) Seismic Condition-1

2-1) Base

	P (kN/m ²)	L (m)	P×l/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×l/2) = 21.15		
Shear Force S (kN/m)	Σ(P×l) = 42.31		

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2-2) Edge

	P (kN/m ²)	L (m)	P×l/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×l/2) = -25.25		
Shear Force S (kN/m)	Σ(P×l) = -50.50		

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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	mm	585.0	90.0
	As1	mm ²	794.4	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	mm	585.0	90.0
	As1	mm ²	794.4	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	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	0.105	0.052
	τa	N/mm ²	0.360	0.360
Allowable Value	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	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	0.072	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

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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

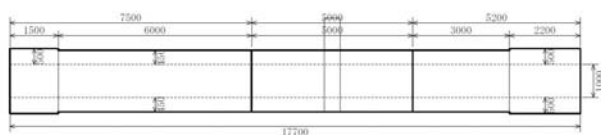
Residual Settlement	: 300.0 (mm)	
Residual Settlement for Rigid Support		: 50.0 (mm)
Relative Displacement	Base Width	: 1.0 (%)
		± : 50.0 (mm)

4) Type of Joint : Flexible Joint

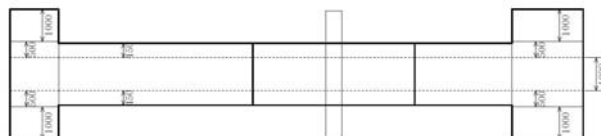
5) Allowable Opening : 100.0 (mm)

6) Allowable Unevenness: 100.0 (mm)

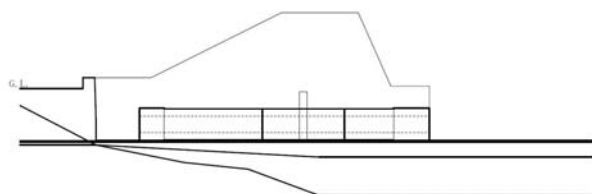
1.1.1 General Side View of Sluiceway



1.1.2 General Plane of Sluiceway



1.1.3 Shape of Levee Cross-section



2

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	0.500	0.450	0.000	0.000
3-2	0.500	0.500	0.500	0.700	1.000

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1.3 Reinforcement

Main Re-bar

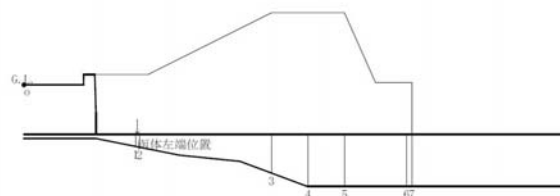
Span No	Block No	Flange		Reinforcing Bar				
		Portion	b (mm)	t (mm)	Outside Diameter@Pitch (Number)	Cover (mm)	Inside Diameter@Pitch (Number)	Cover (mm)
1	1	Top Slab	2000.0	500.0	D16@250 (6)	90.0	D16@250 (8)	90.0
		Bottom Slab	2000.0	500.0	D16@250 (6)	115.0	D16@250 (8)	90.0
	2	Top Slab	1900.0	450.0	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 Settlement 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)

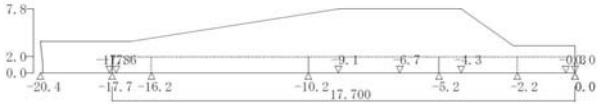


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2.1.2 Summary of Immediate Settlement

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



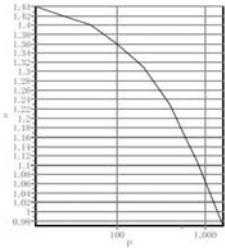
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2.2 Consolidation Settlement

2.2.1 Ground Condition and e-logP Curb

No	Name	Layer	Depth (m)	Unit Weight (Wet) (kN/ m ³)	Unit Weight (Saturated) (kN/ m ³)	Pre-Consolidation Stress q ₀ (kN/m ²)	Elastic Modulus Es (kN/m ²)
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

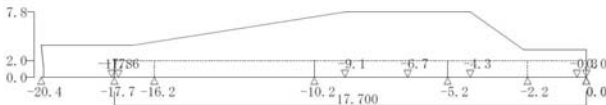
No	Concolidation Pressure P(kN/m ²)	Void Ratio e
1	12.0000	1.4400
2	25.0000	1.4200
3	50.0000	1.4000
4	100.0000	1.3600
5	200.0000	1.3100
6	400.0000	1.2300
7	800.0000	1.1100
8	1600.0000	0.9700



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2.2.2 Summary 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



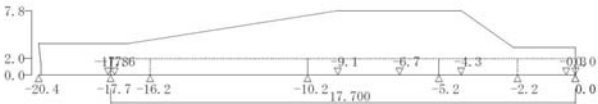
8

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 Vauce	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

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3 Calculation of Box Culvert regarding Longitudinal Direction

3.1 Basic Equation

In case of Axis Direction, the calculation model is a beam on elastic foundation.

$$\frac{EI}{B} \cdot \frac{d^4 w}{dx^4} + k_v (w - w_g) = q \text{ (Swag)}$$

$$\frac{EA}{U} \cdot \frac{d^2 u}{dx^2} + k_s (u - u_g) = p \text{ (Displacement in axial direction of Box Culvert)}$$

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/cm²) {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/cm²) {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 $B \neq L$

$$E_{eq} = \frac{\log \left(\frac{(B+2h_v \cdot \tan \theta) \cdot L}{(L+2h_v \cdot \tan \theta) \cdot B} \right)}{\sum \frac{1}{E \log \left(\frac{(B+2h_v \cdot \tan \theta) \cdot (L+2h_v \cdot \tan \theta)}{(L+2h_v \cdot \tan \theta) \cdot (B+2h_v \cdot \tan \theta)} \right)}}$$

In case of $B=L$

$$E_{eq} = \frac{1}{\sum \frac{1}{E \left(-\frac{1}{B+2h_v \cdot \tan \theta} + \frac{1}{B} \right)}}$$

Thus,

- E_{eq} : Converted Modulus of Deformation
- B : Loading Width = Width of Culvert
- L : Loading Length = Length of a span
- h_v : 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/m²)
- θ : Angle of Load Dispersion ($\theta=30^\circ$)

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.

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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/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	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/m ²)		

※Layer and Depth is the values from the subgrade

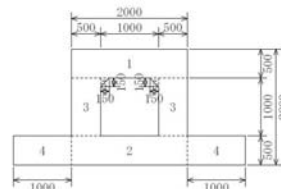
Span3-Block2 River Side

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/m ²)		

※Layer and Depth is the values from the subgrade

3.2.2 Dimensions of Box Culvert

Span1-Block1 Land Side

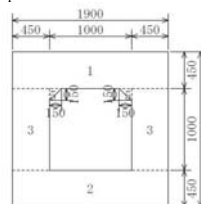


Position	Ai (m ²)	Yi (m)	Ai·Yi (m ³)	Ai·Yi ² (m ³)	Ioi (m ⁴)
1	1.000	1.750	1.7500	3.0625	0.02083
2	1.000	0.250	0.2500	0.0625	0.02083
3	1.000	1.000	1.0000	1.0000	0.08333
4	1.000	0.250	0.2500	0.0625	0.02083
5	0.023	1.450	0.0326	0.0473	0.00003
Total	4.023		3.2826	4.2348	0.14586

$$Y_g = \frac{\sum (A_i \cdot Y_i) \cdot \sum A_i}{\sum A_i} = \frac{3.2826}{4.023} = 0.8161 \text{ (m)}$$

$$I = \frac{\sum (A_i \cdot Y_i^2) + \sum I_{oi} - Y_g^2 \cdot \sum A_i}{2} = \frac{4.2348 + 0.14586 - 0.6660 \cdot 4.023}{2} = 1.70183 \text{ (m}^4\text{)}$$

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

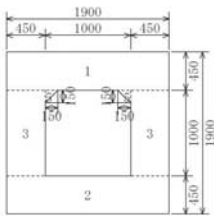
$$Y_g = \frac{\sum (A_i \cdot Y_i) \cdot \sum A_i}{\sum A_i} = \frac{2.5110}{2.633} = 0.9538 \text{ (m)}$$

$$I = \frac{\sum (A_i \cdot Y_i^2) + \sum I_{oi} - Y_g^2 \cdot \sum A_i}{2} = \frac{3.2984 + 0.10388 - 0.9098 \cdot 2.633}{2} = 1.00722 \text{ (m}^4\text{)}$$

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Span2-Block1 Center

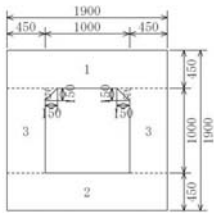


Position	Ai (m²)	Yi (m)	Ai·Yi (m³)	Ai·Yi² (m³)	loi (m³)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.633 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma lo_i - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.633 = 1.00722 \text{ (m}^4\text{)}$$

Span3-Block1 River Side



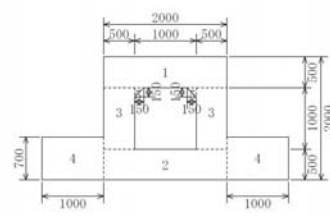
Position	Ai (m²)	Yi (m)	Ai·Yi (m³)	Ai·Yi² (m³)	loi (m³)
1	0.855	1.675	1.4321	2.3988	0.01443
2	0.855	0.225	0.1924	0.0433	0.01443
3	0.900	0.950	0.8550	0.8123	0.07500
5	0.023	1.400	0.0315	0.0441	0.00003
Total	2.633		2.5110	3.2984	0.10388

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 2.5110 / 2.633 = 0.9538 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma lo_i - Y_g^2 \cdot \Sigma A_i = 3.2984 + 0.10388 - 0.9098 \cdot 2.633 = 1.00722 \text{ (m}^4\text{)}$$

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Span3-Block2 River Side



Position	Ai (m²)	Yi (m)	Ai·Yi (m³)	Ai·Yi² (m³)	loi (m³)
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

$$Y_g = \Sigma(A_i \cdot Y_i) / \Sigma A_i = 3.5226 / 4.423 = 0.7965 \text{ (m)}$$

$$I = \Sigma(A_i \cdot Y_i^2) + \Sigma lo_i - Y_g^2 \cdot \Sigma A_i = 4.3438 + 0.18219 - 0.6344 \cdot 4.423 = 1.72015 \text{ (m}^4\text{)}$$

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3.2.3 Table of Modulus of Subgrade Reaction

Coefficient of Lateral Shear Reaction of Soil

$$k_s = \lambda \cdot k_v$$

Thus,

 k_s : 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)

 k_v : 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/m³)	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
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/m³)	k_s (kN/m³)	$k_v \cdot B$ (kN/m²)	$k_s \cdot B$ (kN/m²)
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/m²)	$k_s \cdot B$ (kN/m²)
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/m²)	$k_s \cdot B$ (kN/m²)
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

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3.3 Load

3.3.1 Dead Load (Body Weight)

1) Weight of Main Body

$$W = (A_1 + A_2 + A_3) \cdot \gamma_c \text{ (kN/m)}$$

A1: Cross Sectional Area (Excluding Hunch) (m²)

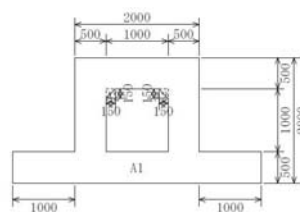
A2: Area of Upper Side Hunch (m²)

A3: Area of Lower Side Hunch (m²)

 γ_c : Unit Weight (Concrete) (kN/m³)

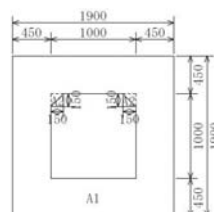
Span No. 1-1 Land Side

$$W = (4.000 + 0.023 + 0.000) \cdot 24.000 = 96.540 \text{ (kN/m)}$$



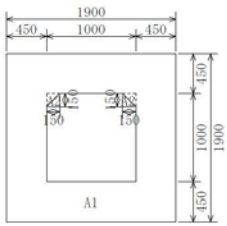
Span No. 1-2 Land Side

$$W = (2.610 + 0.023 + 0.000) \cdot 24.000 = 63.180 \text{ (kN/m)}$$

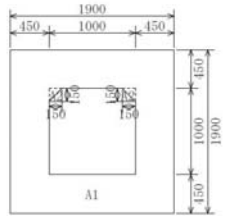


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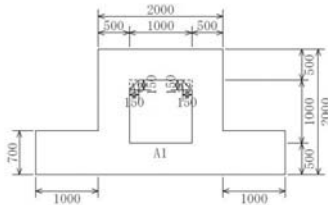
Span No. 2-1 Center
 $W = (2.610 + 0.023 + 0.000) \cdot 24.000$
 $= 63.180 \text{ (kN/m)}$



Span No. 3-1 River Side
 $W = (2.610 + 0.023 + 0.000) \cdot 24.000$
 $= 63.180 \text{ (kN/m)}$



Span No. 3-2 River Side
 $W = (4.400 + 0.023 + 0.000 + 0.000) \cdot 24.000$
 $= 106.140 \text{ (kN/m)}$



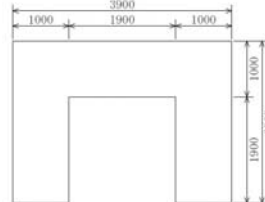
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2) Seepage Cutoff Wall Body Weight

$A1 = X1 \cdot L2$
 $A2 = L1 \cdot Y1 \cdot 2$
 $W = (A1 + A2) \cdot B \cdot \gamma_c \text{ (kN)}$
 $X1$: 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)
 γ_c : Unit Weight (Concrete) (kN/m³)

SpanNo.2-SpanDistance from Base Point (2.400)

$A1 = 3.900 \cdot 1.000$
 $= 3.900 \text{ (m}^2\text{)}$
 $A2 = 1.000 \cdot 1.900 \cdot 2$
 $= 3.800 \text{ (m}^2\text{)}$
 $W = (3.900 + 3.800) \cdot 0.500 \cdot 24.00$
 $= 92.400 \text{ (kN)}$



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3.3.2 Ground Displacement Load (Settlement, Lateral Displacement)

1) Equivalent Load for Ground Settlement

【Normal Condition】

Span1 Name of Span: [Land Side]

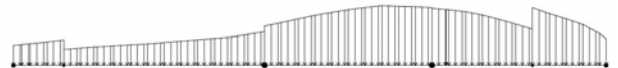
Block	Position X(m)	Bottom Slab Width B(m)	Spring of Ground (kN/m ²)	Ground Displacement (mm)		Load Intensity (kN/m)	
				BP	EP	BP	EP
1-(1)	-17.700~-17.450	4.000	94802.3	42.1	43.8	-3989.002	-4151.567
1-(2)	-17.450~-17.200	4.000	94802.3	43.8	45.5	-4151.567	-4311.168
1-(3)	-17.200~-16.700	4.000	94802.3	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



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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/m ²)	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/m ²)	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

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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	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



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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]

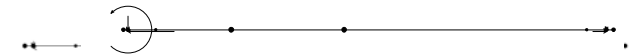
Load Number	Load	Distant from Left Edge (m)	Horizontal Load (kN)	Vertical Load (kN)	Rotational Moment (kN·m)
1	Gate Structure	10.000	0.00	0.00	0.00
2	Left Breast Wall	0.250	-40.40	93.20	-47.97
3	Right Breast Wall	12.920	482.56	249.90	-96.38



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 Seismic 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



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3.3.4 Load Combination Cases

1) Normal Condition

Load Combination

No	Load Type	Load	Premium Coefficient
1	Fixed Load Data 1	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 Data 1	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 Data 1	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

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3.4 Displacement between Sluiceway and Adjoining Levee

3.4.1 Normal Condition

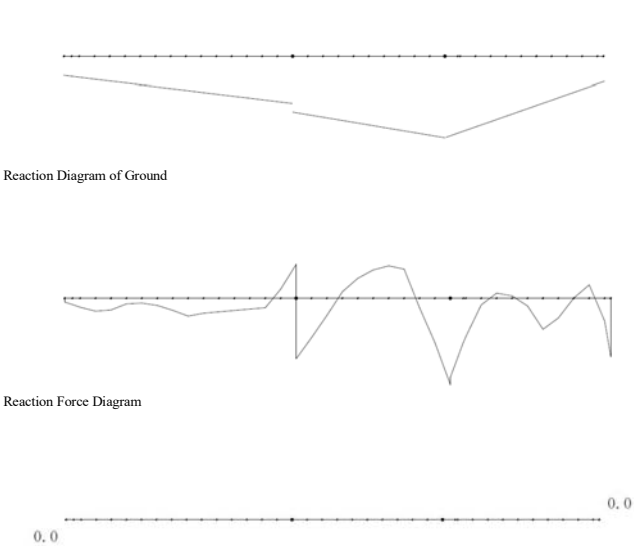
1) Calculation Case1 - Load: [Normal Condition]

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

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Displacement Diagram



Reaction Force Diagram

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

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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

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Span3 Name of Span: [River Side]

Num ber	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



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2) Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Num ber	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]

Num ber	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

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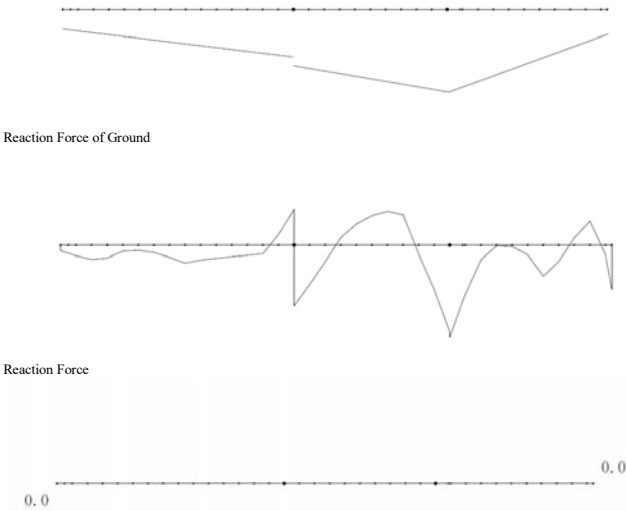
2-315

Span3 Name of Span: [River Side]

Num ber	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

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Displacement Diagram



3.5 Cross Sectional Analysis

3.5.1 Normal Condition

Calculation Case1 - Load: [Normal Condition]

Span1 Name of Span: [Land Side]

Num ber	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

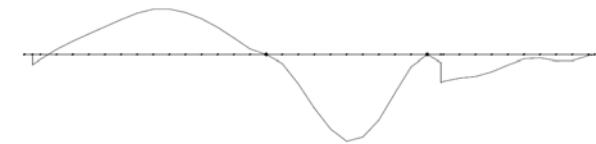
Span2 Name of Span: [Center]

Num ber	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

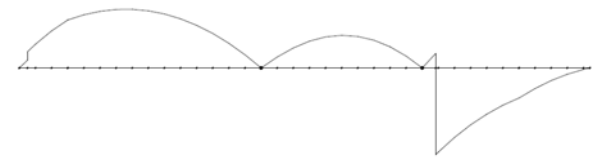
Span3 Name of Span: [River Side]

Num ber	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

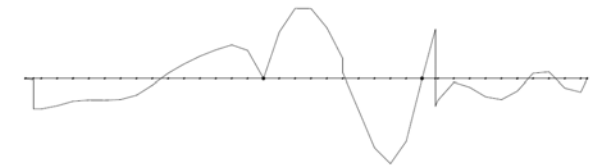
Bending Moment



Axial Force



Shear Force



3.5.2 Seismic Condition

Calculation Case1 - Load: [Seismic Condition Land Side →River Side]

Span1 Name of Span: [Land Side]

Num ber	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]

Num ber	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

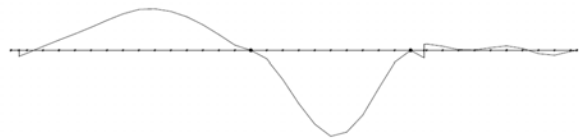
Span3 Name of Span: [River Side]

Num ber	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

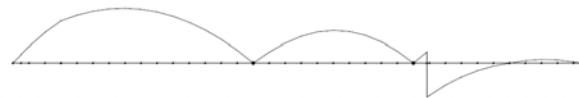
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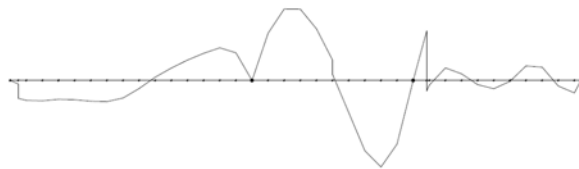
Bending Moment



Axial Force



Shear Force



Calculation Case2 - Load: [Seismic Condition River Side → Land Side]

Span1 Name of Span: [Land Side]

Num ber	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]

Num ber	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

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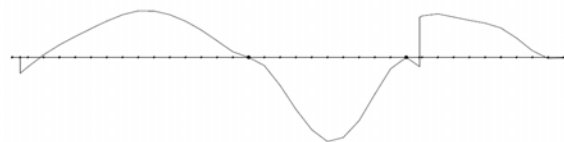
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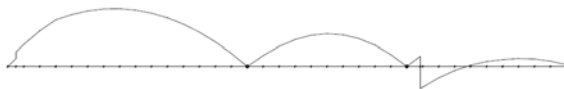
Span3 Name of Span: [River Side]

Num ber	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

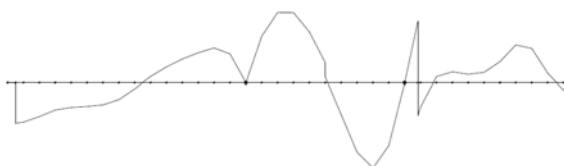
Bending Moment



Axial Force



Shear Force



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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,

θ_1 : Angle of Displacement (Left Side) (rad)

θ_2 : 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)	θ_1 (Degree) (rad)	θ_2 (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)	θ_1 (Degree) (rad)	θ_2 (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)	θ_1 (Degree) (rad)	θ_2 (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

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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

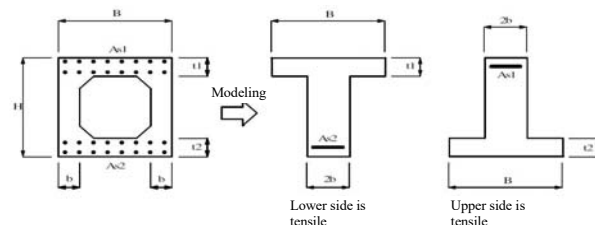
3.7.1 Calculation Condition

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

$$x = \frac{n \cdot (A_s \cdot d + A_s' \cdot d') + B \cdot t^2 / 2}{n \cdot (A_s + A_s') + B \cdot t}$$

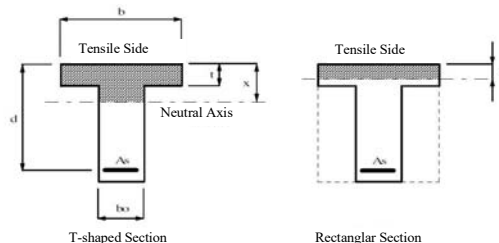
Thus,

- x : Position of Neutral Axis (mm)
- n : Ratio of Young modulus = 9.0
- A_s : Area of Re-bar in tensile side (mm²)
- A_s' : Area of Re-bar in compressive side (mm²)
- 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.



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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	1.900	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 A _s (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Compressive Side A _s ' (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)	Calculation Section
1- 1	2.000	2.000	1.900	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 A _s (mm ²)	Position of Re-bar in Compressive Side d' (m)	Area of Re-bar in Tensile Side A _s ' (mm ²)
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

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3.7.2 Normal Condition

1) Calculation Case1: Normal Condition

Span1-Block1						
Item	Sym bol	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	94.596	-128.551	-128.551	0.000
Rebar Area	Outside of Top Slab	d1 A _{s1}	mm	90.0 D16- 6	90.0 D16- 6	90.0 D16- 6
	Inside of Top Slab	d2 A _{s2}	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Inside of Bottom	d3 A _{s3}	mm	90.0 D16- 8	90.0 D16- 8	90.0 D16- 8
	Outside of Bottom	d4 A _{s4}	mm	115.0 D16- 6	115.0 D16- 6	115.0 D16- 6
Total Area of Rebar	A _s	mm ²	5560.8	5560.8	5560.8	5560.8
Required Area of Re-bar	Top Slab Outside	A _{q1}	mm ²	183.0	249.9	249.9
	Top Slab Inside	A _{q2}	mm ²	244.1	333.1	333.1
	Bottom Slab Inside	A _{q3}	mm ²	244.1	333.1	333.1
	Bottom Slab Outside	A _{q4}	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	σ _c	N/mm ²	0.29	0.40	0.40	----
	σ _s	N/mm ²	22.36	30.41	30.41	----
	σ _s '	N/mm ²	-1.45	-1.52	-1.52	----
Allowable Stress Intensity	σ _{ca}	N/mm ²	8.20	8.20	8.20	8.20
	σ _{sa}	N/mm ²	140.00	140.00	140.00	140.00
	σ _{sa} '	N/mm ²	-140.00	-140.00	-140.00	-140.00
	min	mm ²				----
Minimum Area of Re-Bar	req	mm ²	569.5	777.3	777.3	----
	inp	mm ²	2780.4	2780.4	2780.4	----

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Calculation Case1: Normal Condition

Span1-Block2

Item		Sym bol	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	----	----

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Calculation Case1: Normal Condition

Span2-Block1

Item		Symb ol	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	----

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Calculation Case1: Normal Condition

Span3-Block1

Item		Sym bol	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

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Calculation Case1: Normal Condition

Span3-Block2

Item		Sym bol	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

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3.7.3 Seismic Condition

1) Calculation Case1: Seismic Condition Landside→River Side

Span1-Block1

Item		Symb ol	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	----

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Calculation Case1: Seismic Condition Land Side →River Side

Span1-Block2

Item		Symb ol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span2-Block1

Item		Symb ol	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	----

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Calculation Case1: Seismic Condition Land Side→River Side

Span3-Block1

Item		Symb ol	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

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Calculation Case1: Seismic Condition

Span3-Block2

Item		Sym bol	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

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2) Calculation Case2: Seismic Condition River Side→Land Side

Span1-Block1

Item		Sym bol	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	----

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Span1-Block2

Item		Sym bol	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	----

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Span2-Block1

Item		Sym bol	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	----

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Span3-Block1

Item		Sym bol	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		Symb ol	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	----

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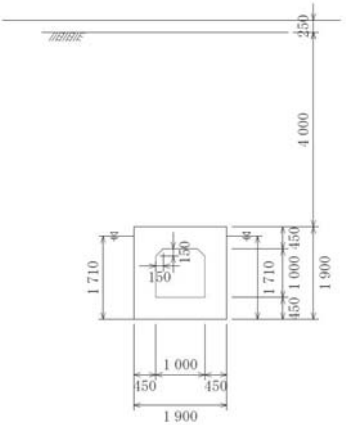
2.2.2.7 SLUCEWAY TYPE J

(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	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil(Wet)	γ_t	kN/m ³	19.00
Soil(Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	σ_{sa}	N/mm ² Normal (General)	140.00
		N/mm ² Normal (Harsh)	140.00
		N/mm ² Seismic	186.00
Allow Compressive Strength	σ_{sa}'	N/mm ² Normal	140.00
		N/mm ² Seismic	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		Right Corner	D16	250	
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		Right Sidewall	D13	250	

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		Right Corner	D16	250	
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 A _w (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 Q _w (kN/m ²)	10.000

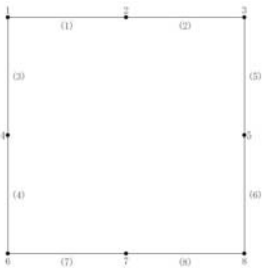
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1.2 Cross-section Calculation

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	Num ber	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 Slab	7	6	7	4.500000E-001	7.593750E-003	2.310000E+007
Right Side of Bottom Slab	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

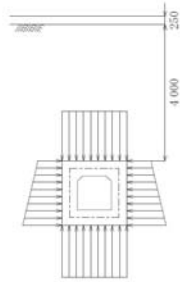
(Note) -1: Fixed, 0: Free

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1.2.2 Load

1) Dead Load (case-1) [RWL]



Weight of Box Culvert

- (1) Top Slab
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (2) Left Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$
- (3) Right Side Wall
 $w = 0.450 \times 24.00 = 10.80 \text{ (kN/m}^2\text{)}$

Surcharge Load

(1) Pavement and Embankment

$$\begin{aligned} \text{Pavement (Above Water Level)} &= 1.000 \times 0.250 \times 22.60 = 5.65 \text{ (kN/m}^2\text{)} \\ \text{Embankment (Above Water Level)} &= 1.000 \times 4.000 \times 18.00 = 72.00 \text{ (kN/m}^2\text{)} \\ \hline \Sigma w_d &= 77.65 \text{ (kN/m}^2\text{)} \end{aligned}$$

(2) Surcharge Load at Road

$$\begin{aligned} \text{Surcharge} &= 10.000 \text{ (kN/m}^2\text{)} \\ \text{Snow Load} &= 0.00 \text{ (kN/m}^2\text{)} \\ \hline \Sigma q_d &= 10.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

(3) Load Acting on Top Slab

$$\begin{aligned} \text{Uniformly Distributed Load} \\ w &= 77.65 + 10.00 = 87.65 \text{ (kN/m}^2\text{)} \end{aligned}$$

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Water and Earth Pressure

Intensity of Earth Pressure and Water Pressure

$$p_i = K_o \times (q_d + \gamma_o \times \gamma_a + Z_u \times \gamma + (Z_o - Z_u) \times \gamma') + (Z_o - Z_u) \times \gamma_w$$

K_o : Coefficient of Earth Pressure at Rest = 0.500

Z_o : Depth of Calculation Point from Embankment Top (m)

(1) Left Side Wall

Symbol	Calculation Point	Z_o (m)	p (kN/m ²)
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	Z_o (m)	p (kN/m ²)
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

$$\begin{aligned} U &= 1.710 \times 1.900 \times 9.80 = 31.84 \text{ (kN/m)} \\ w &= \frac{-31.84}{1.900} = -16.76 \text{ (kN/m}^2\text{)} \end{aligned}$$

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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

$$\begin{aligned} \bar{X} &= \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)} \\ e &= \frac{B}{2} - \bar{X} = 0.000 \text{ (m)} \end{aligned}$$

(2) Subgrade Reaction Intensity

$$M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$$

$$q_l = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 93.34 \text{ (kN/m}^2\text{)}$$

$$q_r = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 93.34 \text{ (kN/m}^2\text{)}$$

$$q_l^* = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 93.34 \text{ (kN/m}^2\text{)}$$

$$q_r^* = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 93.34 \text{ (kN/m}^2\text{)}$$

Thus, T: Thickness of Side Wall

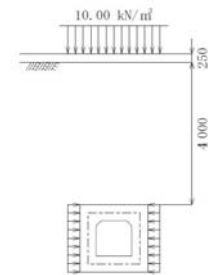
q_l : Subgrade Reaction Intensity on Left Edge

q_r : Subgrade Reaction Intensity on Right Edge

q_l^* : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab

q_r^* : Subgrade Reaction Intensity on Right Edge of Axis Line of Bottom Slab

2) Liver Load (case-1)



Live Load Intensity on Road Surface $q_L = 10.000 \text{ (kN/m}^2\text{)}$

Load

(1) Vertical Load Effecting Top Slab

$$w_l = q_L = 10.00 \text{ (kN/m}^2\text{)}$$

(2) Horizontal Load Acting on Left Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

(3) Horizontal Load Effecting on Right Side Wall

Converted Uniformly Distributed Load

$$w_l = 10.00 \text{ (kN/m}^2\text{)}$$

$$p = K_o \times w_l = 0.500 \times 10.00 = 5.00 \text{ (kN/m}^2\text{)}$$

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

$$\begin{aligned} \bar{X} &= \frac{\Sigma M}{\Sigma V} = 0.950 \text{ (m)} \\ e &= \frac{B}{2} - \bar{X} = 0.000 \text{ (m)} \end{aligned}$$

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(2) Subgrade Reaction Intensity
 $M_e = \Sigma V \times e = 0.00 \text{ (kN.m/m)}$
 $q_l = \frac{\Sigma V}{B} + \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$
 $q_r = \frac{\Sigma V}{B} - \frac{6 \times M_e}{B^2} = 10.00 \text{ (kN/m}^2\text{)}$
 $q_l' = q_l + \frac{q_r - q_l}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$
 $q_r' = q_r + \frac{q_l - q_r}{B} \times \frac{T}{2} = 10.00 \text{ (kN/m}^2\text{)}$

Thus, T : Thickness of Side Wall
 q_l : Subgrade Reaction Intensity on Left Edge
 q_r : Subgrade Reaction Intensity on Right Edge
 q_l' : Subgrade Reaction Intensity on Left Edge of Axis Line of Bottom Slab
 q_r' : 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

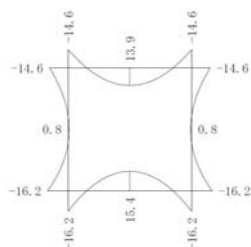
Load Number
13: Member Distribution Load (X Direction)
14: Member Distribution Load (Y Direction)

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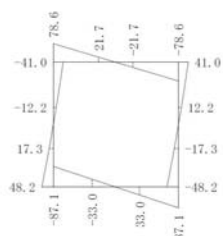
12

1.2.4 Calculation Results of Frame Analysis

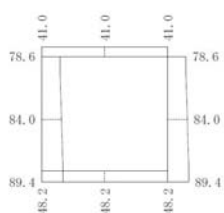
Bending Moment



Shear Force



Axial Force



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1.2.5 Stress Intensity Calculation

Bending Stress Intensity

Top Slab

Item	Unit	Left Corner	Mid-Corner	Right Corner
Bending Moment	M	-14.603	13.899	-14.603
Axial Force	N	0.000	0.000	0.000
Section Width	b	1.000	1.000	1.000
Section Height	h	0.450	0.450	0.450
Outside Cover	d1	90.0	90.0	90.0
Inside Cover	d2	90.0	90.0	90.0
Required Area of Re-Bar	mm ²	301.3	0.0	301.3
	mm ²	0.0	286.5	0.0
Re-Bar	mm ²	D16 @ 250 D-@- 794.4	D16 @ 250 D-@- 794.4	D16 @ 247 D-@- 804.0
	mm ²	D16 @ 250 D-@- 794.4	D16 @ 250 D-@- 794.4	D16 @ 250 D-@- 794.4
Neutral Axis	X	0.065	0.065	0.065
	mm	1.33	1.26	1.32
Stress Intensity	N/mm ²	54.33	51.71	53.70
	N/mm ²	0.00	0.00	0.00
	N/mm ²	8.20	8.20	8.20
Allowable Stress	N/mm ²	140.00	140.00	140.00
	N/mm ²	-186.00	-186.00	-186.00
	mm ²			
Minimum Re-Bar Sectional Area	mm ²	401.8	382.1	401.8
	mm ²	794.4	794.4	804.0
Case	---	---	---	---

※Axial force is not considered.

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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

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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

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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	90.0	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.

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■Shear Stress Intensity

$$\tau_m = \frac{S}{b \times d} \leq \tau_a$$

b = 1000 (mm)

Member	Location	S (kN)	d (mm)	τm (N/mm ²)	τa (N/mm ²)	Cases	L (m)
Top Slab	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

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2.2.2.7 SLUICeway TYPE J

(3) BREAST WALL - LAND SIDE

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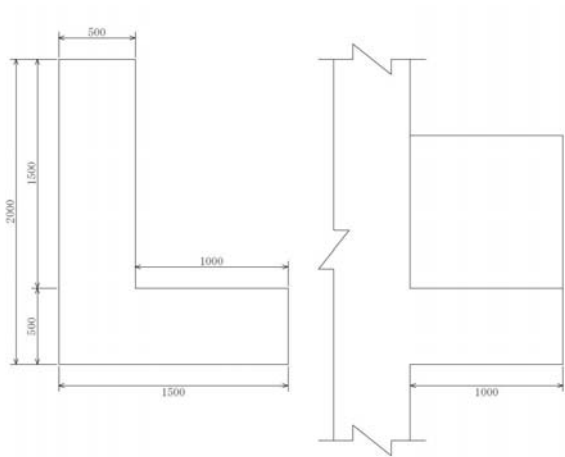
1.3.3 Stress Intensity Calculation.....19

1 Calculation of Land Side Breast Wall

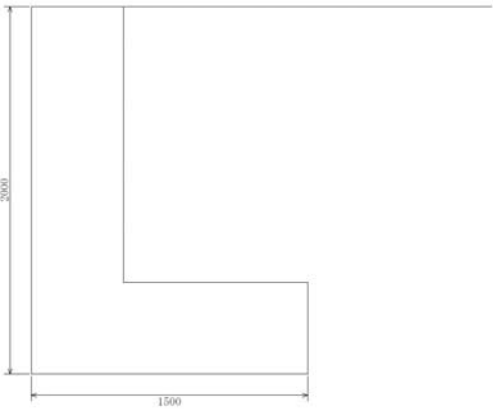
1.1 Design Conditions

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_a	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	osa	N/mm ² Normal (General)	140.00
		N/mm ² Normal (Harsh)	140.00
		N/mm ² Seismic	186.00
Allow Compressive Strength	osa'	N/mm ² Normal	140.00
		N/mm ² Seismic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φ _{res}	○	30
Peak Angle of Internal Friction	φ _{peak}	○	30
Coefficient of Lateral Earth Pressure at-rest	K _o		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	D13	247
	Back Face	90.0	D19	250
Bottom Slab	Top Face	90.0	D16	247
	Bottom Face	115.0	D13	247

■Diagonal Tensile Reinforcement

Location	Spacing in Axial Direction a (mm)	Amount of Reinforcement A _w (mm ² /m)
Side Wall	100	0.0
Bottom Slab	100	0.0

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1.1.4 Loads

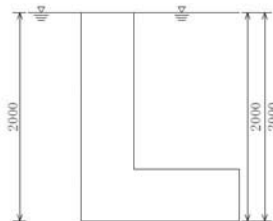
■Basic Load

1) Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

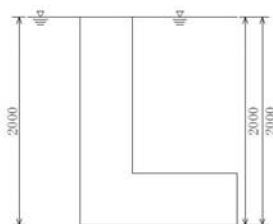
	(m)
Toe	2.000
Heel	2.000



1-2) Seismic Condition Number of Cases [1]

<Case 1>

	(m)
Toe	2.000
Heel	2.000
Direction	Back → Front

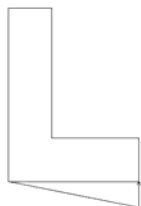


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2) Subgrade Reaction

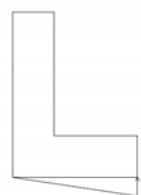
2-1) Normal <Case 1>

	(kN/m ²), (m)
Toe	0.00
Heel	51.54
Load Width	1.500



2-2) Seismic <Case 1>

	(kN/m ²), (m)
Toe	0.00
Heel	38.99
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

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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)

※ξ₀(Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot wq_0) / B \\ &= (0.000 + 10.00 \times 1.500) / 1.500 \\ &= 10.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 10.000 \times 0.500 = 5.000 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.000 + 5.000 \\ &= 5.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Junction

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 1.500 + 5.000 \\ &= 12.650 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P &= p_3 \\ &= 12.650 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

K₀ : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γ_t : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

q₀ : Surcharge (kN/m²)

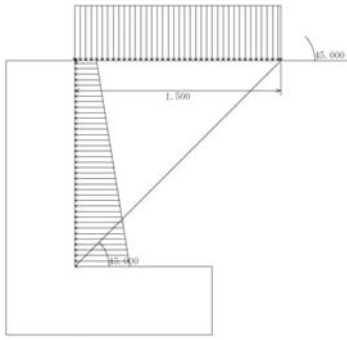
w_{q0} : Width of Surcharge (m)

h₁ : Height above Water Surface (m)

h₂ : Height under Water Surface (m)

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■Converted Load Figure Acting on Breast Wall



1-2) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.500 \times 9.80 = 14.700 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : 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

$$H = B \cdot \gamma_c \cdot kh = 0.500 \times 24.00 \times 0.20 = 2.400$$

Thus,

H : Inertia Force (kN/m²)

B : Thickness of Vertical Wall (m)

γ_c : 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

$$h_1 = 0.000 \text{ (m)}$$

Embankment Height under the water level surface

$$H_2 = 1.500 \text{ (m)}$$

Angle between the vertical wall and vertical plane

$$\theta = 0.00 \text{ (degree)}$$

Unit Weight of Soil (Wet)

$$\gamma_t = 19.00 \text{ (kN/m}^3\text{)}$$

Unit Weight of Soil (Saturated)

$$\gamma_{sat} = 20.00 \text{ (kN/m}^3\text{)}$$

Unit Weight of Water

$$\gamma_w = 9.80 \text{ (kN/m}^3\text{)}$$

Surcharge

$$q_0 = 5.00 \text{ (kN/m}^2\text{)}$$

Load width of Surcharge

$$wq_0 = 1.863 \text{ (m)}$$

Width of Converted Load

$$B = 1.863 \text{ (m)}$$

Internal Friction Angle of Soil

$$\phi = 30.00 \text{ (degree)}$$

Angle between Ground Surface and Horizontal Plane

$$\alpha = 0.00 \text{ (degree)}$$

Friction Angle (Soil and Concrete)

$$\delta_E = 0.00 \text{ (degree)}$$

Design Horizontal Seismic Coefficient

$$kh = 0.20 \text{ (degree)}$$

Apparent Horizontal Seismic Coefficient underwater

$$kh = 0.345 \text{ (degree)}$$

Compound Angle in Seismic Condition

$$\theta_0 = \tan^{-1}(kh) = 19.026 \text{ (degree)}$$

Compound Angle in Seismic Condition underwater

$$\theta_0 = \tan^{-1}(kh) = 19.026 \text{ (degree)}$$

■Active Angle of Rupture in Seismic Condition

$$\begin{aligned} \cot(\xi_{EA} - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \cdot \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \\ \cot(\xi_{EA} - \alpha) &= 0.85094 \end{aligned}$$

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

$$\begin{aligned} \cot(\xi_{EA}' - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0') \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0')}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 19.026^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.026^\circ)}} \\ \cot(\xi_{EA}' - \alpha) &= 1.24217 \end{aligned}$$

Thus,

$$\cot(\xi_{EA}' - 0.00^\circ) = \frac{1}{\tan(\xi_{EA}')} = 1.24217$$

$$\xi_{EA}' = \tan^{-1}\left(\frac{1}{1.24217}\right) = 38.836^\circ$$

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■Coefficient of Active Earth Pressure in Seismic Condition

$$\begin{aligned} K_{EA} &= \frac{\cos^2(\phi - \theta_0 - \theta)}{\cos \theta_0' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0' + \delta_E)} \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2 \\ &= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \\ &\quad \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2 \\ &= 0.4733 \end{aligned}$$

In case $\phi - \alpha - \theta_0 < 0$, $\sin(\phi - \alpha - \theta_0) = 0$.

$$\begin{aligned} K_{EA}' &= \frac{\cos^2(\phi - \theta_0' - \theta)}{\cos \theta_0' \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0' + \delta_E)} \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0')}{\cos(\theta + \theta_0' + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2 \\ &= \frac{\cos^2(30.00^\circ - 19.026^\circ - 0.00^\circ)}{\cos(19.026^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 19.026^\circ + 0.00^\circ)} \\ &\quad \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 19.026^\circ)}{\cos(0.00^\circ + 19.026^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2 \\ &= 0.6214 \end{aligned}$$

In case $\phi - \alpha - \theta_0' < 0$, $\sin(\phi - \alpha - \theta_0') = 0$.

Weight of Embankment $W = 0.000 \text{ (kN/m)}$

$$\begin{aligned} \text{Converted Load } q_0' &= \frac{(W + q_0 + wq_0)}{B} \\ &= \frac{(0.000 + 5.00 \times 1.863)}{1.863} \\ &= 5.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$P_1 = q_0' \cdot K_{EA} = 5.000 \times 0.4733 = 2.366 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} P_2 &= K_{EA} \cdot \gamma_c \cdot h_1 + p_1 \\ &= 0.4733 \times 19.00 \times 0.000 + 2.366 \\ &= 2.366 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Junction

$$\begin{aligned} P_3 &= K_{EA} \cdot (\gamma_{sat} - \gamma_w) \cdot h_2 + p_2 \\ &= 0.6214 \times (20.00 - 9.80) \times 1.500 + 2.366 \end{aligned}$$

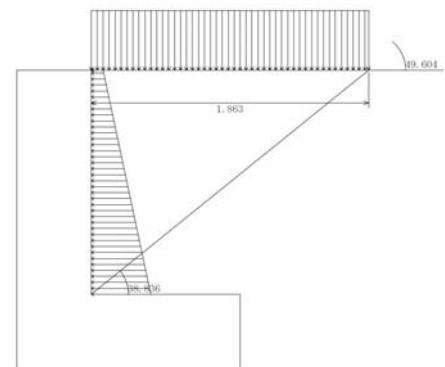
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$$= 11.874 \text{ (kN/m}^2\text{)}$$

Design Earth Pressure

$$\begin{aligned} P_{HE} &= P_3 \cdot \cos \delta = 11.874 \times \cos(0.00^\circ) \\ &= 11.874 \text{ (kN/m}^2\text{)} \end{aligned}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h_h \cdot \gamma_w = 1.500 \times 9.80 = 14.700 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

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1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-I

	P (kN/m ²)	L (m)	P•l/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) = 13.68	
Shear Force	S (kN/m)	Σ(P•l) = 27.35	

2) Seismic Condition-I

	P (kN/m ²)	L (m)	P•l/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) = 14.49	
Shear Force	S (kN/m)	Σ(P•l) = 28.97	

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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-I

	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-I

	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

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2) Shear Stress Intensity

■Normal Condition-I

	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-I

	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

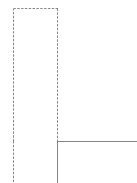
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1.3 Calculation of Heel Slab

1.3.1 Load

(1) Normal Condition-I

1-1) Self-weight of Wall



$$Sw = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

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



$$Pw1 = (h1 \cdot \gamma_s + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

$$Pw2 = (h1 \cdot \gamma_s + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

Thus,

Pw1 : Weight 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_s : 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/m ²)
Base	17.18
Edge	51.54

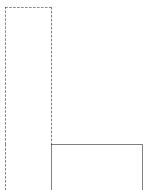
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1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unit (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



$$Sw = h \cdot \gamma_c = 0.500 \times 24.00 = 12.000$$

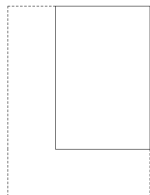
Thus,

Sw : Weight of Wall (kN/m²)

H : Height of Bottom Slab (m)

γ_c : Unit Weight of Concrete (kN/m³)

2-2) Weight of the Embankment



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 0.000 \times 19.00 + 1.500 \times 20.00 = 30.000$$

Thus,

Pw1 : Weight 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)

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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)	Unit (kN/m ²)
Base	2.000× 9.80	19.600
Edge	2.000× 9.80	19.600

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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)	$\Sigma(P \cdot l^2/2) = -7.61$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = -15.22$		

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)	$\Sigma(P \cdot l^2/2) = 9.57$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 19.14$		

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)	$\Sigma(P \cdot l^2/2) = -7.20$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = -14.40$		

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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)	$\Sigma(P \cdot l^2/2) = 5.80$		
Shear Force S (kN/m)	$\Sigma(P \cdot l) = 11.59$		

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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	mm	90.0	385.0
	As1	mm ²	794.4	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	mm	90.0	385.0
	As1	mm ²	794.4	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	mm	90.0	385.0
	As1	mm ²	794.4	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
	τa	N/mm ²	0.360	0.360
Allowable Value	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	mm	90.0	385.0
	As1	mm ²	794.4	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
	τa	N/mm ²	0.540	0.540
Allowable Value	τa2	N/mm ²	2.400	2.400

1 Calculation of River Side Breast Wall.....1

1.1 Design Condition 1

1.1.1 Dimensions.....1

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1.3 Calculation of Bottom Slab 14

1.3.1 Load 14

1.3.2 Summary of Cross Sectional Force.....17

1.3.3 Stress Intensity Calculation.....19

2.2.2.7 SLUICEWAY TYPE J

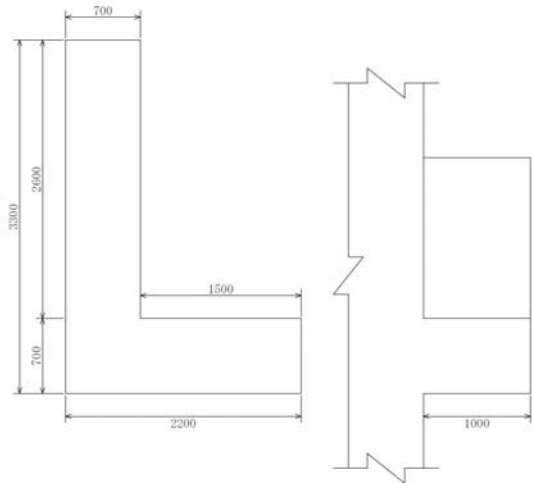
(4) BREAST WALL - RIVER SIDE

1 Calculation of River Side Breast Wall

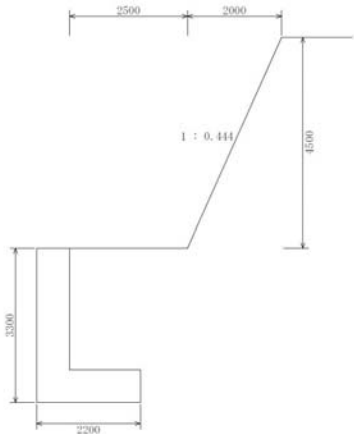
1.1 Design Condition

1.1.1 Dimensions

■Geometry of Wall



■Geometry of Embankment



1.1.2 Material and Design Parameters

■Unit Weights

Reinforced Concrete	γ_c	kN/m ³	24.00
Water	γ_w	kN/m ³	9.80
Soil (Wet)	γ_t	kN/m ³	19.00
Soil (Saturated)	γ_{sat}	kN/m ³	20.00

■Concrete

			Sidewall	Bottom Slab
Criterial Strength	σ_{ck}	N/mm ²	20.70	20.70
Modulus of Young's *10 ⁴	E_c	N/mm ²	2.31	2.31
Allow Flexural Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Axial Strength	σ_{ca}	N/mm ²	8.20	8.20
Allow Shear Strength	τ_{a1}	N/mm ²	0.360	0.360
Allow Shear Strength	τ_{a2}	N/mm ²	1.600	1.600
Young's modulus ratio	E_s/E_c		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	σ _{sa}	N/mm ²	Normal (General)	140.00
		N/mm ²	Normal (Harsh)	140.00
		N/mm ²	Seismic	186.00
Allow Compressive Strength	σ _{sa} '	N/mm ²	Normal	140.00
		N/mm ²	Seismic	186.00

■Soil

Backfill Angle of Internal Friction	φ	○	30.00
Residual Angle of Internal Friction	φ_{res}	○	30
Peak Angle of Internal Friction	φ_{peak}	○	30
Coefficient of Lateral Earth Pressure at-rest	K_0		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 A_w (mm ² /m)
Side Wall	100	0.0
Bottom Slab	100	0.0

1.1.4 Loads

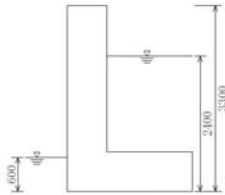
■Basic Load

1)Water Level

1-1) Normal Condition Number of Cases [1]

<Case 1>

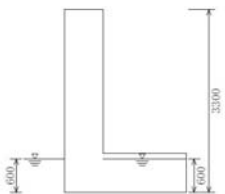
	(m)
Toe	0.600
Heel	2.400



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/m ²), (m)
Toe	151.82
Heel	0.00
Load Width	2.200



2-2) Seismic <Case 1>

	(kN/m ²), (m)
Toe	129.02
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 $W = 115.425$ (kN/m)

$\times \xi_a$ (Normal Condition Earth Pressure at Rest Angle of Rupture) = 45.0°

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot wq_0) / B \\ &= (115.425 + 10.00 \times 2.600) / 2.600 \\ &= 54.394 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$p_1 = q_0' \cdot K_0 = 54.394 \times 0.500 = 27.197 \text{ (kN/m}^2\text{)}$$

Earth Pressure at Water Level

$$\begin{aligned} p_2 &= K_0 \cdot \gamma_s \cdot h_1 + p_1 \\ &= 0.500 \times 19.00 \times 0.900 + 27.197 \\ &= 35.747 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at Bottom Surface of Base

$$\begin{aligned} p_3 &= K_0 \cdot (\gamma_{sat} \cdot \gamma_w) \cdot h_2 + p_2 \\ &= 0.500 \times (20.00 - 9.80) \times 1.700 + 35.747 \\ &= 44.417 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P &= p_3 \\ &= 44.417 \text{ (kN/m}^2\text{)} \end{aligned}$$

Thus,

K_0 : Coefficient of Earth Pressure at Rest = 0.50

B : Converted Load Width (m)

γ_t : Unit Weight of Soil (Wet) (kN/m³)

γ_{sat} : Unit Weight of Soil (Saturated) (kN/m³)

γ_w : Unit Weight of Water (kN/m³)

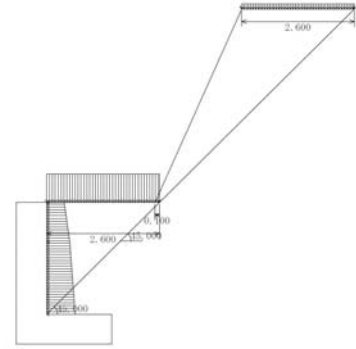
q_0 : Surcharge (kN/m²)

w_{q_0} : 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

$$P_h = h_h \cdot \gamma_w = 1.700 \times 9.80 = 16.660 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : 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

$$H = B \cdot \gamma_c \cdot kh = 0.700 \times 24.00 \times 0.20 = 3.360$$

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	h_1	= 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	q_0	= 5.00	(kN/m ²)
Load width of Surcharge	wq_0	= 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

$$\begin{aligned} \cot(\xi_{EA} - \alpha) &= -\tan(\phi + \delta_E + \theta - \alpha) + \sec(\phi + \delta_E + \theta - \alpha) \sqrt{\frac{\cos(\theta + \delta_E + \theta_0) \cdot \sin(\phi + \delta_E)}{\cos(\theta - \alpha) \cdot \sin(\phi - \alpha - \theta_0)}} \\ &= -\tan(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad + \sec(30.00^\circ + 0.00^\circ + 0.00^\circ - 0.00^\circ) \\ &\quad \times \sqrt{\frac{\cos(0.00^\circ + 0.00^\circ + 11.310^\circ) \times \sin(30.00^\circ + 0.00^\circ)}{\cos(0.00^\circ - 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}} \\ \cot(\xi_{EA} - \alpha) &= 0.85094 \end{aligned}$$

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

$$\begin{aligned} K_{EA} &= \frac{\cos^2(\phi - \theta - \theta_0)}{\cos^2 \theta \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0 + \delta_E) \left[1 + \sqrt{\frac{\sin(\phi + \delta_E) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta_E) \cdot \cos(\theta - \alpha)}} \right]^2} \\ &= \frac{\cos^2(30.00^\circ - 11.310^\circ - 0.00^\circ)}{\cos(11.310^\circ) \times \cos^2(0.00^\circ) \times \cos(0.00^\circ + 11.310^\circ + 0.00^\circ)} \\ &\quad \times \left[1 + \sqrt{\frac{\sin(30.00^\circ + 0.00^\circ) \times \sin(30.00^\circ - 0.00^\circ - 11.310^\circ)}{\cos(0.00^\circ + 11.310^\circ + 0.00^\circ) \times \cos(0.00^\circ - 0.00^\circ)}} \right]^2 \\ &= 0.4733 \end{aligned}$$

In case $\phi - \alpha - \theta_0 < 0$, $\sin(\phi - \alpha - \theta_0) = 0$.

Weight of Embankment W = 0.000 (kN/m)

$$\begin{aligned} \text{Converted Load } q_0' &= (W + q_0 \cdot wq_0) / B \\ &= (0.000 + 5.00 \times 0.000) / 2.212 \\ &= 0.000 \text{ (kN/m}^2\text{)} \end{aligned}$$

Earth Pressure at the Top

$$P_1 = q_0' \cdot K_{EA} = 0.000 \times 0.4733 = 0.000 \text{ (kN/m}^2\text{)}$$

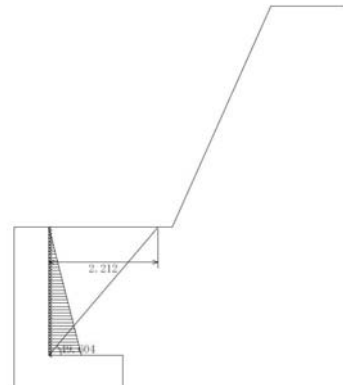
Earth Pressure at Water Level

$$\begin{aligned} P_2 &= K_{EA} \cdot \gamma_t \cdot h_1 + p_1 \\ &= 0.4733 \times 19.00 \times 2.600 + 0.000 \\ &= 23.379 \text{ (kN/m}^2\text{)} \end{aligned}$$

Design Earth Pressure

$$\begin{aligned} P_{HE} &= P_3 \cdot \cos \delta = 23.379 \times \cos(0.00^\circ) \\ &= 23.379 \text{ (kN/m}^2\text{)} \end{aligned}$$

■Figure of Converted Load Acting on Breast Wall



2-3) Water Pressure

$$P_h = h_h \cdot \gamma_w = 0.000 \times 9.80 = 0.000 \text{ (kN/m}^2\text{)}$$

Thus,

h_h : Height from the base of Vertical Wall to Water Surface in Back Side (m)

γ_w : Unit Weight of Water (kN/m³)

1.2.2 Summary of Cross-sectional Internal Forces

1) Normal Condition-1

	P (kN/m ²)	L (m)	P•l/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•l/2) = 30.53	
Shear Force	S (kN/m)	Σ(P•l) = 61.08	

2) Seismic Condition-1

	P (kN/m ²)	L (m)	P•l/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•l/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	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	30.54
Re-bar	d1 As1	mm mm ²	610.0 794.4
Required Area of Re-bar	Back	mm ²	369.8
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm ²	1.21
	σs	N/mm ²	66.15
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	493.1
	inp	mm ²	794.4

■Seismic Condition-1

	Symbol	Unit	Junction
Bending Moment	M	kN.m	13.37
Re-bar	d1 As1	mm mm ²	610.0 794.4
Required Area of Re-bar	Back	mm ²	120.2
Neutral Axis	X	m	0.087
Stress Intensity	σc	N/mm ²	0.53
	σs	N/mm ²	28.96
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	160.2
	inp	mm ²	794.4

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2) Shear Stress Intensity

■Normal Condition-1

	Symbol	Unit	Junction
Shear Force	S	kN	61.08
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	0.100
Allowable Value	τa	N/mm ²	0.360
	τa2	N/mm ²	1.600

■Seismic Condition-1

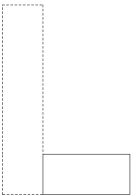
	Symbol	Unit	Junction
Shear Force	S	kN	26.74
Re-bar	d1 As1	mm mm ²	610.0 794.4
Effective Height	d	mm	610.0
Cross Section Width	b	mm	1000.0
Average Shear Stress Intensity	τm	N/mm ²	0.044
Allowable Value	τa	N/mm ²	0.540
	τa2	N/mm ²	2.400

1.3 Calculation of Bottom Slab

1.3.1 Load

(1) Normal Condition-1

1-1) Self-weight of Wall



$$Sw = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

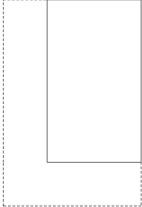
Thus,

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



$$Pw1 = (h1 \cdot \gamma_1 + h2 \cdot \gamma_{sat}) = 0.900 \times 19.00 + 1.700 \times 20.00 = 51.100$$

$$Pw2 = (h1 \cdot \gamma_1 + h2 \cdot \gamma_{sat}) = 0.900 \times 19.00 + 1.700 \times 20.00 = 51.100$$

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 under water (m)

γ1 : Wet Unit Weight of Soil (kN/m³)

γsat : Unit Weight of Soil under water (kN/m³)

1-3) Subgrade Reaction Force

	Intensity of subgrade reaction (kN/m ²)
Base	103.51
Edge	0.00

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1-4) Uplift Force

	Calculating Formula Height of Water Level×Unit Weight of Water (γ_w)	Unit (kN/m^2)
Base	1.173×9.80	11.493
Edge	2.400×9.80	23.520

(2)) Seismic Condition-1

2-1) Self-weight of Wall



$$S_w = h \cdot \gamma_c = 0.700 \times 24.00 = 16.800$$

Thus,

S_w : 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



$$Pw1 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 2.600 \times 19.00 + 0.000 \times 20.00 = 49.400$$

$$Pw2 = (h1 \cdot \gamma_t + h2 \cdot \gamma_{sat}) = 2.600 \times 19.00 + 0.000 \times 20.00 = 49.400$$

Thus,

$Pw1$: Weight 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)

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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)	Unit (kN/m^2)
Base	0.600×9.80	5.880
Edge	0.600×9.80	5.880

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1.3.2 Summary of Cross Sectional Force

1) Normal Condition-1

1-1) Junction Section

	P (kN/m^2)	L (m)	$P \cdot L^2/2$ (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) $\Sigma(P \cdot L^2/2) = 23.55$			
Shear Force S (kN/m) $\Sigma(P \cdot L) = 47.11$			

1-2) Edge

	P (kN/m^2)	L (m)	$P \cdot L^2/2$ (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) $\Sigma(P \cdot L^2/2) = -22.19$			
Shear Force S (kN/m) $\Sigma(P \cdot L) = -44.38$			

2) Seismic Condition-1

2-1) Base

	P (kN/m^2)	L (m)	$P \cdot L^2/2$ (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) $\Sigma(P \cdot L^2/2) = 13.82$			
Shear Force S (kN/m) $\Sigma(P \cdot L) = 27.65$			

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2-2) Edge

	P (kN/m^2)	L (m)	$P \cdot L^2/2$ (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) $\Sigma(P \cdot L^2/2) = -30.16$			
Shear Force S (kN/m) $\Sigma(P \cdot L) = -60.32$			

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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
	τa	N/mm ²	0.360	0.360
Allowable Value	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