EARTHQUAKE RECONSTRUCTION AND REHABILITATION AUTHORITY (ERRA)
THE ISLAMIC REPUBLIC OF PAKISTAN

No.

URGENT REHABILITATION PROJECT: WEST BANK BYPASS DESIGN

UNDER

THE URGENT DEVELOPMENT STUDY ON REHABILITATION AND RECONSTRUCTION IN MUZAFFARABAD CITY

IN

THE ISLAMIC REPUBLIC OF PAKISTAN

FINAL REPORT

Appendix B:

Structural Calculation (East Side Approach Viaduct)

MARCH 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.

SD
JR
08-014

APPENDIX B
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Design Calculation of Superstructure

1. DESIGN CRITERIA

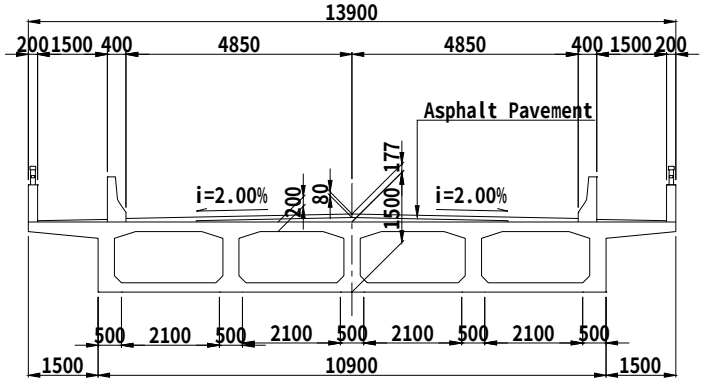
1.1 Design Criteria

Design Criteria of East Side Approach Viaduct are shown as follows.

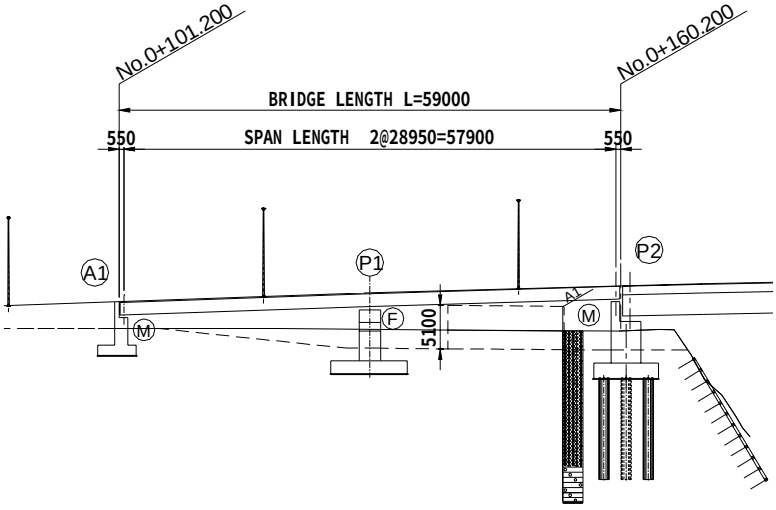
Superstructure	: 2Spans Continuous PC-Box Girder
Bridge Length	: 59.000m
Girder Length	: 58.800m
Span Length	: 2@28.950
Bridge Width	: 13.900m
Effective Width	: Carriage Way 9.70m
	: Foot Way 2 x 1.50m
Live Load	: Class-A, Class-AA
Curvature	: R=∞
Gradient	: i=3.500% ↙~ 2.000% ↙
Super Elevation	: i = 2.000% ↙ ↘
Skew Angle	: θ = 90 deg
Support Condition	: A1 Fixed support
	: P1 P2 Movable Support
Asphalt Pavement	: Carriage Way 80mm～
	Foot Way 30mm～

Bridge Profile

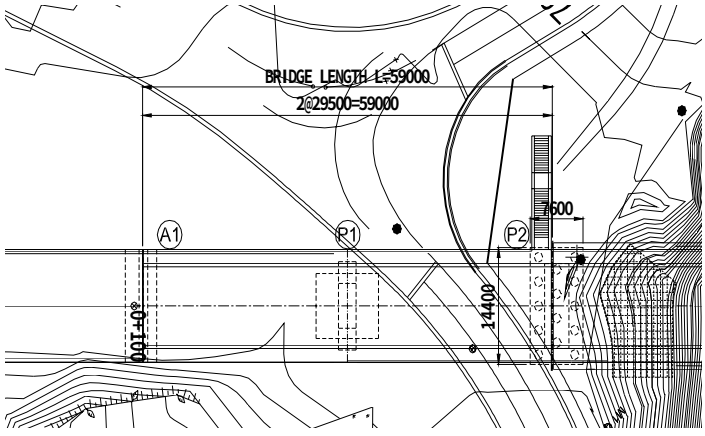
Typical Cross Section



Profile



Plan



1.2 Material Properties

1.2.1 Concrete

Table 1.2.1 Material Property of Concrete

(N/mm^2)

	PC-Box girder PC	Cross beam RC	Deck slab RC
Class	D1	D1	D1
28Days Cylinder Strength	35	35	35
Modulus of Elasticity	2.95×10^4	2.95×10^4	2.95×10^4
Allowable Compression Stress	14.00	14.00	14.00
Allowable Tensile Stress	-2.96	-	-
Temperature coefficient	10×10^{-6}	10×10^{-6}	10×10^{-6}
Maximum Shear Stress Carried on Concrete Only	0.47	0.47	0.47

1.2.2 PC Cable

Table 1.2.2 Material Property of PC Cable

	Unit	Longitudinal 12S15.2
Ultimate Strength	N/mm^2	1860
Minimum Breaking Strength	kN	3128.4
Minimum Yeild Strength	kN	2815.6
Friction coefficient per 1 meter	1/m	0.0020
Friction coefficient per 1 radian	1/Rad	0.250
Set Losses	mm	9
Relaxation	%	1.5
Modulus of Elasticity	$x10^5N/mm^2$	2.0
Sectional area	mm^2	1664.4
Diameter of sheath	mm	75

1.2.3 Reinforcement

Table 1.2.3 Material Property of Reinforcement

(N/mm^2)

Yield strength	420
Modulus of Elasticity ($\times10^5$)	2.0
Allowable Tensile Stress	168

1.2.4 Load Combination Group

Table 1.2.4 Loading Combination Table for Service Load Design

Group	γ	β											%
		D	(L+I)n	(L+I)p	CF	E	B	SF	W	WL	LF	R+S+T	
I	1.0	1	1	0	1	βE	1	1	0	0	0	0	100
II	1.0	1	0	0	0	1	1	1	1	0	0	0	125
III	1.0	1	1	0	1	βE	1	1	0.3	1	1	0	125
IV	1.0	1	1	0	1	βE	1	1	0	0	0	1	125
V	1.0	1	0	0	0	1	1	1	1	0	0	1	140
VI	1.0	1	1	0	1	βE	1	1	0.3	1	1	1	140

Table 1.2.5 Loading Combination Table for Load Factor Design

Group	γ	β										
		D	(L+I)n	(L+I)p	CF	E	B	SF	W	WL	LF	R+S+T
I	1.3	β_D	1.67	0	1.0	βE	1	1	0	0	0	0
II	1.3	β_D	0	0	0	βE	1	1	1	0	0	0
III	1.3	β_D	1	0	1	βE	1	1	0.3	1	1	0
IV	1.3	β_D	1	0	1	βE	1	1	0	0	0	1
V	1.25	β_D	0	0	0	βE	1	1	1	0	0	1
VI	1.25	β_D	1	0	1	βE	1	1	0.3	1	1	1

D: dead load L: live load I: live load impact
E: earth pressure B: buoyancy
W: wind load on structure WL: wind load on live load
LF: longitudinal force CF: centrifugal force
R: rib shortening S: shrinkage T: temperature
EQ: earthquake SF: stream flow pressure

* %: percentage to be applied for the basic unit stress
* (load factor) for all cases, is 1.0.

1.2.5 Seismic Design Condition

Table 1.2.4 Result of Eigenvalue Analyses

Design Seismic Coefficient :(Longitudinal)

Structure	A1 Abutment	P1 pier	P2 Pier
Natural Period	0.093	0.325	0.806
Design Seismic Coefficient	0.35	0.35	0.35

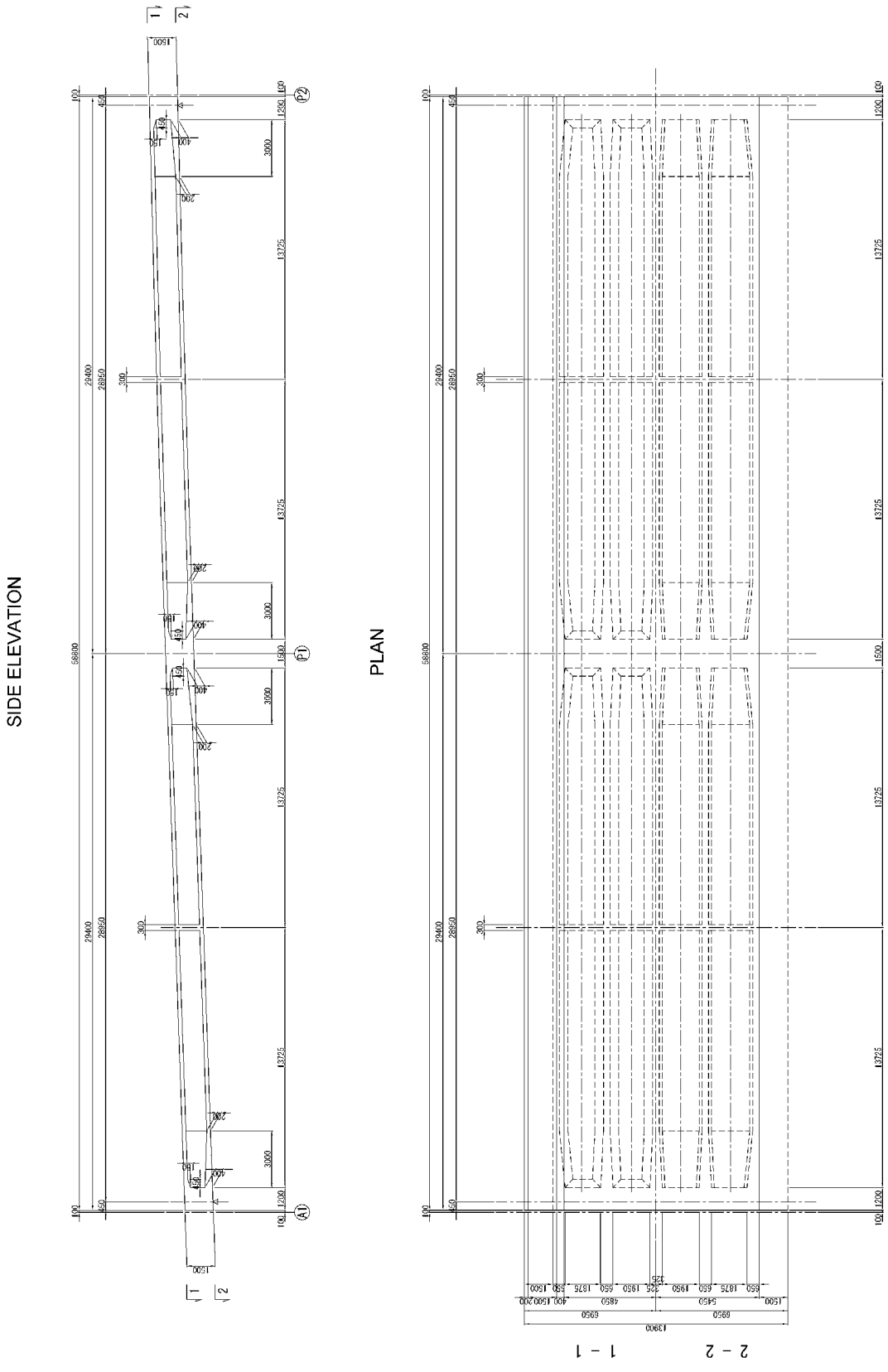
Design Seismic Coefficient :(Transverse Direction)

Structure	A1 Abutment	P1 pier	P2 Pier
Natural Period	0.512	0.512	0.512
Design Seismic Coefficient	0.35	0.35	0.35

(Source : JICA Study Team)

2. DESIGN CALCULATION OF MAIN GIRDER

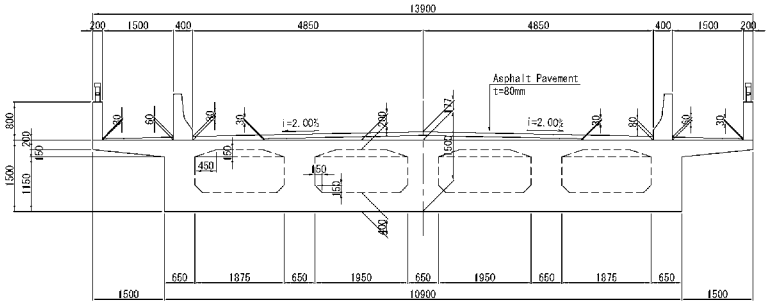
2.1 General Arrangement of Superstructure



East Viaduct Superst.-7

CROSS SECTION

3 – 3



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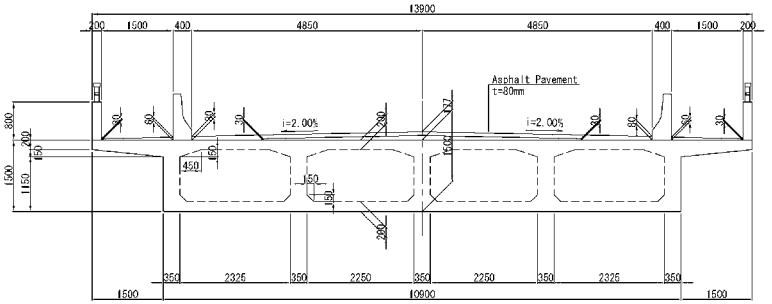

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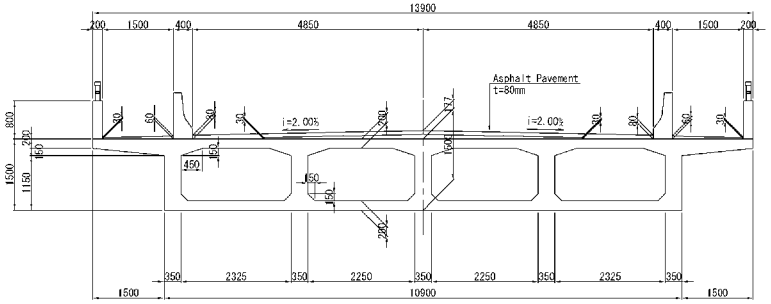
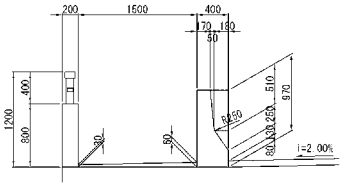
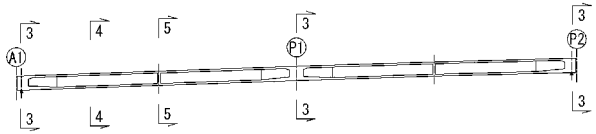


DETAIL OF PARAPET AND RAILING



LOCATION DIAGRAM



MATERIALS LIST

MATERIAL	CLASS	DESIGN STRENGTH (N/sq.mm)	STRUCTURAL MEMBERS
CONCRETE	D1	35	PC BOX GIRDER
	A1 1	24	BARRIER
REINFORCEMENT BAR	ASTM A615	GRADE420(fy=420)	PC BOX GIRDER,BARRIER
PRESTRESSING TENDON	ASTM A416	GRADE1860(fy=1860)	PC BOX GIRDER(12S15.2)

2.2 Analysis Model

Support Section

Analysis model of superstructure which consideration as plane flame model shown as below.

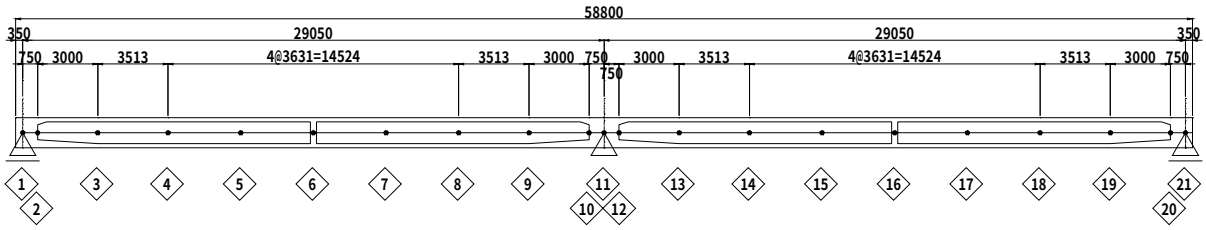


Figure 2.2 Analysis Frame Model

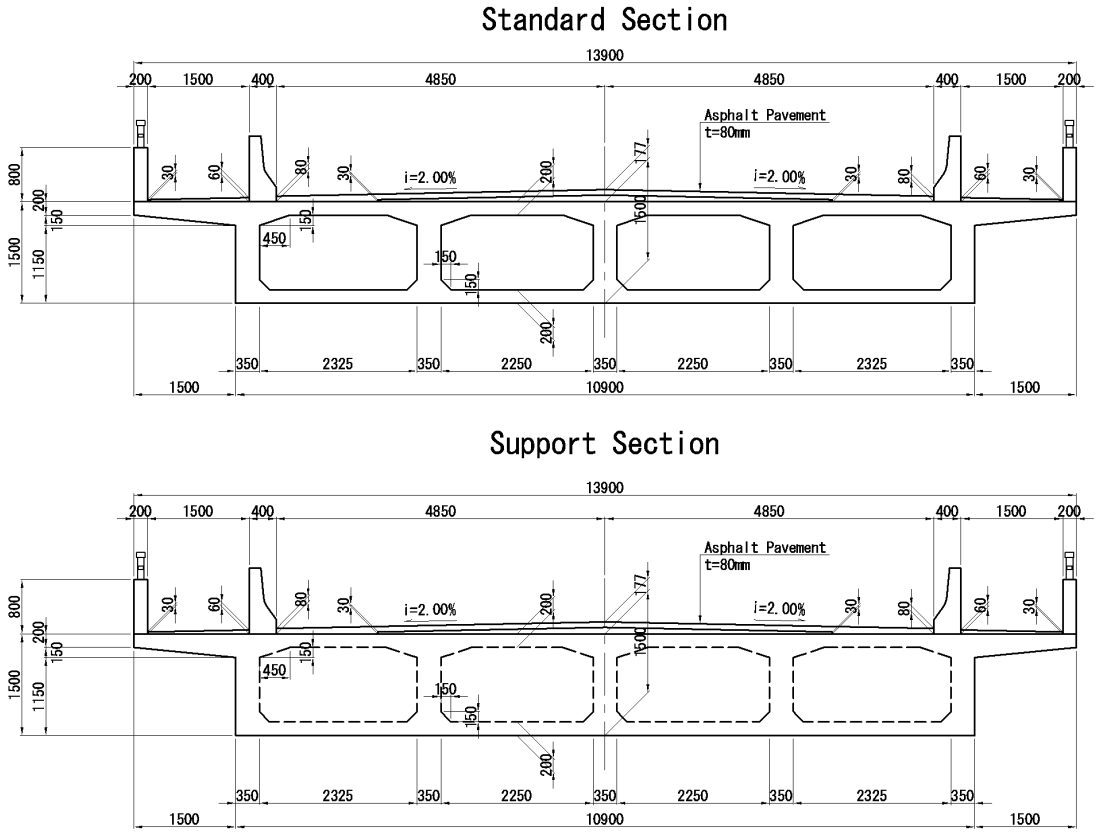


Figure 2.2.1 Plane Frame Analysis Model

2.3 Loadings

2.3.1 Dead Load

(1) Unit Weight

Unit weight for calculate dead load that should be taken as following value.

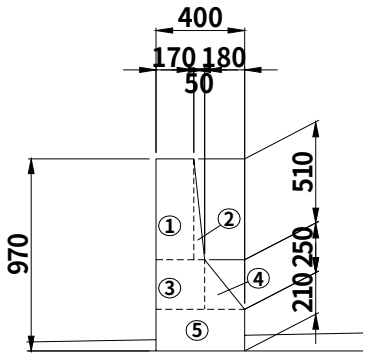
Reinforced Concrete	24.5N/m^3
Plain Concrete	23.0N/m^3
Structural Steel	77.0N/m^3
Asphalt Pavement	22.5N/m^3

(2) Self-weight of Girder

The self-weight of girder calculate according to section area, the software for design calculation that calculate girder self-weight automatically used input data.

(3) Surfacing

a. Parapet of Carriage Way



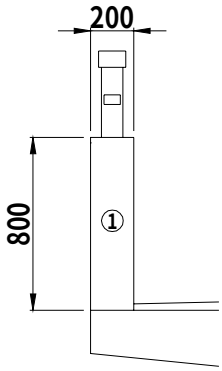
	A	X	AX
①	0.170×0.510×1.0=0.087	0.085	0.007
②	0.050×0.510×0.5=0.013	0.187	0.002
③	0.220×0.250×1.0=0.055	0.110	0.006
④	0.180×0.250×0.5=0.023	0.280	0.006
⑤	0.400×0.210×1.0=0.084	0.200	0.017
計	0.261		0.038

X = ∑AX/∑A = 0.146 m

P = 0.261 × 24.5 = 6.393 kN/m

b. Parapet of Foot Way

Concrete barrier



	A	X	AX
①	0.200×0.800×1.0=0.160	0.100	0.01600
Total	0.160		0.01600

X = ∑ AX/∑ A = 0.1 m

P = 0.160 × 24.5 = 3.92 kN/m

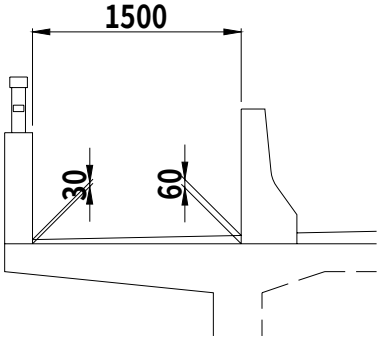
M = 0.100 × 3.920 = 0.392 kN・m/m

Steel Railing

W= 0.300kN/m

c. Asphalt Pavement

Foot Way (t=30mm~60mm)



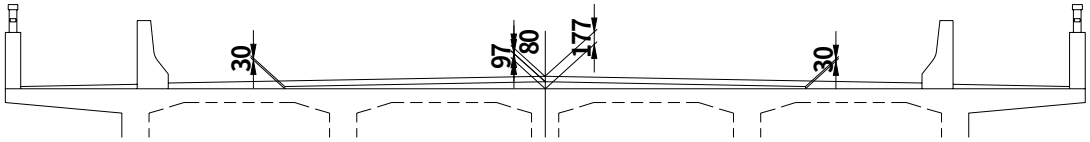
W = 0.03 × 22.5 = 0.675 kN/m^2

W = 0.06 × 22.5= 1.35 kN/m^2

Carriage Way (t=80mm)

W = 0.08 × 22.5 = 1.8 kN/m^2

d. Leveling Concrete

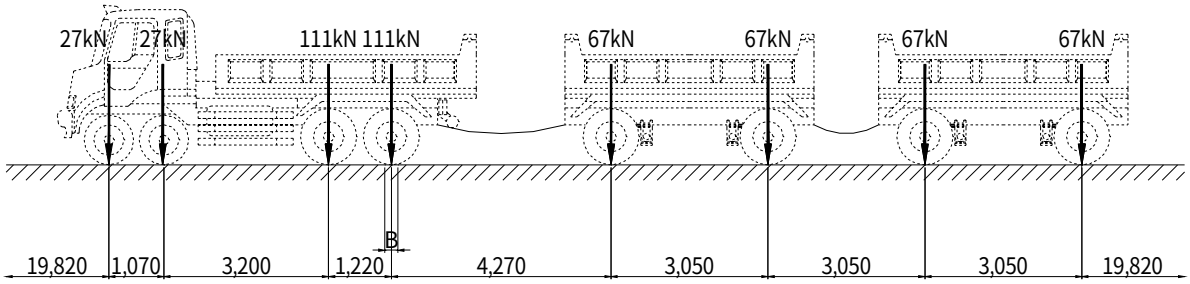


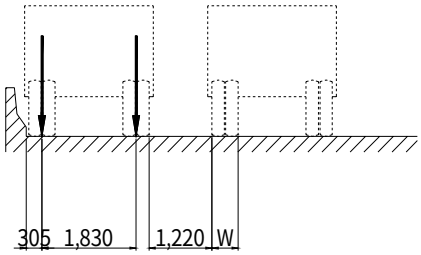
W = 0.03 × 23.0 = 0.69 kN/m^2

W = 0.097 × 23.0 = 2.231 kN/m^2

2.3.2 Live Load

a. Class-A Loading



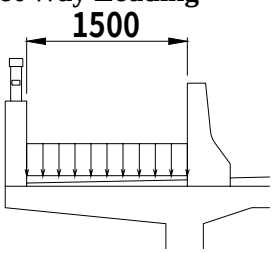


Class of Loading	Axle Load	Ground Contact Area	
		B	W
	kN	mm	mm
A	111	254	508
	67	203	381
	27	152	203

b. Impact Factor

i= 15.24/(L+38) L: Span Length (m)
= 15.24/(28.95+38)
= 0.228

c. Foot Way Loading

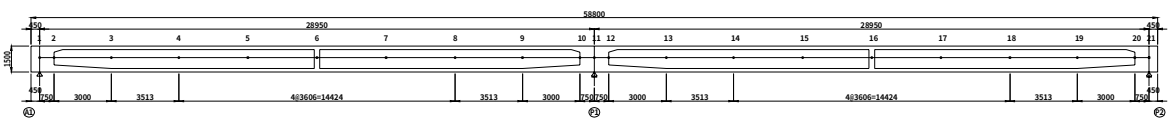


q = 2.87 kN/m^2

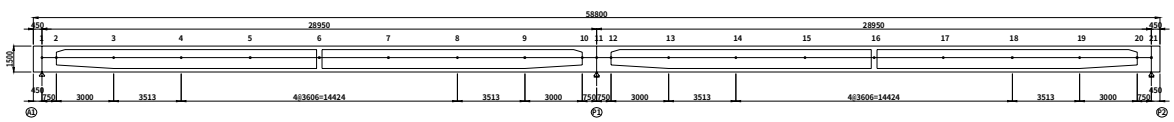
2.4 Calculation Result of Sectional Force

2.4.1 List of Sectional Force per Each Section

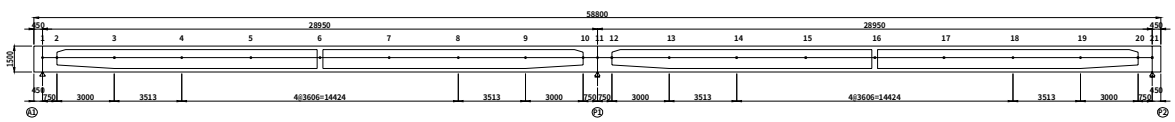
Member No.	Self Weight (D)			Surfacing (D)			Secondary Force by Pre-stress (D)		
	M (kNm)	S (kN)	N (kN)	M (kNm)	S (kN)	N (kN)	M (kNm)	S (kN)	N (kN)
1-i	-26.7	2182.4	0.0	0.0	686.9	0.0	0.0	165.5	0.0
1-j	1536.0	1984.7	0.0	497.2	639.0	0.0	124.1	165.4	0.0
2-i	1536.0	1984.7	0.0	497.2	639.0	0.0	124.1	165.4	0.0
2-j	6420.7	1310.7	0.0	2126.3	447.1	0.0	601.0	160.3	0.0
3-i	6420.7	1310.7	0.0	2126.3	447.1	0.0	601.0	160.3	0.0
3-j	9879.4	658.3	0.0	3302.5	222.5	0.0	1151.7	158.6	0.0
4-i	9879.4	658.3	0.0	3302.5	222.5	0.0	1151.7	158.6	0.0
4-j	11045.9	-11.3	0.0	3689.2	-8.1	0.0	1730.0	159.2	0.0
5-i	11045.9	-11.3	0.0	3689.2	-8.1	0.0	1730.0	159.2	0.0
5-j	9797.6	-681.0	0.0	3244.4	-238.6	0.0	2295.4	158.6	0.0
6-i	9797.6	-752.3	0.0	3244.4	-238.6	0.0	2295.4	158.6	0.0
6-j	5877.2	-1422.0	0.0	1968.2	-469.2	0.0	2907.3	160.8	0.0
7-i	5877.2	-1422.0	0.0	1968.2	-469.2	0.0	2907.3	160.8	0.0
7-j	-458.0	-2091.7	0.0	-139.4	-699.8	0.0	3515.3	162.1	0.0
8-i	-458.0	-2091.7	0.0	-139.4	-699.8	0.0	3515.3	162.1	0.0
8-j	-8952.1	-2744.1	0.0	-2992.2	-924.4	0.0	4019.1	159.5	0.0
9-i	-8952.1	-2744.1	0.0	-2992.2	-924.4	0.0	4019.1	159.5	0.0
9-j	-18136.9	-3418.1	0.0	-6053.1	-1116.2	0.0	4648.0	164.8	0.0
10-i	-18136.9	-3418.1	0.0	-6053.1	-1116.2	0.0	4648.0	164.8	0.0
10-j	-20774.6	-3615.8	0.0	-6908.2	-1164.2	0.0	4814.0	166.3	0.0
11-i	-20774.6	3615.8	0.0	-6908.2	1164.2	0.0	4814.0	-166.3	0.0
11-j	-18136.9	3418.1	0.0	-6053.1	1116.2	0.0	4648.0	-164.8	0.0
12-i	-18136.9	3418.1	0.0	-6053.1	1116.2	0.0	4648.0	-164.8	0.0
12-j	-8952.1	2744.1	0.0	-2992.2	924.4	0.0	4019.1	-159.5	0.0
13-i	-8952.1	2744.1	0.0	-2992.2	924.4	0.0	4019.1	-159.5	0.0
13-j	-458.0	2091.7	0.0	-139.4	699.8	0.0	3515.2	-162.1	0.0
14-i	-458.0	2091.7	0.0	-139.4	699.8	0.0	3515.2	-162.1	0.0
14-j	5877.2	1422.0	0.0	1968.2	469.2	0.0	2907.3	-160.8	0.0
15-i	5877.2	1422.0	0.0	1968.2	469.2	0.0	2907.3	-160.8	0.0
15-j	9797.6	752.3	0.0	3244.4	238.6	0.0	2295.4	-158.6	0.0
16-i	9797.6	681.0	0.0	3244.4	238.6	0.0	2295.4	-158.6	0.0
16-j	11045.9	11.3	0.0	3689.2	8.1	0.0	1730.0	-159.2	0.0
17-i	11045.9	11.3	0.0	3689.2	8.1	0.0	1730.0	-159.2	0.0
17-j	9879.4	-658.3	0.0	3302.5	-222.5	0.0	1150.7	-158.4	0.0
18-i	9879.4	-658.3	0.0	3302.5	-222.5	0.0	1150.7	-158.4	0.0
18-j	6420.7	-1310.7	0.0	2126.3	-447.1	0.0	600.4	-160.1	0.0
19-i	6420.7	-1310.7	0.0	2126.3	-447.1	0.0	600.4	-160.1	0.0
19-j	1536.0	-1984.7	0.0	497.2	-639.0	0.0	124.0	-165.4	0.0
20-i	1536.0	-1984.7	0.0	497.2	-639.0	0.0	124.0	-165.4	0.0
20-j	-26.7	-2182.4	0.0	0.0	-686.9	0.0	0.0	-165.4	0.0



Member No.	Live Load Mmax (L)			Live Load Mmin (L)			Live Load Smax (L)		
	M (kNm)	S (kN)	N (kN)	M (kNm)	S (kN)	N (kN)	M (kNm)	S (kN)	N (kN)
1-i	0.0	0.0	0.0	0.0	0.0	0.0	0.0	901.1	0.0
1-j	649.6	862.9	0.0	-81.7	-108.9	0.0	647.2	863.0	0.0
2-i	649.6	862.9	0.0	-81.7	-108.9	0.0	647.2	863.0	0.0
2-j	2753.9	710.3	0.0	-408.5	-108.9	0.0	2678.3	714.2	0.0
3-i	2753.9	710.3	0.0	-408.5	-108.9	0.0	2678.3	714.2	0.0
3-j	4422.5	525.2	0.0	-791.3	-108.9	0.0	4005.3	551.5	0.0
4-i	4422.5	525.2	0.0	-791.3	-108.9	0.0	4005.3	551.5	0.0
4-j	5130.2	169.4	0.0	-1184.1	-108.9	0.0	4346.6	399.9	0.0
5-i	5130.2	169.4	0.0	-1184.1	-108.9	0.0	4346.6	399.9	0.0
5-j	4940.4	-201.9	0.0	-1577.0	-108.9	0.0	3863.9	266.9	0.0
6-i	4940.4	-201.9	0.0	-1577.0	-108.9	0.0	3863.9	266.9	0.0
6-j	4321.1	-385.1	0.0	-1969.9	-108.9	0.0	2936.1	162.4	0.0
7-i	4321.1	-385.1	0.0	-1969.9	-108.9	0.0	2936.1	162.4	0.0
7-j	2807.3	-733.1	0.0	-2362.7	-108.9	0.0	1843.9	85.0	0.0
8-i	2807.3	-733.1	0.0	-2362.7	-108.9	0.0	1843.9	85.0	0.0
8-j	970.7	-598.8	0.0	-3172.1	-426.0	0.0	831.7	33.0	0.0
9-i	970.7	-598.8	0.0	-3172.1	-426.0	0.0	831.7	33.0	0.0
9-j	105.5	-276.4	0.0	-4692.1	-602.3	0.0	104.0	3.7	0.0
10-i	105.5	-276.4	0.0	-4692.1	-602.3	0.0	104.0	3.7	0.0
10-j	0.0	0.0	0.0	-5164.7	-691.3	0.0	0.0	0.0	0.0
11-i	0.0	0.0	0.0	-5164.7	691.3	0.0	-2796.1	1056.0	0.0
11-j	105.5	276.4	0.0	-4692.1	602.3	0.0	-2232.3	1030.1	0.0
12-i	105.5	276.4	0.0	-4692.1	602.3	0.0	-2232.3	1030.1	0.0
12-j	970.7	598.8	0.0	-3172.1	426.0	0.0	-235.3	923.5	0.0
13-i	970.7	598.8	0.0	-3172.1	426.0	0.0	-235.3	923.5	0.0
13-j	2807.3	733.1	0.0	-2362.7	108.9	0.0	1500.3	793.4	0.0
14-i	2807.3	733.1	0.0	-2362.7	108.9	0.0	1500.3	793.4	0.0
14-j	4321.1	385.1	0.0	-1969.9	108.9	0.0	2554.0	653.7	0.0
15-i	4321.1	385.1	0.0	-1969.9	108.9	0.0	2554.0	653.7	0.0
15-j	4940.4	201.9	0.0	-1577.0	108.9	0.0	2784.7	510.5	0.0
16-i	4940.4	201.9	0.0	-1577.0	108.9	0.0	2784.7	510.5	0.0
16-j	5130.2	-169.4	0.0	-1184.1	108.9	0.0	2496.1	381.7	0.0
17-i	5130.2	-169.4	0.0	-1184.1	108.9	0.0	2496.1	381.7	0.0
17-j	4422.5	-525.2	0.0	-791.3	108.9	0.0	1863.6	264.6	0.0
18-i	4422.5	-525.2	0.0	-791.3	108.9	0.0	1863.6	264.6	0.0
18-j	2753.9	-710.3	0.0	-408.5	108.9	0.0	1012.6	168.4	0.0
19-i	2753.9	-710.3	0.0	-408.5	108.9	0.0	1012.6	168.4	0.0
19-j	649.6	-862.9	0.0	-81.7	108.9	0.0	121.9	113.1	0.0
20-i	649.6	-862.9	0.0	-81.7	108.9	0.0	121.9	113.1	0.0
20-j	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.9	0.0

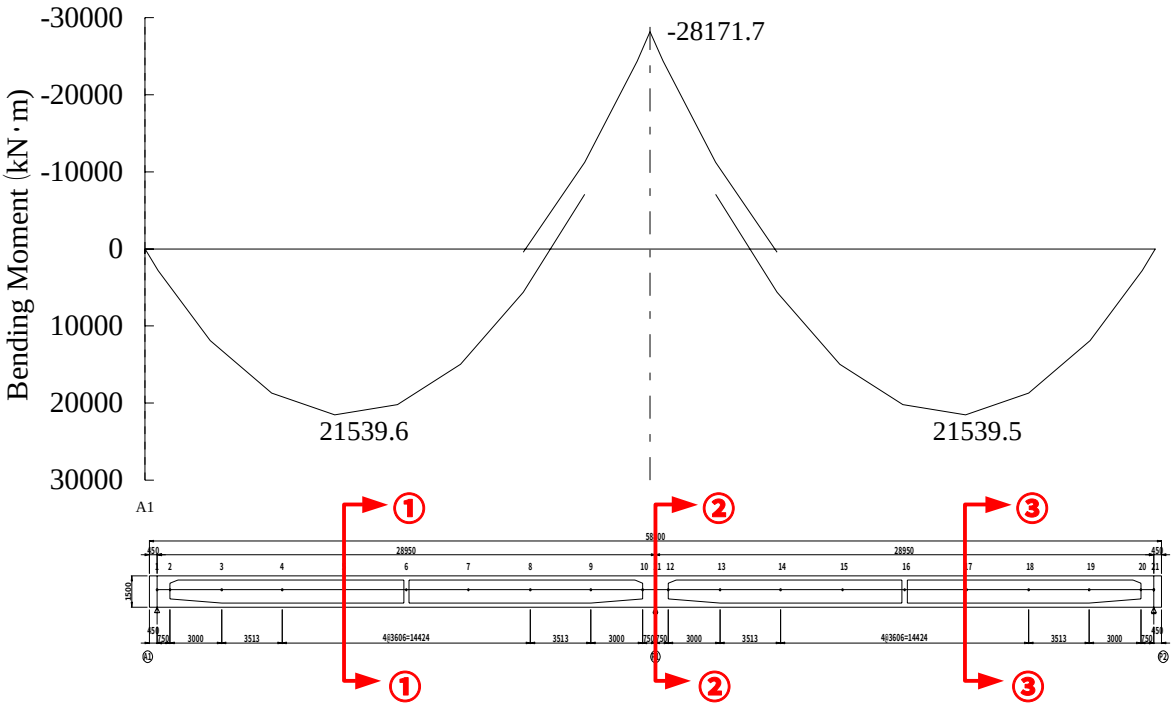


Member No.	Live Load Smin (L)			Temperature Difference (T)		
	M (kNm)	S (kN)	N (kN)	M (kNm)	S (kN)	N (kN)
1-i	0.0	-108.9	0.0	-3476.6	153.6	-5711.9
1-j	121.9	-113.1	0.0	-3361.4	153.6	-5711.9
2-i	121.9	-113.1	0.0	-3361.4	364.1	-5711.9
2-j	1012.6	-168.4	0.0	-2269.1	364.1	-5380.1
3-i	1012.6	-168.4	0.0	-2269.1	153.6	-5380.1
3-j	1863.6	-264.6	0.0	-1729.5	153.6	-5380.1
4-i	1863.6	-264.6	0.0	-1729.5	153.6	-5380.1
4-j	2496.1	-381.7	0.0	-1175.7	153.6	-5380.1
5-i	2496.1	-381.7	0.0	-1175.7	153.6	-5380.1
5-j	2784.7	-510.5	0.0	-621.8	153.6	-5380.1
6-i	2784.7	-510.5	0.0	-621.8	153.6	-5380.1
6-j	2554.0	-653.7	0.0	-68.0	153.6	-5380.1
7-i	2554.0	-653.7	0.0	-68.0	153.6	-5380.1
7-j	1500.3	-793.4	0.0	485.8	153.6	-5380.1
8-i	1500.3	-793.4	0.0	485.8	153.6	-5380.1
8-j	-235.3	-923.5	0.0	1025.4	153.6	-5380.1
9-i	-235.3	-923.5	0.0	1025.4	-56.9	-5380.1
9-j	-2232.3	-1030.1	0.0	854.6	-56.9	-5711.9
10-i	-2232.3	-1030.1	0.0	854.6	153.6	-5711.9
10-j	-2796.1	-1056.0	0.0	969.8	153.6	-5711.9
11-i	0.0	0.0	0.0	969.8	-153.6	-5711.9
11-j	104.0	-3.7	0.0	854.6	-153.6	-5711.9
12-i	104.0	-3.7	0.0	854.6	56.9	-5711.9
12-j	831.7	-33.0	0.0	1025.4	56.9	-5380.1
13-i	831.7	-33.0	0.0	1025.4	-153.6	-5380.1
13-j	1843.9	-85.0	0.0	485.8	-153.6	-5380.1
14-i	1843.9	-85.0	0.0	485.8	-153.6	-5380.1
14-j	2936.1	-162.4	0.0	-68.0	-153.6	-5380.1
15-i	2936.1	-162.4	0.0	-68.0	-153.6	-5380.1
15-j	3863.9	-266.9	0.0	-621.8	-153.6	-5380.1
16-i	3863.9	-266.9	0.0	-621.8	-153.6	-5380.1
16-j	4346.6	-399.9	0.0	-1175.7	-153.6	-5380.1
17-i	4346.6	-399.9	0.0	-1175.7	-153.6	-5380.1
17-j	4005.3	-551.5	0.0	-1729.5	-153.6	-5380.1
18-i	4005.3	-551.5	0.0	-1729.5	-153.6	-5380.1
18-j	2678.3	-714.2	0.0	-2269.1	-153.6	-5380.1
19-i	2678.3	-714.2	0.0	-2269.1	-364.1	-5380.1
19-j	647.2	-863.0	0.0	-3361.4	-364.1	-5711.9
20-i	647.2	-863.0	0.0	-3361.4	-153.6	-5711.9
20-j	0.0	-901.1	0.0	-3476.6	-153.6	-5711.9



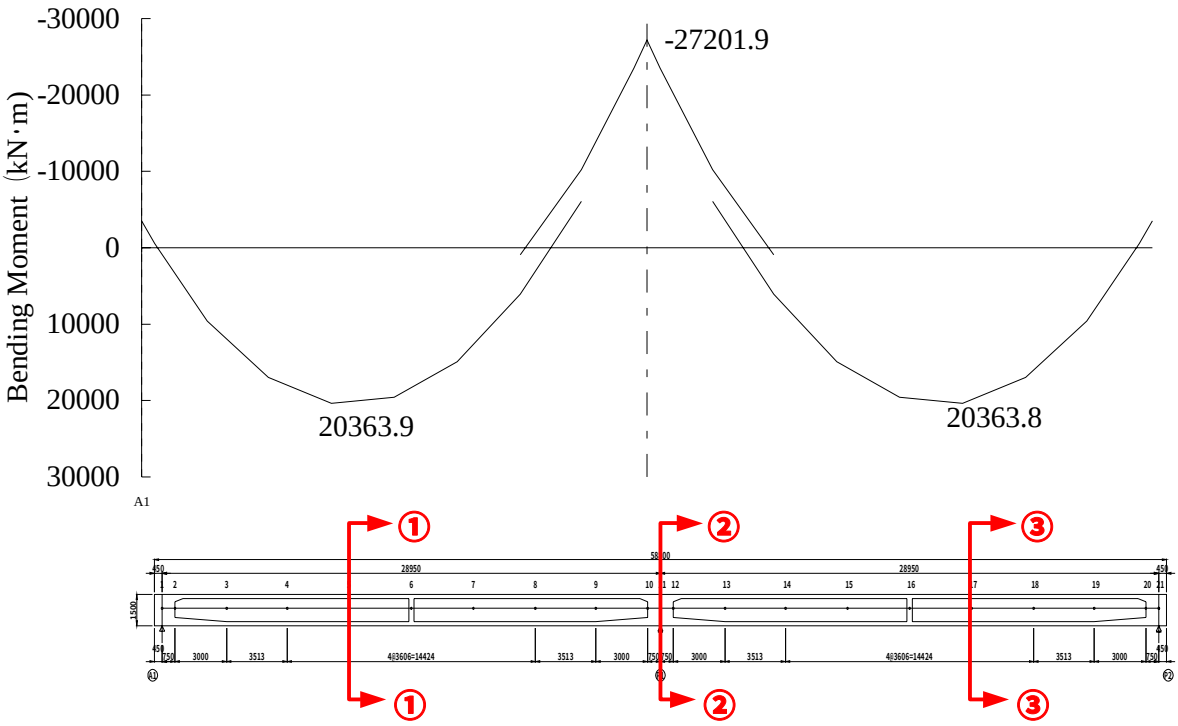
2.4.2 Bending Moment Diagram for Service Load Design

Gruop-I (D+L)



*) Marking is Maximum or Miminum Moment Section

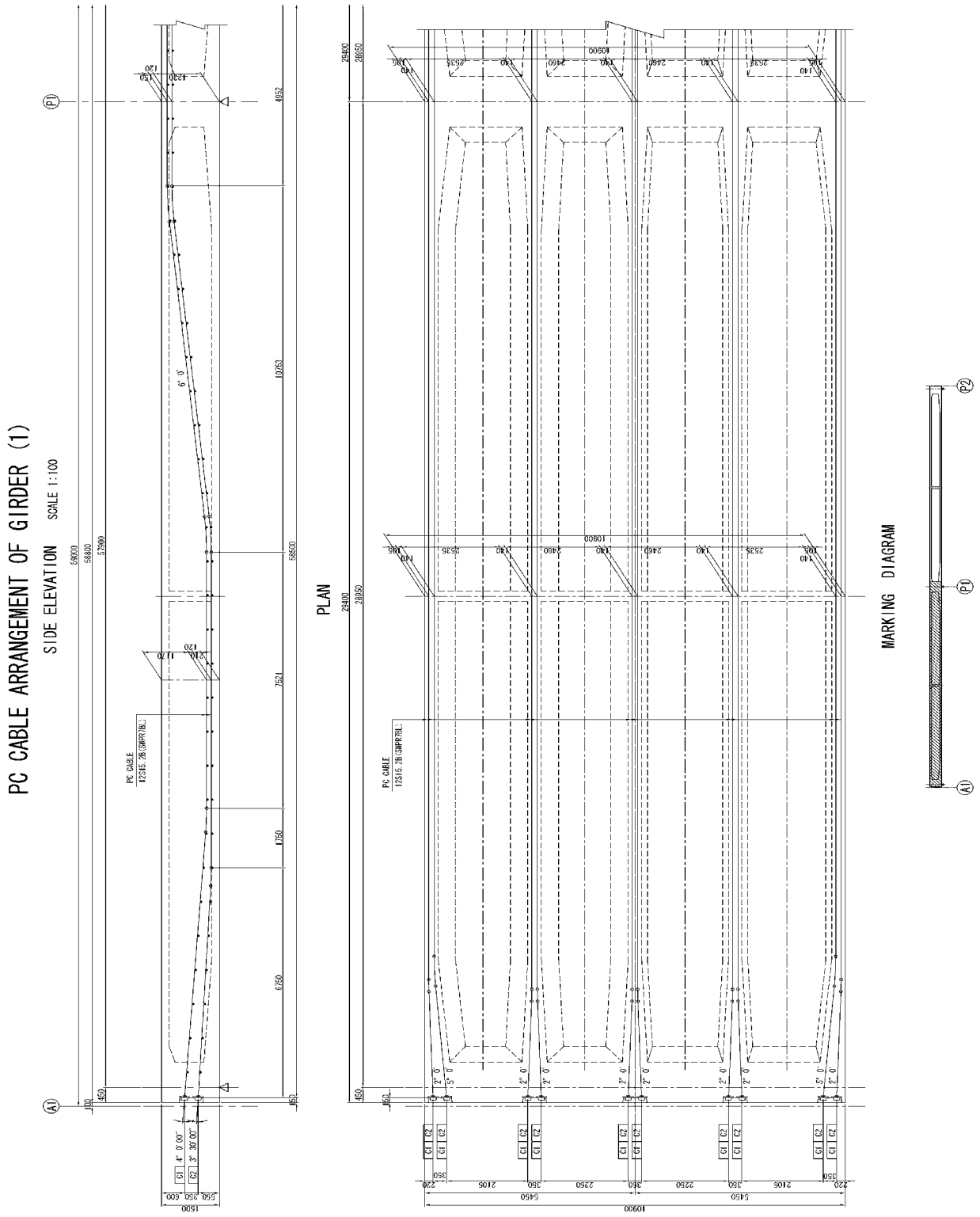
Group-IV (D+L+T)



*) Marking is Maximum or Miminum Moment Section

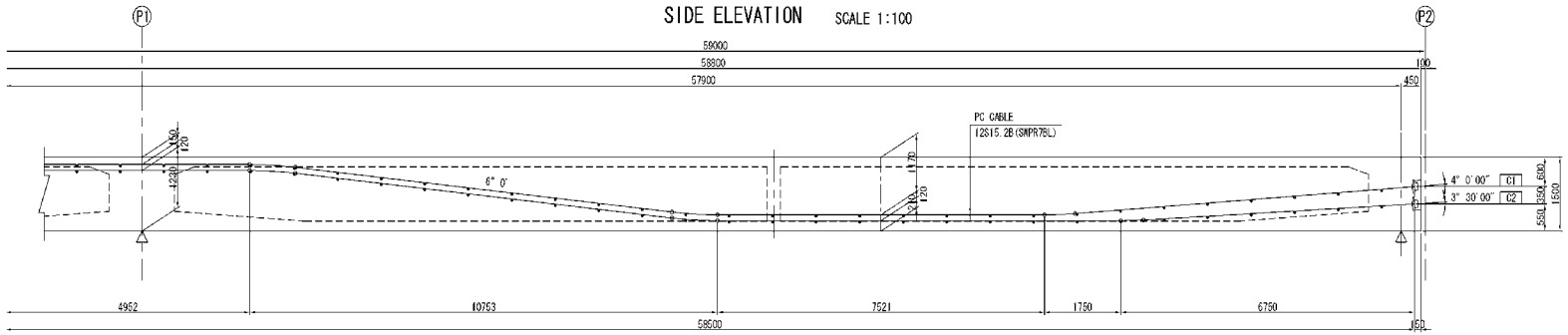
2.5 Calculation of Pre-Stress

2.5.1 PC Steel Arrangement

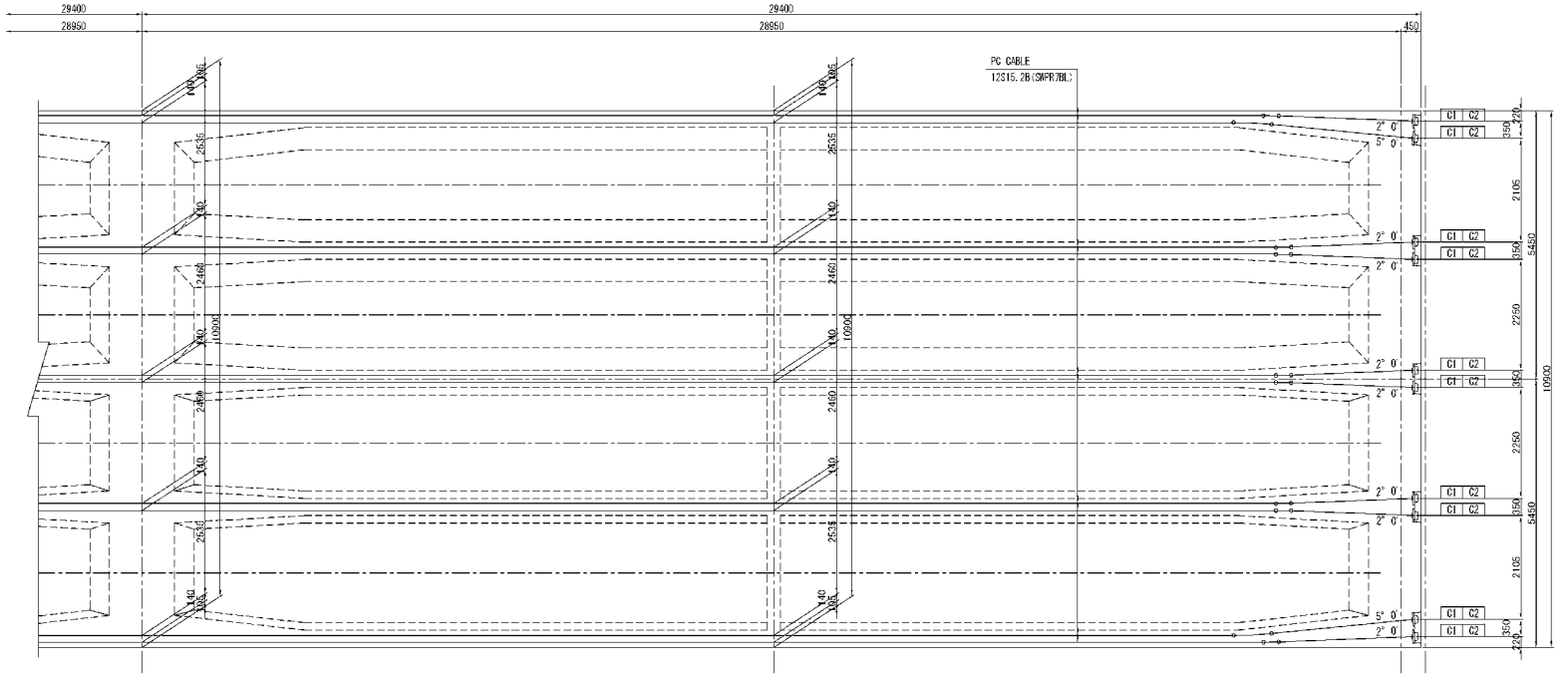


PC CABLE ARRANGEMENT OF GIRDER (2)

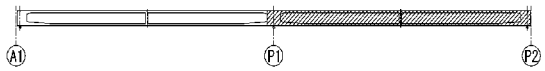
SIDE ELEVATION SCALE 1:100



PLAN

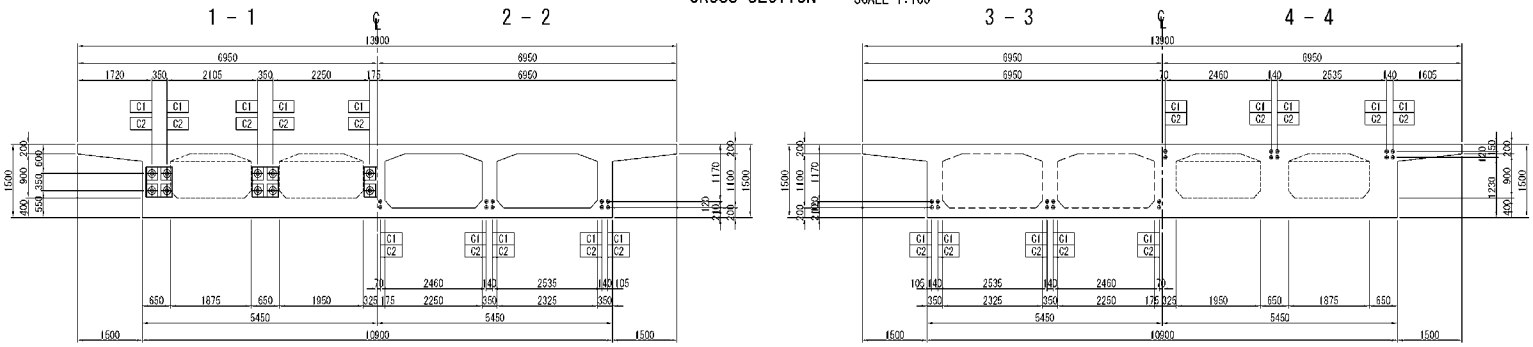


MARKING DIAGRAM

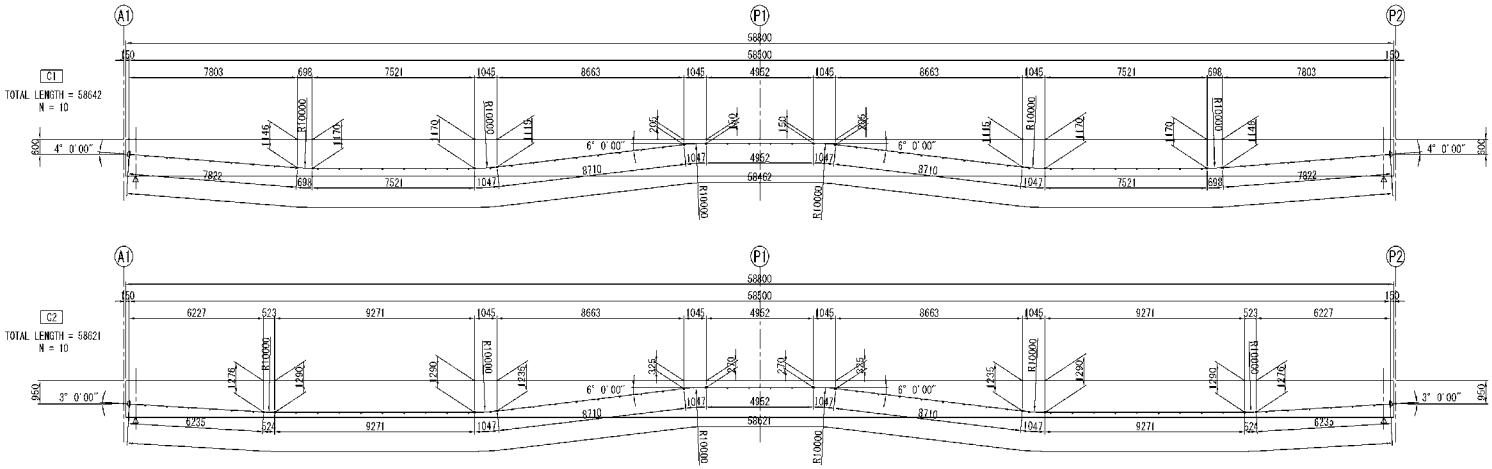


PC CABLE ARRANGEMENT OF GIRDER (3)

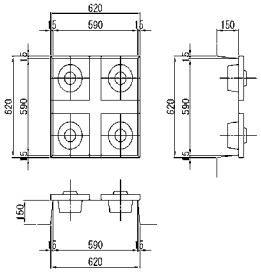
CROSS SECTION SCALE 1:100



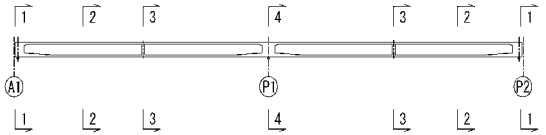
CABLE PROFILE SCALE 1:200



HOLLW SPACE FOR ANCHORAGE SCALE 1:30



MARKING DIAGRAM



2.5.2 Stress of PC Steel after Transfer

Member No.	Initial Pretress σpt' (N/mm^2)	Nos. (Each)	ep (m)	Pt' (kN)	Mpt' (kN.m)
1-i	1127.904	20	-0.043	37545.7	-1602.4
1-j	1129.844	20	-0.089	37610.2	-3344.8
2-i	1129.844	20	-0.089	37610.2	-3344.8
2-j	1137.604	20	-0.364	37868.6	-13783.2
3-i	1137.604	20	-0.364	37868.6	-13783.2
3-j	1154.994	20	-0.553	38447.4	-21256.7
4-i	1154.994	20	-0.553	38447.4	-21256.7
4-j	1175.102	20	-0.574	39116.8	-22441.0
5-i	1175.102	20	-0.574	39116.8	-22441.0
5-j	1184.12	20	-0.574	39417.0	-22613.2
6-i	1184.12	20	-0.574	39417.0	-22613.2
6-j	1202.167	20	-0.379	40017.7	-15146.0
7-i	1202.167	20	-0.379	40017.7	-15146.0
7-j	1193.502	20	0.005	39729.3	198.4
8-i	1193.502	20	0.005	39729.3	198.4
8-j	1185.061	20	0.379	39448.3	14934.3
9-i	1185.061	20	0.379	39448.3	14934.3
9-j	1147.533	20	0.546	38199.1	20837.7
10-i	1147.533	20	0.546	38199.1	20837.7
10-j	1145.815	20	0.546	38141.9	20806.5
11-i	1145.815	20	0.546	38141.9	20806.5
11-j	1147.189	20	0.546	38187.6	20831.4
12-i	1147.189	20	0.546	38187.6	20831.4
12-j	1184.705	20	0.379	39436.5	14929.8
13-i	1184.705	20	0.379	39436.5	14929.8
13-j	1193.144	20	0.005	39717.4	198.3
14-i	1193.144	20	0.005	39717.4	198.3
14-j	1201.806	20	-0.379	40005.7	-15141.5
15-i	1201.806	20	-0.379	40005.7	-15141.5
15-j	1184.922	20	-0.574	39443.7	-22628.5
16-i	1184.922	20	-0.574	39443.7	-22628.5
16-j	1175.905	20	-0.574	39143.5	-22456.4
17-i	1175.905	20	-0.574	39143.5	-22456.4
17-j	1155.805	20	-0.558	38474.4	-21475.8
18-i	1155.805	20	-0.558	38474.4	-21475.8
18-j	1138.422	20	-0.373	37895.8	-14144.9
19-i	1138.422	20	-0.373	37895.8	-14144.9
19-j	1130.662	20	-0.098	37637.5	-3695.4
20-i	1130.662	20	-0.098	37637.5	-3695.4
20-j	1128.722	20	-0.052	37572.9	-1951.1

Member No.	Sectional Properties Ac (m^2)	Wcg ($m^{3)}$)	σctg' (N/mm^2)	σcg' (N/mm^2)	Elastic Shortening △σp2 (N/mm^2)	σpt (N/mm^2)
1-i	10.672	-69.330	3.54	0.00	13.62	1114.28
1-j	10.672	-33.267	3.63	-0.05	13.75	1116.10
2-i	10.672	-33.267	3.63	-0.05	13.75	1116.10
2-j	7.492	-6.660	7.12	-1.07	23.29	1114.31
3-i	7.492	-6.660	7.12	-1.07	23.29	1114.31
3-j	7.492	-4.359	10.01	-2.57	28.60	1126.40
4-i	7.492	-4.359	10.01	-2.57	28.60	1126.40
4-j	7.492	-4.198	10.57	-3.11	28.69	1146.41
5-i	7.492	-4.198	10.57	-3.11	28.69	1146.41
5-j	7.492	-4.198	10.65	-2.97	29.54	1154.59
6-i	7.492	-4.198	10.65	-2.97	29.54	1154.59
6-j	7.492	-6.406	7.71	-1.44	24.11	1178.06
7-i	7.492	-6.406	7.71	-1.44	24.11	1178.06
7-j	7.492	488.056	5.30	0.01	20.43	1173.08
8-i	7.492	488.035	5.30	0.01	20.43	1173.08
8-j	7.492	6.404	7.60	-0.67	26.63	1158.43
9-i	7.492	6.404	7.60	-0.67	26.63	1158.43
9-j	10.672	5.381	7.45	-2.41	19.41	1128.12
10-i	10.672	5.381	7.45	-2.41	19.41	1128.12
10-j	10.672	5.381	7.44	-2.87	17.58	1128.23
11-i	10.672	5.381	7.44	-2.87	17.58	1128.23
11-j	10.672	5.381	7.45	-2.41	19.40	1127.79
12-i	10.672	5.381	7.45	-2.41	19.40	1127.79
12-j	7.492	6.404	7.60	-0.67	26.63	1158.08
13-i	7.492	6.404	7.60	-0.67	26.63	1158.08
13-j	7.492	488.035	5.30	0.01	20.42	1172.72
14-i	7.492	488.056	5.30	0.01	20.42	1172.72
14-j	7.492	-6.406	7.70	-1.44	24.10	1177.71
15-i	7.492	-6.406	7.70	-1.44	24.10	1177.71
15-j	7.492	-4.198	10.66	-2.97	29.56	1155.36
16-i	7.492	-4.198	10.66	-2.97	29.56	1155.36
16-j	7.492	-4.198	10.57	-3.11	28.72	1147.19
17-i	7.492	-4.198	10.57	-3.11	28.72	1147.19
17-j	7.492	-4.317	10.11	-2.60	28.89	1126.91
18-i	7.492	-4.317	10.11	-2.60	28.89	1126.91
18-j	7.492	-6.493	7.24	-1.10	23.62	1114.80
19-i	7.492	-6.493	7.24	-1.10	23.62	1114.80
19-j	10.672	-30.131	3.65	-0.06	13.82	1116.84
20-i	10.672	-30.131	3.65	-0.06	13.82	1116.84
20-j	10.672	-56.978	3.56	0.00	13.68	1115.05

2.5.3 Pre-Stress after Transfer

Member No.	Pt (kN)	Mpt (kN.m)	Wc' ($m^{3)}$)	Wc ($m^{3)}$)	Upper Edge σct' (N/mm^2)	Lower Edge σct (N/mm^2)
1-i	37092.2	-1583.0	3.942	-3.949	3.07	3.88
1-j	37152.6	-3304.1	3.943	-3.946	2.64	4.32
2-i	37152.6	-3304.1	3.943	-3.946	2.64	4.32
2-j	37093.2	-13501.0	3.680	-2.882	1.28	9.64
3-i	37093.2	-13501.0	3.680	-2.882	1.28	9.64
3-j	37495.5	-20730.5	3.671	-2.858	-0.64	12.26
4-i	37495.5	-20730.5	3.671	-2.858	-0.64	12.26
4-j	38161.8	-21893.2	3.670	-2.855	-0.87	12.76
5-i	38161.8	-21893.2	3.670	-2.855	-0.87	12.76
5-j	38433.8	-22049.2	3.670	-2.855	-0.88	12.85
6-i	38433.8	-22049.2	3.670	-2.855	-0.88	12.85
6-j	39215.2	-14842.3	3.682	-2.882	1.20	10.39
7-i	39215.2	-14842.2	3.682	-2.882	1.20	10.39
7-j	39049.4	195.0	3.676	-2.912	5.27	5.15
8-i	39049.4	195.0	3.676	-2.912	5.27	5.15
8-j	38561.7	14598.7	3.633	-2.912	9.17	0.13
9-i	38561.7	14598.7	3.633	-2.912	9.17	0.13
9-j	37552.9	20485.2	3.885	-3.943	8.79	-1.68
10-i	37552.9	20485.2	3.885	-3.943	8.79	-1.68
10-j	37556.6	20487.2	3.885	-3.943	8.79	-1.68
11-i	37556.6	20487.2	3.885	-3.943	8.79	-1.68
11-j	37541.8	20479.1	3.885	-3.943	8.79	-1.68
12-i	37541.8	20479.1	3.885	-3.943	8.79	-1.68
12-j	38550.2	14594.3	3.633	-2.912	9.16	0.13
13-i	38550.2	14594.3	3.633	-2.912	9.16	0.13
13-j	39037.6	194.9	3.676	-2.912	5.26	5.14
14-i	39037.6	194.9	3.676	-2.912	5.26	5.14
14-j	39203.5	-14837.8	3.682	-2.882	1.20	10.38
15-i	39203.5	-14837.8	3.682	-2.882	1.20	10.38
15-j	38459.6	-22064.0	3.670	-2.855	-0.88	12.86
16-i	38459.6	-22064.0	3.670	-2.855	-0.88	12.86
16-j	38187.7	-21908.0	3.670	-2.855	-0.87	12.77
17-i	38187.7	-21908.0	3.670	-2.855	-0.87	12.77
17-j	37512.7	-20939.0	3.671	-2.857	-0.70	12.34
18-i	37512.7	-20939.0	3.671	-2.857	-0.70	12.34
18-j	37109.5	-13851.4	3.680	-2.881	1.19	9.76
19-i	37109.5	-13851.4	3.680	-2.881	1.19	9.76
19-j	37177.3	-3650.2	3.944	-3.946	2.56	4.41
20-i	37177.3	-3650.2	3.944	-3.946	2.56	4.41
20-j	37117.7	-1927.5	3.942	-3.948	2.99	3.97

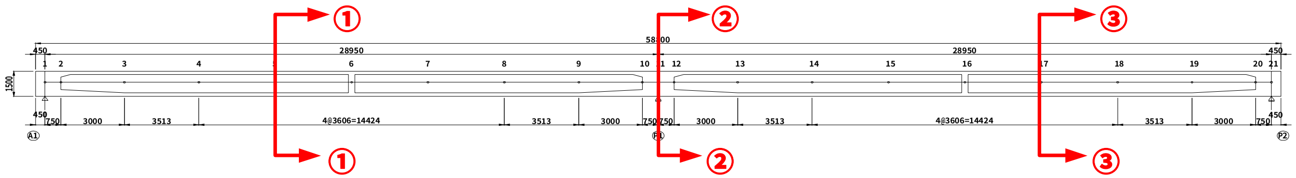
2.5.4 Effective Pre-Stress

Member No.	Relaxation R (%)	△σpr (N/mm^2)	σpt (N/mm^2)	σpe (N/mm^2)	η	Upper Edge σce' (N/mm^2)	Lower Edge σce (N/mm^2)
1-i	1.5	16.71	1114.28	1000.64	0.898	2.76	3.48
1-j	1.5	16.74	1116.10	1002.15	0.898	2.37	3.88
2-i	1.5	16.74	1116.10	1002.15	0.898	2.37	3.88
2-j	1.5	16.72	1114.31	969.29	0.870	1.12	8.38
3-i	1.5	16.72	1114.31	969.29	0.870	1.12	8.38
3-j	1.5	16.90	1126.40	969.42	0.861	-0.55	10.55
4-i	1.5	16.90	1126.40	969.42	0.861	-0.55	10.55
4-j	1.5	17.20	1146.41	990.39	0.864	-0.75	11.03
5-i	1.5	17.20	1146.41	990.39	0.864	-0.75	11.03
5-j	1.5	17.32	1154.59	993.75	0.861	-0.76	11.06
6-i	1.5	17.32	1154.59	993.75	0.861	-0.76	11.06
6-j	1.5	17.67	1178.06	1028.12	0.873	1.05	9.06
7-i	1.5	17.67	1178.06	1028.12	0.873	1.05	9.06
7-j	1.5	17.60	1173.08	1032.04	0.880	4.63	4.53
8-i	1.5	17.60	1173.08	1032.04	0.880	4.63	4.53
8-j	1.5	17.38	1158.43	1002.79	0.866	7.93	0.12
9-i	1.5	17.38	1158.43	1002.79	0.866	7.93	0.12
9-j	1.5	16.92	1128.12	1009.21	0.895	7.87	-1.50
10-i	1.5	16.92	1128.12	1009.21	0.895	7.87	-1.50
10-j	1.5	16.92	1128.23	1018.28	0.903	7.94	-1.51
11-i	1.5	16.92	1128.23	1018.28	0.903	7.94	-1.51
11-j	1.5	16.92	1127.79	1008.92	0.895	7.86	-1.50
12-i	1.5	16.92	1127.79	1008.92	0.895	7.86	-1.50
12-j	1.5	17.37	1158.08	1002.48	0.866	7.93	0.12
13-i	1.5	17.37	1158.08	1002.48	0.866	7.93	0.12
13-j	1.5	17.59	1172.72	1031.72	0.880	4.63	4.53
14-i	1.5	17.59	1172.72	1031.72	0.880	4.63	4.53
14-j	1.5	17.67	1177.71	1027.81	0.873	1.05	9.06
15-i	1.5	17.67	1177.71	1027.81	0.873	1.05	9.06
15-j	1.5	17.33	1155.36	994.41	0.861	-0.76	11.07
16-i	1.5	17.33	1155.36	994.41	0.861	-0.76	11.07
16-j	1.5	17.21	1147.19	991.05	0.864	-0.75	11.03
17-i	1.5	17.21	1147.19	991.05	0.864	-0.75	11.03
17-j	1.5	16.90	1126.91	969.03	0.860	-0.60	10.61
18-i	1.5	16.90	1126.91	969.03	0.860	-0.60	10.61
18-j	1.5	16.72	1114.80	968.72	0.869	1.03	8.48
19-i	1.5	16.72	1114.80	968.72	0.869	1.03	8.48
19-j	1.5	16.75	1116.84	1002.61	0.898	2.30	3.96
20-i	1.5	16.75	1116.84	1002.61	0.898	2.30	3.96
20-j	1.5	16.73	1115.05	1001.18	0.898	2.68	3.56

2.6 Service Load Design

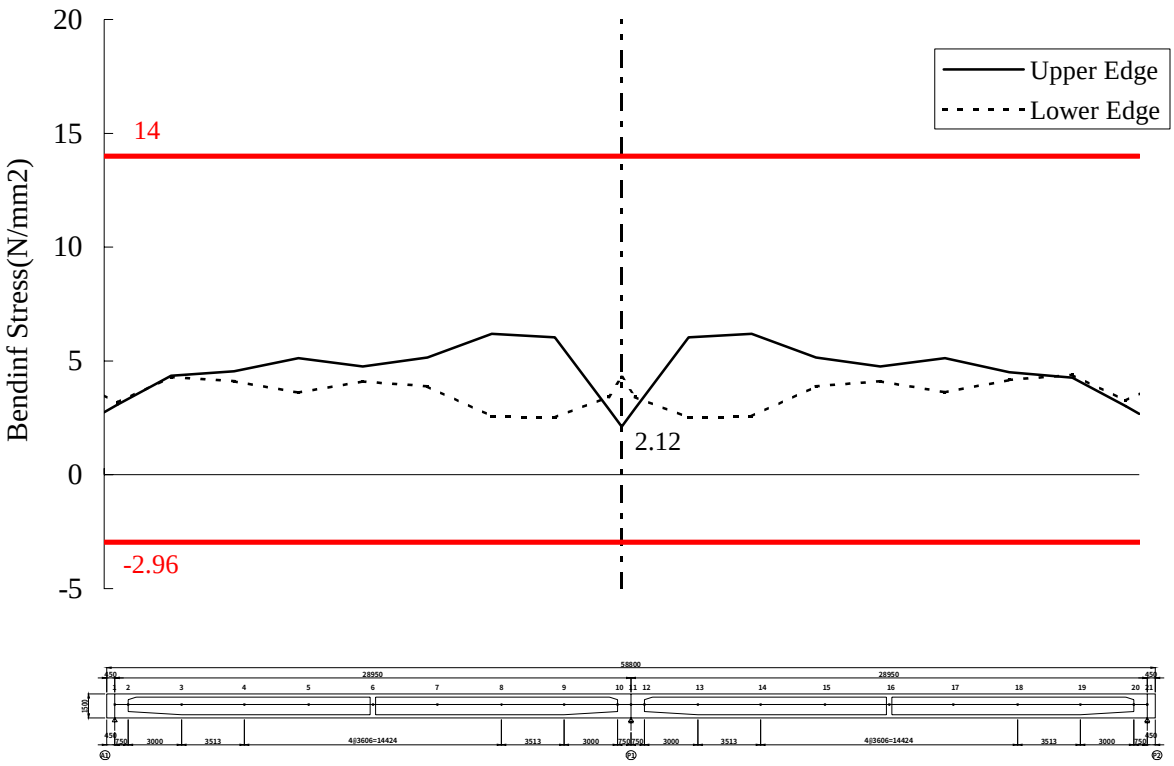
2.6.1 Checking of Bending Stress at Critical Section

Loadings	Type of Load	SECTION-①				SECTION-②				SECTION-③			
		Sectional Force		Upper Egde σcu	Lower Egde σcl	Sectional Force		Upper Egde σcu	Lower Egde σcl	Sectional Force		Upper Egde σcu	Lower Egde σcl
		M(kNm)	N(kN)	(N/mm^2)	(N/mm^2)	M(kNm)	N(kN)	(N/mm^2)	(N/mm^2)	M(kNm)	N(kN)	(N/mm^2)	(N/mm^2)
Self-Weight	D	11046	0	3.01	-3.87	-20775	0	-5.35	5.27	11046	0	3.01	-3.87
Surfacing	D	3689	0	1.00	-1.23	-6908	0	-1.71	1.74	3689	0	1.00	-1.23
Secondary Force by Pre-Stress	D	1730	0	0.47	-0.61	4814	0	1.24	-1.22	1730	0	0.47	-0.61
Effective Pre-Stress	D	-18914	32968	-0.75	11.03	18491	33897	7.94	-1.51	-18926	32990	-0.75	11.03
Temparature Difference	T	-1176	-5380	0.46	-0.31	970	-5712	1.19	-0.77	-1176	-5380	0.46	-0.31
Live Load with Impact Mmax	L1	5130	0	1.39	-1.71	0	0	0.00	0.00	5130	0	1.39	-1.71
Live Load with Impact Mmin	L2	-1184	0	-0.32	0.40	-5165	0	-1.28	1.30	-1184	0	-0.32	0.40
Losd Combination Group													
Group-I (Mmax) ΣD+L1				5.12	3.61			2.12	4.27			5.12	3.62
Group-I (Mmin) ΣD+L2				3.41	5.72			0.83	5.57			3.41	5.72
Allowable Stress for Group-I		-2.96<σ<14.00				-2.96<σ<14.00				-2.96<σ<14.00			
Group-IV (Mmax) ΣD+L1+T				5.58	3.31			3.31	3.51			5.58	3.31
Group-IV (Mmin) ΣD+L2+T				3.87	5.41			2.03	4.81			3.87	5.42
Allowable Stress for Group-IV		-3.70<σ<17.50				-3.70<σ<17.50				-3.70<σ<17.50			

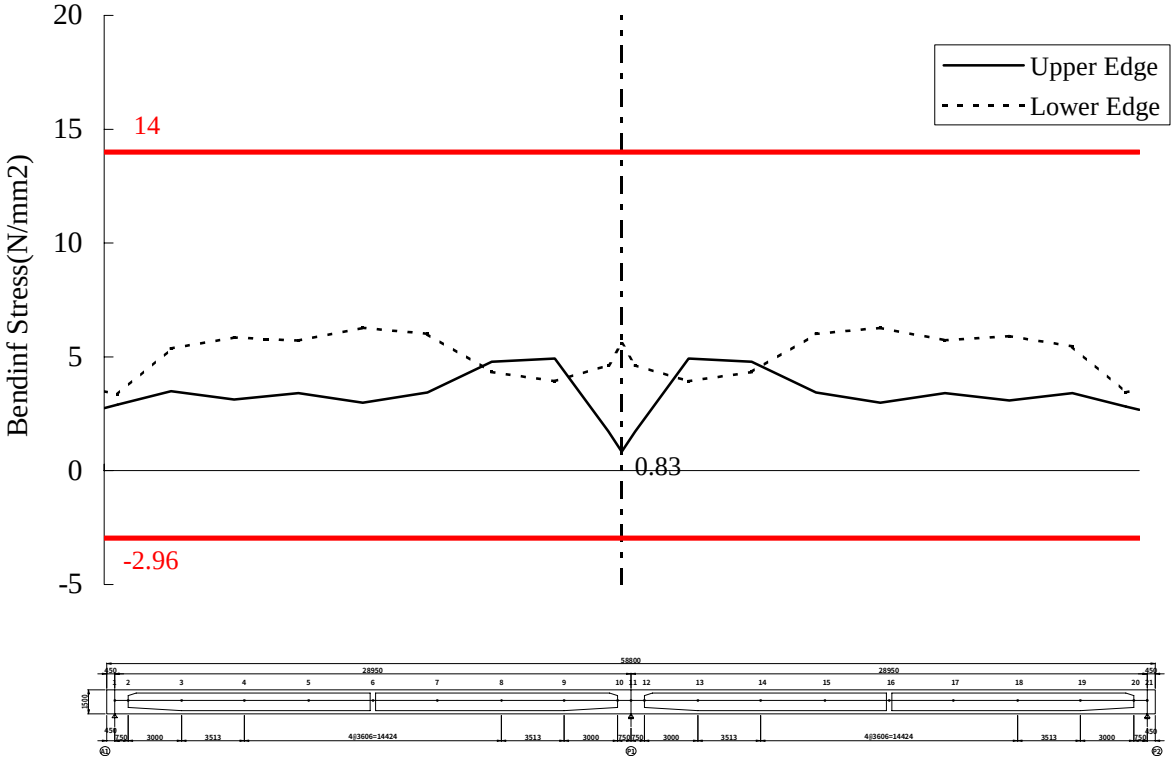


2.6.2 Bending Stress Diagram

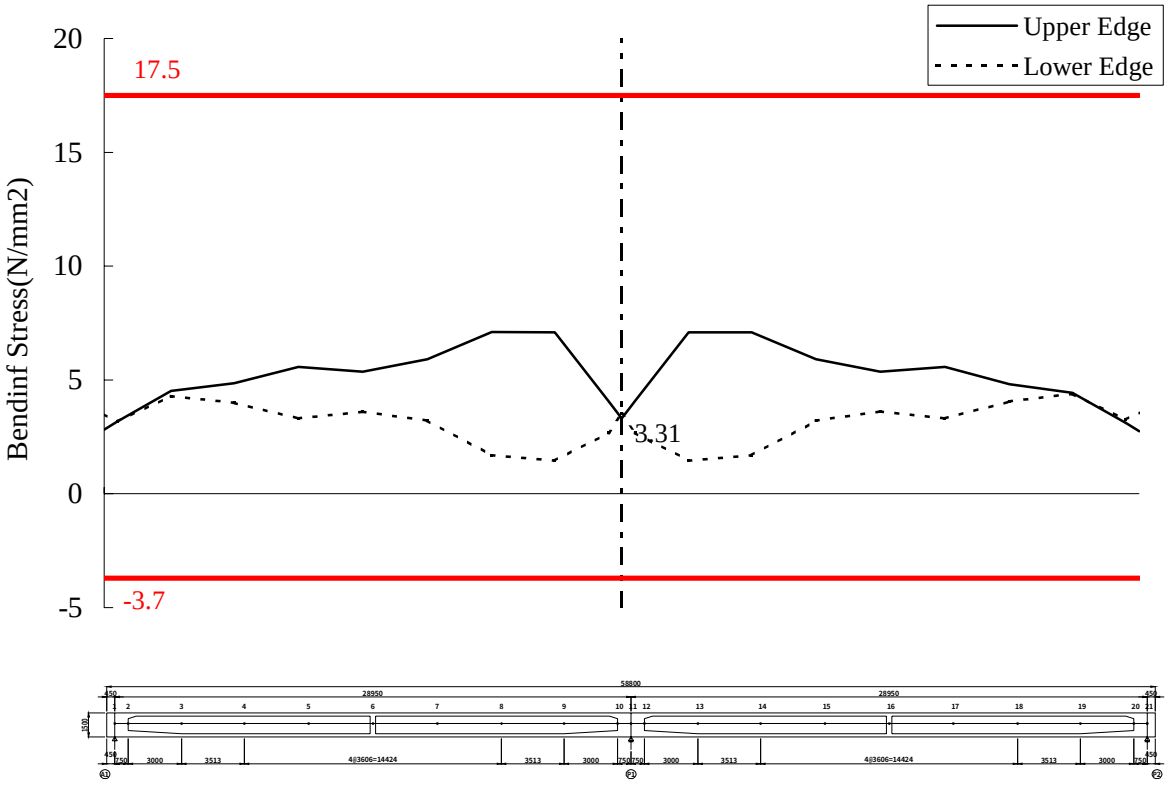
Group-I (D+Lmax)



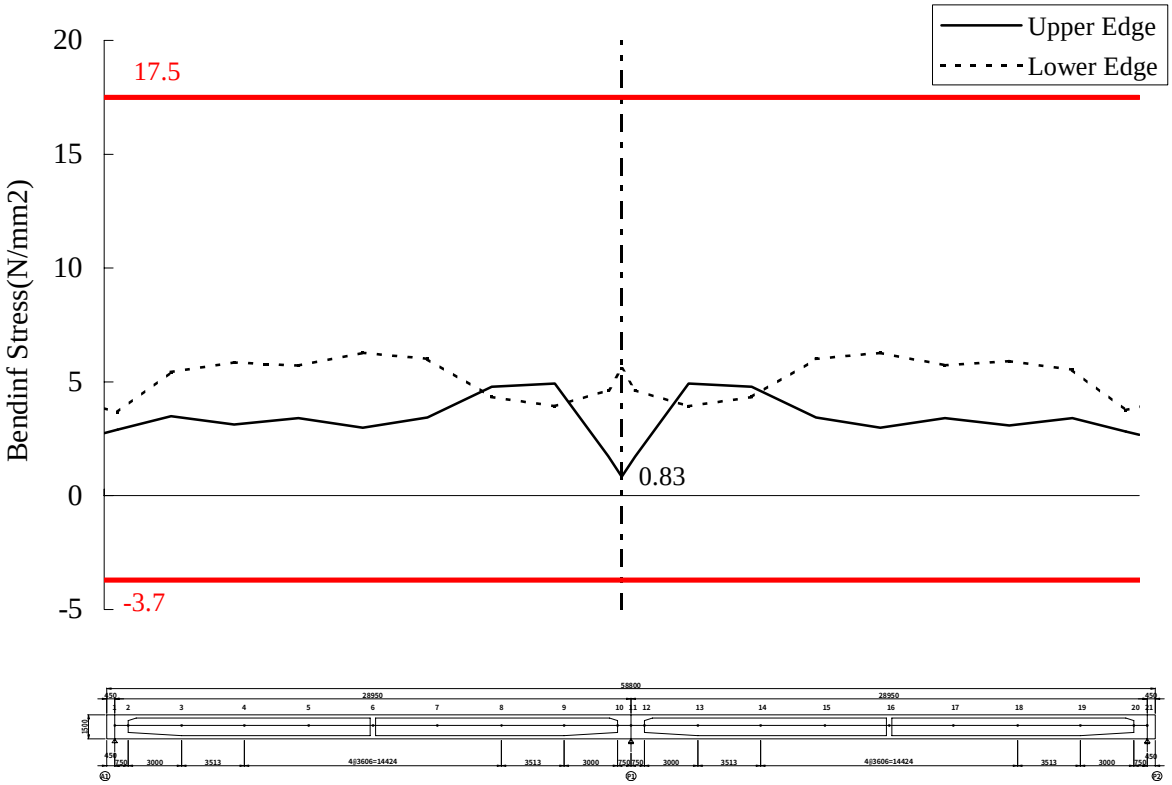
Group-I (D+Lmin)



Group-IV (D+Lmax+T)



Group-IV (D+Lmin+T)



2.7 Load Factor Design

2.7.1 Checking Flexural Strength

Group-I : D+L , Group-IV : D+L+T

Member No.	Combination Group		Factored Force		Flexural Strength φMn(kN.m)	φMn / Mu	Neutral Axis (cm)
			Nu(kN)	Mu(kN.m)			
1-i	Group-I	Mmax	0.0	-34.7	-34790.8	999.99	21.2
		Mmin	0.0	-34.7	-34790.8	999.99	21.2
	Group-IV	Mmax	0.0	-34.7	-34790.8	999.99	21.2
		Mmin	0.0	-34.7	-34790.8	999.99	21.2
1-j	Group-I	Mmax	0.0	4214.0	44318.3	10.52	16.7
		Mmin	0.0	2627.1	44318.3	16.87	16.7
	Group-IV	Mmax	0.0	3648.9	44318.3	12.15	16.7
		Mmin	0.0	2698.2	44318.3	16.43	16.7
2-i	Group-I	Mmax	0.0	4214.0	44318.3	10.52	16.7
		Mmin	0.0	2627.1	44318.3	16.87	16.7
	Group-IV	Mmax	0.0	3648.9	44318.3	12.15	16.7
		Mmin	0.0	2698.2	44318.3	16.43	16.7
2-j	Group-I	Mmax	0.0	17868.4	54884.8	3.07	16.7
		Mmin	0.0	11005.9	54884.8	4.99	16.7
	Group-IV	Mmax	0.0	15472.5	54884.8	3.55	16.7
		Mmin	0.0	11361.3	54884.8	4.83	16.7
3-i	Group-I	Mmax	0.0	17868.4	54884.8	3.07	16.7
		Mmin	0.0	11005.9	54884.8	4.99	16.7
	Group-IV	Mmax	0.0	15472.5	54884.8	3.55	16.7
		Mmin	0.0	11361.3	54884.8	4.83	16.7
3-j	Group-I	Mmax	0.0	28230.4	65635.3	2.32	16.7
		Mmin	0.0	16916.6	65635.3	3.88	16.7
	Group-IV	Mmax	0.0	24382.9	65635.3	2.69	16.7
		Mmin	0.0	17605.0	65635.3	3.73	16.7
4-i	Group-I	Mmax	0.0	28230.4	65635.3	2.32	16.7
		Mmin	0.0	16916.6	65635.3	3.88	16.7
	Group-IV	Mmax	0.0	24382.9	65635.3	2.69	16.7
		Mmin	0.0	17605.0	65635.3	3.73	16.7
4-j	Group-I	Mmax	0.0	32537.1	66819.9	2.05	16.7
		Mmin	0.0	18835.0	66819.9	3.55	16.7
	Group-IV	Mmax	0.0	28073.8	66819.9	2.38	16.7
		Mmin	0.0	19865.2	66819.9	3.36	16.7
5-i	Group-I	Mmax	0.0	32537.1	66819.9	2.05	16.7
		Mmin	0.0	18835.0	66819.9	3.55	16.7
	Group-IV	Mmax	0.0	28073.8	66819.9	2.38	16.7
		Mmin	0.0	19865.2	66819.9	3.36	16.7
5-j	Group-I	Mmax	0.0	30659.3	66819.9	2.18	16.7
		Mmin	0.0	16516.5	66819.9	4.05	16.7
	Group-IV	Mmax	0.0	26361.1	66819.9	2.53	16.7
		Mmin	0.0	17888.5	66819.9	3.74	16.7
6-i	Group-I	Mmax	0.0	30659.3	66819.9	2.18	16.7
		Mmin	0.0	16516.5	66819.9	4.05	16.7
	Group-IV	Mmax	0.0	26361.1	66819.9	2.53	16.7
		Mmin	0.0	17888.5	66819.9	3.74	16.7

Group-I : D+L , Group-IV : D+L+T

Member No.	Combination Group		Factored Force		Flexural Strength φMn(kN.m)	φMn / Mu	Neutral Axis (cm)
			Nu(kN)	Mu(kN.m)			
6-j	Group-I	Mmax	0.0	23355.3	55710.4	2.39	16.7
		Mmin	0.0	9703.9	55710.4	5.74	16.7
	Group-IV	Mmax	0.0	19596.0	55710.4	2.84	16.7
		Mmin	0.0	11417.7	55710.4	4.88	16.7
7-i	Group-I	Mmax	0.0	23355.3	55710.4	2.39	16.7
		Mmin	0.0	9703.9	55710.4	5.74	16.7
	Group-IV	Mmax	0.0	19596.0	55710.4	2.84	16.7
		Mmin	0.0	11417.7	55710.4	4.88	16.7
7-j	Group-I	Mmax	0.0	9885.1	33752.8	3.41	16.6
		Mmin	0.0	-1333.9	-43023.5	32.25	22.1
	Group-IV	Mmax	0.0	7442.7	33752.8	4.54	16.6
		Mmin	0.0	721.7	33752.8	46.77	16.6
8-i	Group-I	Mmax	0.0	9885.1	33752.8	3.41	16.6
		Mmin	0.0	-1333.9	-43023.5	32.25	22.1
	Group-IV	Mmax	0.0	7442.7	33752.8	4.54	16.6
		Mmin	0.0	721.7	33752.8	46.77	16.6
8-j	Group-I	Mmax	0.0	-8196.2	-64509.9	7.87	22.3
		Mmin	0.0	-17186.1	-64509.9	3.75	22.3
	Group-IV	Mmax	0.0	-9040.7	-64509.9	7.14	22.3
		Mmin	0.0	-14426.4	-64509.9	4.47	22.3
9-i	Group-I	Mmax	0.0	-8196.2	-64509.9	7.87	22.3
		Mmin	0.0	-17186.1	-64509.9	3.75	22.3
	Group-IV	Mmax	0.0	-9040.7	-64509.9	7.14	22.3
		Mmin	0.0	-14426.4	-64509.9	4.47	22.3
9-j	Group-I	Mmax	0.0	-25175.6	-69027.0	2.74	21.9
		Mmin	0.0	-35586.3	-69027.0	1.94	21.9
	Group-IV	Mmax	0.0	-25267.4	-69027.0	2.73	21.9
		Mmin	0.0	-31504.2	-69027.0	2.19	21.9
10-i	Group-I	Mmax	0.0	-25175.6	-69027.0	2.74	21.9
		Mmin	0.0	-35586.3	-69027.0	1.94	21.9
	Group-IV	Mmax	0.0	-25267.4	-69027.0	2.73	21.9
		Mmin	0.0	-31504.2	-69027.0	2.19	21.9
10-j	Group-I	Mmax	0.0	-29729.4	-69027.0	2.32	21.9
		Mmin	0.0	-40936.9	-69027.0	1.69	21.9
	Group-IV	Mmax	0.0	-29729.4	-69027.0	2.32	21.9
		Mmin	0.0	-36443.6	-69027.0	1.89	21.9
11-i	Group-I	Mmax	0.0	-29729.4	-69027.0	2.32	21.9
		Mmin	0.0	-40936.9	-69027.0	1.69	21.9
	Group-IV	Mmax	0.0	-29729.4	-69027.0	2.32	21.9
		Mmin	0.0	-36443.6	-69027.0	1.89	21.9
11-j	Group-I	Mmax	0.0	-25175.6	-69027.0	2.74	21.9
		Mmin	0.0	-35586.3	-69027.0	1.94	21.9
	Group-IV	Mmax	0.0	-25267.4	-69027.0	2.73	21.9
		Mmin	0.0	-31504.2	-69027.0	2.19	21.9
12-i	Group-I	Mmax	0.0	-25175.6	-69027.0	2.74	21.9
		Mmin	0.0	-35586.3	-69027.0	1.94	21.9
	Group-IV	Mmax	0.0	-25267.4	-69027.0	2.73	21.9
		Mmin	0.0	-31504.2	-69027.0	2.19	21.9

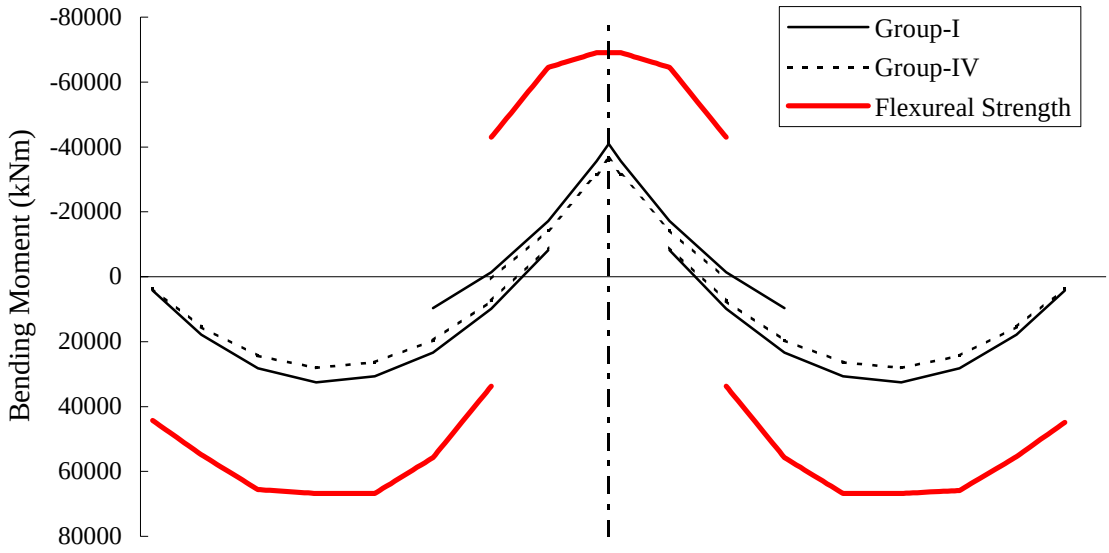
Group-I : D+L , Group-IV : D+L+T

Member No.	Combination Group		Factored Force		Flexural Strength	φMn / Mu	Neutral Axis
			Nu(kN)	Mu(kN.m)	φMn(kN.m)		(cm)
12-j	Group-I	Mmax	0.0	-8196.2	-64509.9	7.87	22.3
		Mmin	0.0	-17186.1	-64509.9	3.75	22.3
	Group-IV	Mmax	0.0	-9040.8	-64509.9	7.14	22.3
		Mmin	0.0	-14426.4	-64509.9	4.47	22.3
13-i	Group-I	Mmax	0.0	-8196.2	-64509.9	7.87	22.3
		Mmin	0.0	-17186.1	-64509.9	3.75	22.3
	Group-IV	Mmax	0.0	-9040.8	-64509.9	7.14	22.3
		Mmin	0.0	-14426.4	-64509.9	4.47	22.3
13-j	Group-I	Mmax	0.0	9885.0	33752.8	3.41	16.6
		Mmin	0.0	-1333.9	-43023.5	32.25	22.1
	Group-IV	Mmax	0.0	7442.7	33752.8	4.54	16.6
		Mmin	0.0	721.6	33752.8	46.77	16.6
14-i	Group-I	Mmax	0.0	9885.0	33752.8	3.41	16.6
		Mmin	0.0	-1333.9	-43023.5	32.25	22.1
	Group-IV	Mmax	0.0	7442.7	33752.8	4.54	16.6
		Mmin	0.0	721.6	33752.8	46.77	16.6
14-j	Group-I	Mmax	0.0	23355.3	55710.4	2.39	16.7
		Mmin	0.0	9703.9	55710.4	5.74	16.7
	Group-IV	Mmax	0.0	19596.0	55710.4	2.84	16.7
		Mmin	0.0	11417.7	55710.4	4.88	16.7
15-i	Group-I	Mmax	0.0	23355.3	55710.4	2.39	16.7
		Mmin	0.0	9703.9	55710.4	5.74	16.7
	Group-IV	Mmax	0.0	19596.0	55710.4	2.84	16.7
		Mmin	0.0	11417.7	55710.4	4.88	16.7
15-j	Group-I	Mmax	0.0	30659.2	66819.9	2.18	16.7
		Mmin	0.0	16516.5	66819.9	4.05	16.7
	Group-IV	Mmax	0.0	26361.1	66819.9	2.53	16.7
		Mmin	0.0	17888.5	66819.9	3.74	16.7
16-i	Group-I	Mmax	0.0	30659.2	66819.9	2.18	16.7
		Mmin	0.0	16516.5	66819.9	4.05	16.7
	Group-IV	Mmax	0.0	26361.1	66819.9	2.53	16.7
		Mmin	0.0	17888.5	66819.9	3.74	16.7
16-j	Group-I	Mmax	0.0	32537.1	66819.9	2.05	16.7
		Mmin	0.0	18835.0	66819.9	3.55	16.7
	Group-IV	Mmax	0.0	28073.8	66819.9	2.38	16.7
		Mmin	0.0	19865.2	66819.9	3.36	16.7
17-i	Group-I	Mmax	0.0	32537.1	66819.9	2.05	16.7
		Mmin	0.0	18835.0	66819.9	3.55	16.7
	Group-IV	Mmax	0.0	28073.8	66819.9	2.38	16.7
		Mmin	0.0	19865.2	66819.9	3.36	16.7
17-j	Group-I	Mmax	0.0	28229.2	65937.3	2.34	16.7
		Mmin	0.0	16915.3	65937.3	3.9	16.7
	Group-IV	Mmax	0.0	24381.6	65937.3	2.7	16.7
		Mmin	0.0	17603.7	65937.3	3.75	16.7
18-i	Group-I	Mmax	0.0	28229.2	65937.3	2.34	16.7
		Mmin	0.0	16915.3	65937.3	3.9	16.7
	Group-IV	Mmax	0.0	24381.6	65937.3	2.7	16.7
		Mmin	0.0	17603.7	65937.3	3.75	16.7

Group-I : D+L , Group-IV : D+L+T

Member No.	Combination Group		Factored Force		Flexural Strength	φMn / Mu	Neutral Axis
			Nu(kN)	Mu(kN.m)	φMn(kN.m)		(cm)
18-j	Group-I	Mmax	0.0	17867.6	55413.1	3.1	16.7
		Mmin	0.0	11005.1	55413.1	5.04	16.7
	Group-IV	Mmax	0.0	15471.7	55413.1	3.58	16.7
		Mmin	0.0	11360.5	55413.1	4.88	16.7
19-i	Group-I	Mmax	0.0	17867.6	55413.1	3.1	16.7
		Mmin	0.0	11005.1	55413.1	5.04	16.7
	Group-IV	Mmax	0.0	15471.7	55413.1	3.58	16.7
		Mmin	0.0	11360.5	55413.1	4.88	16.7
19-j	Group-I	Mmax	0.0	4214.0	44846.7	10.64	16.7
		Mmin	0.0	2627.1	44846.7	17.07	16.7
	Group-IV	Mmax	0.0	3648.8	44846.7	12.29	16.7
		Mmin	0.0	2698.2	44846.7	16.62	16.7
20-i	Group-I	Mmax	0.0	4214.0	44846.7	10.64	16.7
		Mmin	0.0	2627.1	44846.7	17.07	16.7
	Group-IV	Mmax	0.0	3648.8	44846.7	12.29	16.7
		Mmin	0.0	2698.2	44846.7	16.62	16.7
20-j	Group-I	Mmax	0.0	-34.7	-34261.4	987.39	21.2
		Mmin	0.0	-34.7	-34261.4	987.39	21.2
	Group-IV	Mmax	0.0	-34.7	-34261.4	987.39	21.2
		Mmin	0.0	-34.7	-34261.4	987.39	21.2

Bending Stress Diagram



2.7.3 Checking Shear Reinforcement

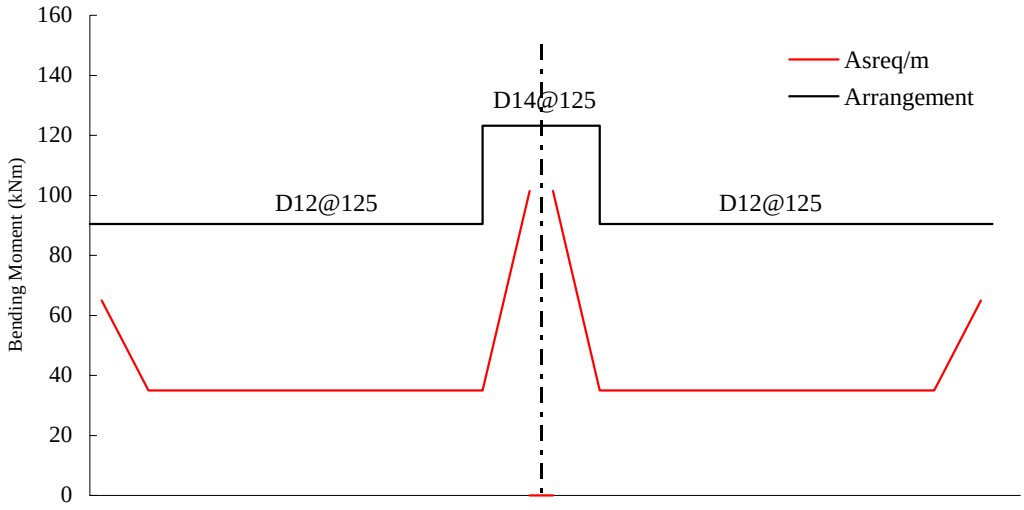
Group-I : D+L , Group-IV : D+L+T

Member No.	Combination Group	Factored Force			Sh (kN)	Sc (kN)	fy (N/mm^2)	Awmin (cm^2)	Awreq (cm^2)
		S(kN)	N(kN)	M(kN.m)					
2-i	Group-I	5498	0	4209	5498	4583	420	65.00	0.00
	Group-IV	4748	0	3646	4748	4583	420	65.00	0.00
2-j	Group-I	4043	0	17704	4043	2468	420	35.00	0.00
	Group-IV	3422	0	15374	3422	2468	420	35.00	0.00
3-i	Group-I	4043	0	17704	4043	2468	420	35.00	0.00
	Group-IV	3422	0	15374	3422	2468	420	35.00	0.00
3-j	Group-I	2548	0	27325	2548	2468	420	35.00	0.00
	Group-IV	2068	0	23841	2068	2468	420	35.00	0.00
4-i	Group-I	2548	0	27325	2548	2468	420	35.00	0.00
	Group-IV	2068	0	23841	2068	2468	420	35.00	0.00
4-j	Group-I	1050	0	30837	1050	2468	420	35.00	0.00
	Group-IV	702	0	27055	702	2468	420	35.00	0.00
5-i	Group-I	1050	0	30837	1050	2468	420	35.00	0.00
	Group-IV	702	0	27055	702	2468	420	35.00	0.00
5-j	Group-I	-410	0	28323	-410	2468	420	35.00	0.00
	Group-IV	-642	0	24962	-642	2468	420	35.00	0.00
6-i	Group-I	-503	0	28323	-503	2468	420	35.00	0.00
	Group-IV	-735	0	24962	-735	2468	420	35.00	0.00
6-j	Group-I	-1897	0	20350	-1897	2468	420	35.00	0.00
	Group-IV	-2038	0	17796	-2038	2468	420	35.00	0.00
7-i	Group-I	-1897	0	20350	-1897	2468	420	35.00	0.00
	Group-IV	-2038	0	17796	-2038	2468	420	35.00	0.00
7-j	Group-I	-3234	0	7795	-3234	2468	420	35.00	0.00
	Group-IV	-3308	0	6190	-3308	2468	420	35.00	0.00
8-i	Group-I	-3234	0	7795	-3234	2468	420	35.00	0.00
	Group-IV	-3308	0	6190	-3308	2468	420	35.00	0.00
8-j	Group-I	-6566	0	10813	-6566	2468	420	35.00	11.11
	Group-IV	-4519	0	-9222	-4519	2468	420	35.00	0.00
9-i	Group-I	-6566	0	10813	-6566	2468	420	35.00	11.11
	Group-IV	-4519	0	-9222	-4519	2468	420	35.00	0.00
9-j	Group-I	-7916	0	30249	-7916	4583	420	65.00	60.84
	Group-IV	-7019	0	28307	-7019	4583	420	65.00	44.48
12-i	Group-I	7916	0	30249	7916	4583	420	65.00	60.84
	Group-IV	7019	0	28307	7019	4583	420	65.00	44.48
12-j	Group-I	6566	0	10813	6566	2468	420	35.00	11.13
	Group-IV	5762	0	10609	5762	2468	420	35.00	0.00
13-i	Group-I	6566	0	10813	6566	2468	420	35.00	11.13
	Group-IV	5762	0	10609	5762	2468	420	35.00	0.00
13-j	Group-I	5140	0	7049	5140	2468	420	35.00	0.00
	Group-IV	4450	0	5744	4450	2468	420	35.00	0.00
14-i	Group-I	5140	0	7049	5140	2468	420	35.00	0.00
	Group-IV	4450	0	5744	4450	2468	420	35.00	0.00
14-j	Group-I	3668	0	19521	3668	2468	420	35.00	0.00
	Group-IV	3099	0	17299	3099	2468	420	35.00	0.00
15-i	Group-I	3668	0	19521	3668	2468	420	35.00	0.00
	Group-IV	3099	0	17299	3099	2468	420	35.00	0.00
15-j	Group-I	2190	0	25981	2190	2468	420	35.00	0.00
	Group-IV	1746	0	23559	1746	2468	420	35.00	0.00
16-i	Group-I	2097	0	25981	2097	2468	420	35.00	0.00
	Group-IV	1653	0	23559	1653	2468	420	35.00	0.00

Group-I : D+L , Group-IV : D+L+T

Member No.	Combination Group	Factored Force			Sh (kN)	Sc (kN)	fy (N/mm^2)	Awmin (cm^2)	Awreq (cm^2)
		S(kN)	N(kN)	M(kN.m)					
16-j	Group-I	647	0	26821	647	2468	420	35.00	0.00
	Group-IV	315	0	24649	315	2468	420	35.00	0.00
17-i	Group-I	647	0	26821	647	2468	420	35.00	0.00
	Group-IV	315	0	24649	315	2468	420	35.00	0.00
17-j	Group-I	-777	0	22676	-777	2468	420	35.00	0.00
	Group-IV	-1007	0	21055	-1007	2468	420	35.00	0.00
18-i	Group-I	-777	0	22676	-777	2468	420	35.00	0.00
	Group-IV	-1007	0	21055	-1007	2468	420	35.00	0.00
18-j	Group-I	-2128	0	14089	-2128	2468	420	35.00	0.00
	Group-IV	-2274	0	13208	-2274	2468	420	35.00	0.00
19-i	Group-I	-2128	0	14089	-2128	2468	420	35.00	0.00
	Group-IV	-2274	0	13208	-2274	2468	420	35.00	0.00
19-j	Group-I	-3380	0	3069	-3380	4583	420	65.00	0.00
	Group-IV	-3479	0	2963	-3479	4583	420	65.00	0.00

2.7.4 Arrangement Shear Reinforcement (Stirrup)



3. ESIGN CALCULATION OF CROSS SECTION

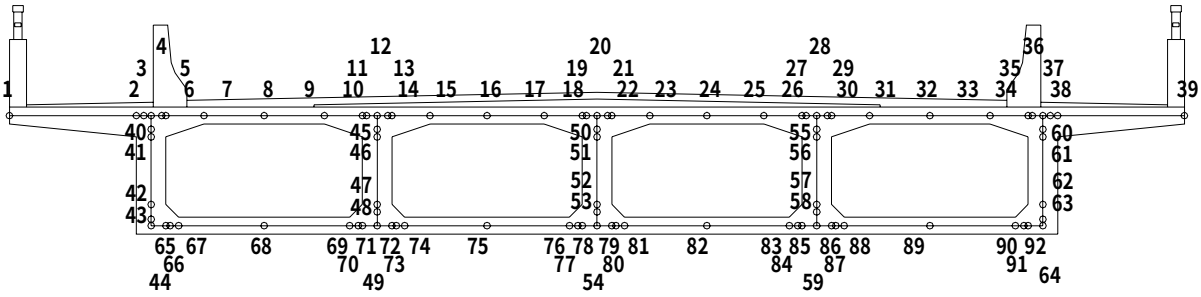
3.1 General of Analysis

3.1.1 Analysis model

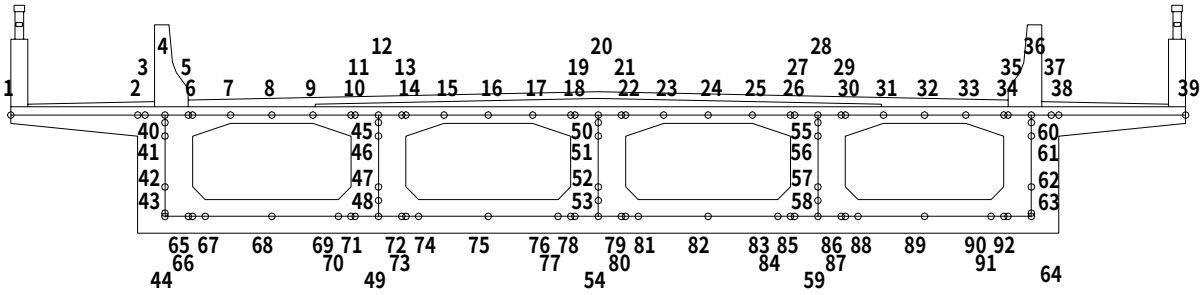
Cross section design should be analyzed by plain flame method.

Modeling of each member, plain flame configure as centurial axis of each member. Analysis model is shown as following figure.

a. Intermediate Span



b. Girder End



3.1.2 Loadings

a. Unit weight

Self-weight of girder and wearing surface load should be considered as distribution load.

Unit weight for calculate load intensity which should be taken as following value.

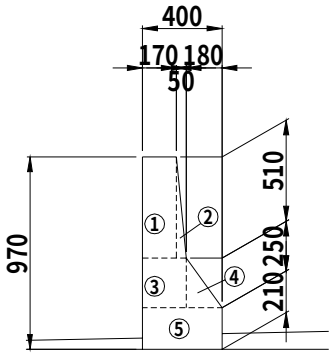
Reinforced Concrete	24.5 kN/m^3
Leveling Concrete	23.0 kN/m^3
Asphalt Pavement	22.5 kN/m^3

b. Girder self-weight

Load of girder self-weigh is calculated automatically by design calculation software. Load intensity is collected from section area of each member.

c. Wearing surface

Concrete barrier for carriage way

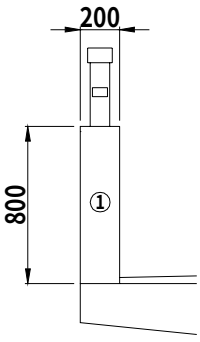


	A	X	AX
①	0.170×0.510×1.0=0.087	0.085	0.007
②	0.050×0.510×0.5=0.013	0.187	0.002
③	0.220×0.250×1.0=0.055	0.110	0.006
④	0.180×0.250×0.5=0.023	0.280	0.006
⑤	0.400×0.210×1.0=0.084	0.200	0.017
計	0.261		0.038

X = ∑AX/∑A = 0.146 m

P = 0.261 × 24.5 = 6.393 kN/m

Concrete barrier for foot way



	A	X	AX
①	0.200×0.800×1.0=0.160	0.100	0.01600
計	0.160		0.01600

X = ∑AX/∑A = 0.1 m

P = 0.160 × 24.5 = 3.92 kN/m

M = 0.100 × 3.920 = 0.392 kN・m/m

Steel railing for foot way barrier

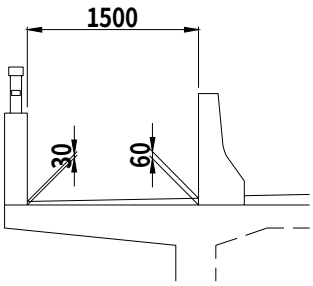
W= 0.30 kN/m

Asphalt Pavement

Foot way(t = 30mm)

W = 0.03 × 22.5 = 0.675 kN/m 2

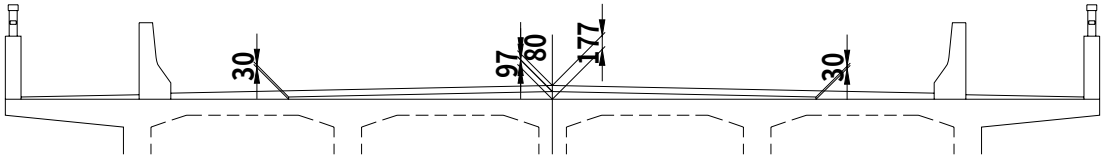
W = 0.06 × 22.5= 1.35 kN/m 2



Carriage way(t = 80mm)

W= 0.080 x 22.5 = 1.80 kN/m^2

Leveling concrete



W = 0.03 × 23.0 = 0.69 kN/m 2

W = 0.097 × 23.0 = 2.231 kN/m 2

d. Temperature difference

Temperature difference between top fiber of girder to lower fiber of girder should be taken as following value.

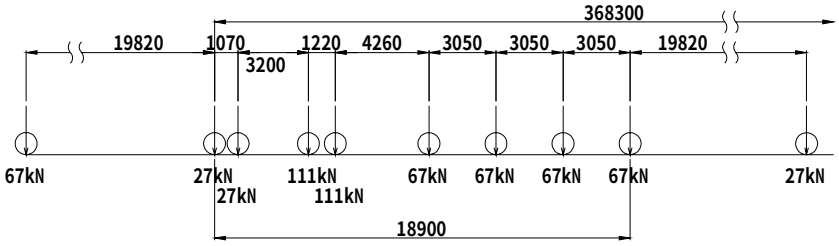
Temperature difference T= 5.0 Degree Celsius

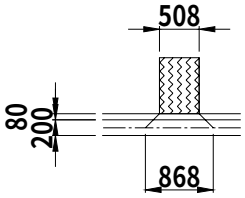
e. Live Load

Load Intensity due to Live Load

For section design, live load is according to Class A Loading. And load should be taken from most heavy axle load of Class A Loading. So that reason, loading for section design is taken as 111kN axle load.

Loading for plain frame model, which act distributed from road surface to centurial axis of slab for 45 degree.





Loaded width of wheel load	0.508m
Distance from surface to centurial axis of slab	0.180m
Distribution width at centurial axis of slab	0.868m

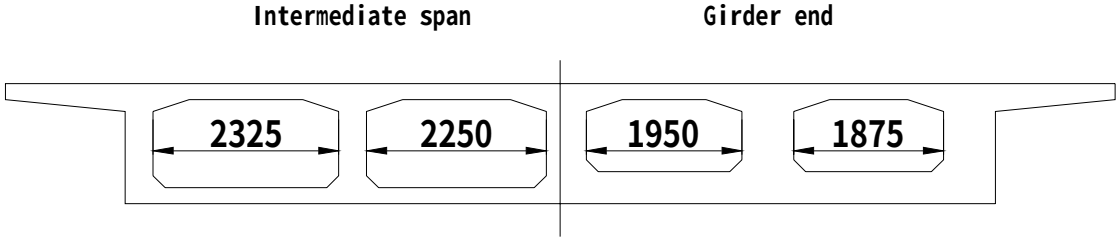
Loading at centurial axis of slab

w = 111 / 2 / 0.868 = 63.940kN/m (half side of axle load)

Impact coefficient

i = 15.24/(L+38)

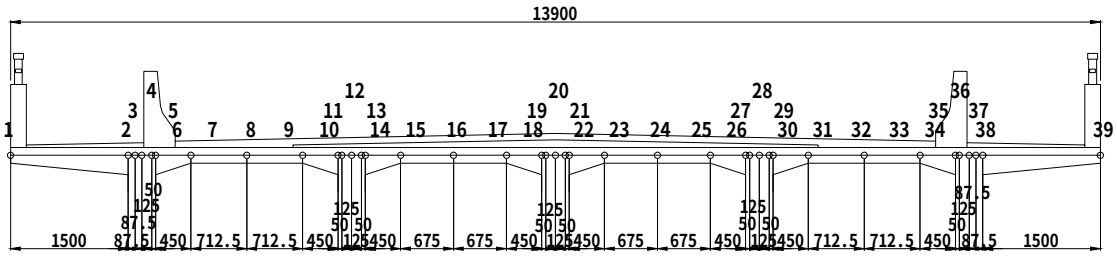
Intermediate span	L = 2.250m , i = 0.379
Girder end	L = 1.875m , i = 0.382



Footway Live Load

$q = 2.87\ kN/m^2$

3.1.3 Calculation Result



Service Load Design

		1-j	6-i	8-i	9-j	14-i
Critical Load Group		Group-I	Group-IV	Group-I	Group-I	Group-I
Bending Moment	kN·m	-15.20	-47.70	13.10	-32.60	-34.70
Axial Force	kN	0.00	12.40	-5.50	-5.50	-3.60
Concrete Stress σc	N/mm^2	1.03	3.25	2.68	2.20	2.34
Reinforcement Stress σs	N/mm^2	36.76	111.06	61.46	80.44	84.83
Required reinforcement	cm^2	6.70	18.20	10.80	15.10	16.00
Reinforcement Arrangement		D16ctc125	D16ctc125	D16ctc125	D16ctc125	D16ctc125
		D16ctc125	D16ctc125	D16ctc125	D16ctc125	D16ctc125

		15-j	17-j	22-i	23-j	24-i
Load Combination		Group-I	Group-I	Group-I	Group-I	Group-I
Bending Moment	kN·m	14.00	-34.90	-33.80	13.40	13.40
Axial Force	kN	-3.60	-3.60	-5.10	-5.10	-5.10
Concrete Stress σc	N/mm^2	2.88	2.36	2.28	2.76	2.76
Reinforcement Stress σs	N/mm^2	65.24	85.40	83.12	63.01	63.01
Required reinforcement	cm^2	11.50	16.10	15.60	11.10	11.10
Reinforcement Arrangement		D16ctc125	D16ctc125	D16ctc125	D16ctc125	D16ctc125
		D16ctc125	D16ctc125	D16ctc125	D16ctc125	D16ctc125

		25-j	30-i	31-j	33-j	38-i
Load Combination		Group-I	Group-I	Group-I	Group-IV	Group-I
Bending Moment	kN·m	-33.10	-32.00	13.10	-47.90	-15.90
Axial Force	kN	-5.10	-6.10	-6.10	11.90	0.00
Concrete Stress σc	N/mm^2	2.24	2.15	2.68	3.26	1.08
Reinforcement Stress σs	N/mm^2	81.59	79.04	61.61	111.70	38.35
Required reinforcement	cm^2	15.30	14.80	10.80	18.30	7.00
Reinforcement Arrangement		D16ctc125	D16ctc125	D16ctc125	D16ctc125	D16ctc125
		D16ctc125	D16ctc125	D16ctc125	D16ctc125	D16ctc125

4. DESIGN CALCULATION OF CROSS BEAM

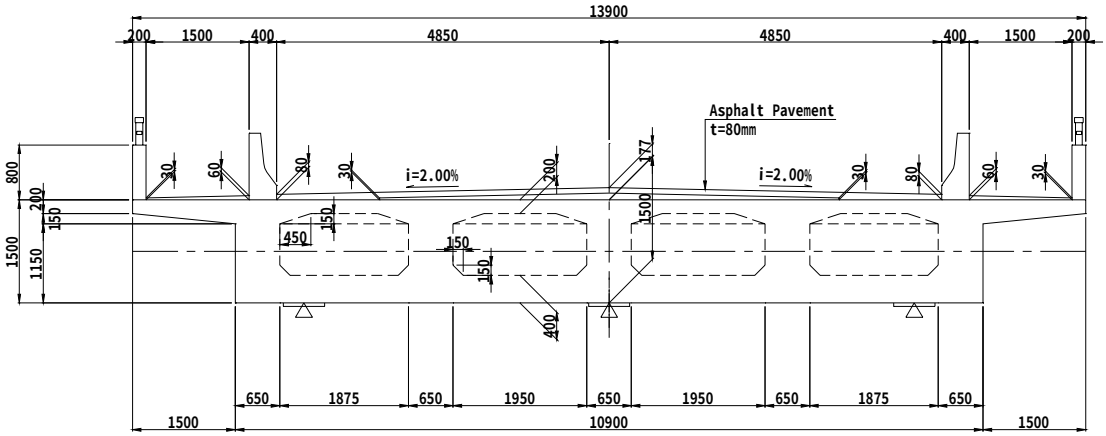
4.1 Design of End Cross Beam

4.1.1 Analysis Model

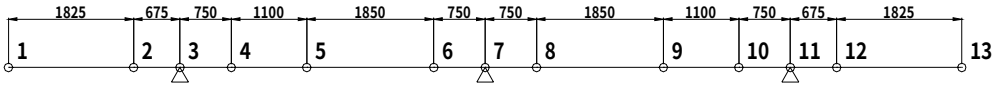
Design calculation for cross beam analysis model should be considered two type of support condition is apply for model.

Model-1 : Cross beam support by bearing and overlying load affect web as concentrate load

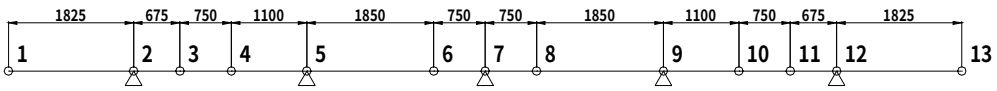
Model-2 : Cross beam support by web and overlying load affect as distribution load

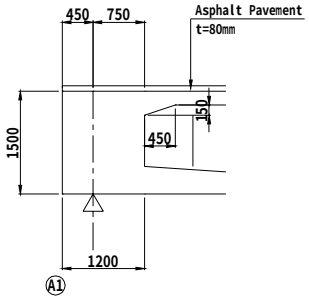


Support position considered as bearing position



Support position considered as center of web





d.Concrete barrier and steel railing

Concrete barrier for carriage way (Left side)

P = 1.906 × 6.393 = 12.185 (kN)

Concrete barrier for carriage way (Right side)

P = 1.906 × 6.393 = 12.185 (kN)

Concrete barrier for foot way (left side)

P = 1.906 × 3.920 = 7.472 (kN)

Concrete barrier for foot way (Right side)

P = 1.906 × 3.920 = 7.472 (kN)

Steel railing

P = 1.906 × 0.300 = 0.572 (kN) one side

Foot way live load (consider as concentrate load)

P = 1.906 × 4.305 = 8.205 (kN) one side

c. Outlying dead load diffuse from web

The posision of bearing assumed as support. The force due to outlying dead load diffuded from web, which consider as reaction force affect on web or distribution load affect on slab girder.

ΣRd = 3,363.075 (kN)

ΣWd = 751.577 (kN)

Concentrate load

Pd = (ΣRd — ΣWd) / nw

Distribution load

qd = (ΣRd — ΣWd) / B

where

ΣRd : Reaction force due to dead load calculated by overall bridge model

ΣWd : Dead load affect on effective width directory

nw : Nos of web = 5 nos

B : Slab girder width = 10.900 m

Pd = (3,363.075 - 751.577) × 1/5 = 522.300 (kN)

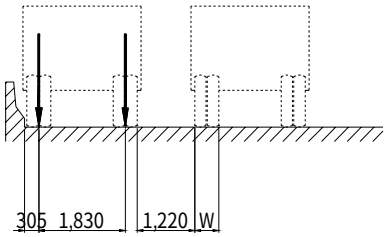
qd = (3,363.075 - 751.577) × 1/10.900 = 239.587 (kN/m)

2) Live Load

a.Class A Load affect on effective width

$$i = \frac{15.24}{38 + L} = \frac{15.24}{38 + 4.450} = 0.359$$

i : impact coefficient



Class of Loading	Axle Load	Ground Contact Area	
		B	W
	kN	mm	mm
A	111	254	508
	67	203	381
	27	152	203

b.Class A Loading affected beyond effective width

The posision of bearing assumed as support. The force due to outlying Class A Loading diffuded from web, which consider as reaction force affect on web or distribution load affect on slab girder.

$\Sigma Rl = 887.283$ (kN)

Concentrate load

$Pl = (\Sigma Rl - \Sigma Wl) / nw$

Distribution load

$ql = (\Sigma Rl - \Sigma Wl) / B$

where

ΣRl : Reaction force due to dead load calculated by overall bridge model

ΣWl : Dead load affect on effective width directory

nw : Nos of web = 5 nos

B : Slab girder width = 10.900 m

Class A Loading one lane

$P = (887.283 - 144.300 \times 2) / 5 = 119.737$ (kN)

$q = (887.283 - 144.300 \times 2) / 10.900 = 54.925$ (kN/m)

Class A Loading two lane

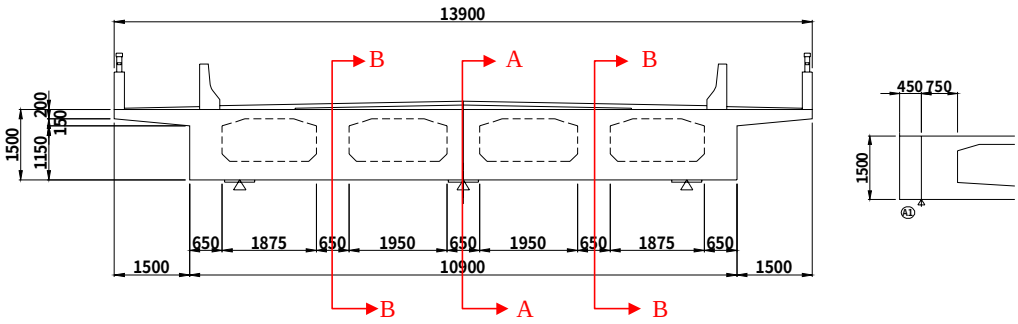
$P = (887.283 - 144.300 \times 4) / 5 = 62.017$ (kN)

$q = (887.283 - 144.300 \times 4) / 10.900 = 28.448$ (kN/m)

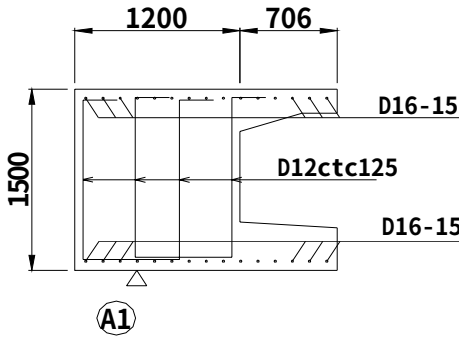
4.1.2 Calculation Result

End Cross Beam at A1

Section Profile



Reinforcement Arrangement



					Section-A (At Support)	Section-B (Mid Span)
Sectional Force	Bending Moment	Dead Load	D	(kN·m)	-631.10	328.09
		Live Load	L	(kN·m)	-221.96	225.58
	Shear Force	Dead Load	D	(kN)	-760.76	444.91
		Live Load	L	(kN)	341.52	162.38
Service Load Design	Group-I (D+L)	Design Moment		(kN·m)	-853.07	553.67
		Bar Arrangement		-	15-D16	15-D16
		Bending Stress	fc	(N/mm^2)	2.10	1.54
			fs	(N/mm^2)	133.57	132.04
		Allowable Stress	fca	(N/mm^2)	14.00	14.00
			fsa	(N/mm^2)	168.00	168.00
Load Factor Design	Group-I (D+L)	Factored Force	Mu	(kN·m)	-1302.3	916.2
			Su	(kN)	-247.5	930.9
		Flexural Strength	Mrs	(kN·m)	-2814.5	1861.7
			Mrs / Mu		2.16	2.03
		Shear Reinforcement	Asreq	(cm^2)	24.0	24.0
			As	(cm^2)	D12@125=36.2	D12@125=36.2

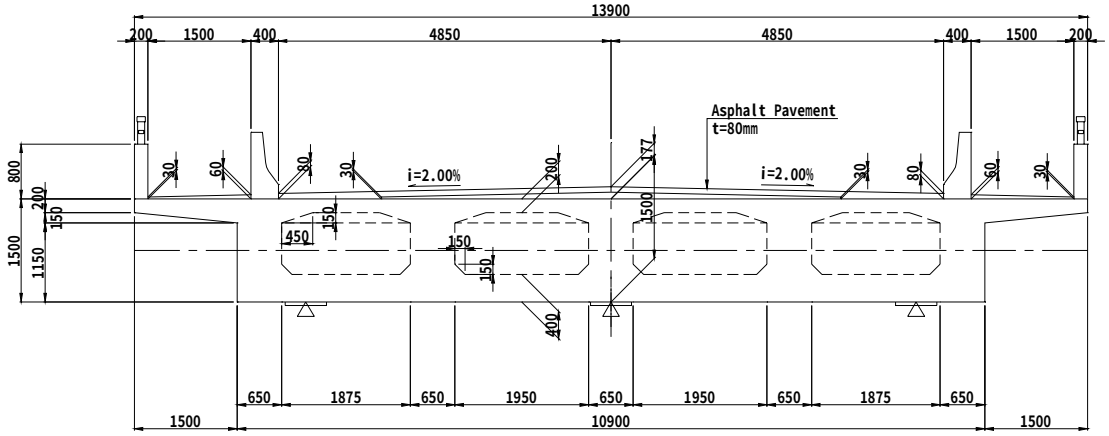
4.2 Design of Intermediate Supported Cross Beam

4.2.1 Analysis Model

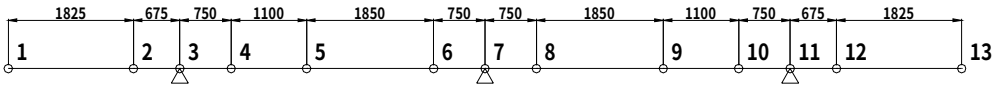
Design calculation for cross beam analysis model should be considered two type of support condition is apply for model.

Model-1 : Cross beam support by bearing and overlying load affect web as concentrate load

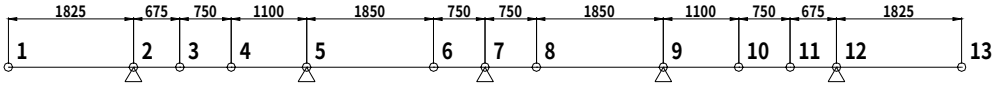
Model-2 : Cross beam support by web and overlying load affect as distribution load

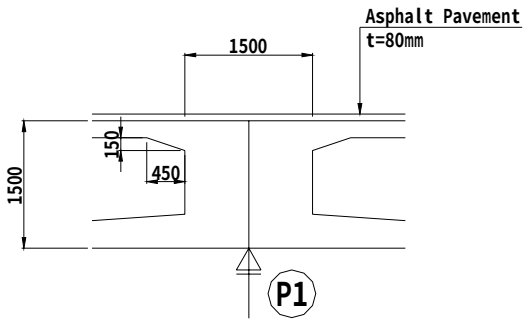


Support position considered as bearing position



Support position considered as center of web





(1) Effective section of cross beam

culation of effective width of cross beam should be calculated as following formula.

be= ds ＋ n × λ

be :Effective width of cross beam (m)
ds :Width of cross beam (m) = 1.500 m
n :for end cross beam : n = 1 , for intermediate cross beam : n = 2
λ :Effective width of compressive flange (m)
L :Span length = bearing spacing (4.450 m)
bs :Effective width of hunch (m)

λ = 4.450 × 1/8 + 0.150 = 0.706 (m)

be = 1.500 + 0.706 × 2 = 2.912 (m)

(2) Loadings

1) Dead Load

a.Self-weight and surfacing

Standard section of cross beam

A = 0.706 × 2 × (0.200 + 0.400) + 1.500 × 1.500
+ 1/2 × 0.45 × 0.15 - 1/2 × (0.40 - 0.353) ×0.706
= 3.132 (m2)

W = 3.132 × 24.5 = 76.734 (kN/m)

Base of cantilever slab

W = 2.912 × 0.350 × 24.5 = 24.970 (kN/m)

Tip of cantilever slab

W = 2.912 × 0.200 × 24.5 = 14.269 (kN/m)

b.Asphalt pavement

Carriage way

W = 2.912 × 0.080 × 22.5 = 5.242 (kN/m)

Foot way

W = 2.912 × 0.030 × 22.5 = 1.966 (kN/m)

W = 2.912 × 0.060 × 22.5 = 3.931 (kN/m)

c.Leveling concrete

W = 2.912 × 0.030 × 23.0 = 2.009 (kN/m)

W = 2.912 × 0.097 × 23.0 = 6.497 (kN/m)

d.Concrete barrier and steel railing

Concrete barrier for carriage way (Left side)

$P = 2.912 \times 6.393 = 18.616$ (kN)

Concrete barrier for carriage way (Right side)

$P = 2.912 \times 6.393 = 18.616$ (kN)

Concrete barrier for foot way (left side)

$P = 2.912 \times 3.920 = 11.415$ (kN)

Concrete barrier for foot way (Right side)

$P = 2.912 \times 3.920 = 11.415$ (kN)

Steel railing

$P = 2.912 \times 0.300 = 0.874$ (kN) one side

Foot way live load (consider as concentrate load)

$P = 2.912 \times 4.305 = 12.536$ (kN) one side

c. Outlying dead load diffuse from web

The posision of bearing assumed as support. The force due to outlying dead load diffuded from web, which consider as reaction force affect on web or distribution load affect on slab girder.

$\Sigma Rd = 9{,}476.671$ (kN)

$\Sigma Wd = 1{,}070.329$ (kN)

Concentrate load

$Pd = (\Sigma Rd - \Sigma Wd) / nw$

Distribution load

$qd = (\Sigma Rd - \Sigma Wd) / B$

where

ΣRd : Reaction force due to dead load calculated by overall bridge model

ΣWd : Dead load affect on effective width directory

nw : Nos of web = 5 nos

B : Slab girder width = 10.900 m

$Pd = (9{,}476.671 - 1{,}070.329) \times 1/5 = 1{,}681.268$ (kN)

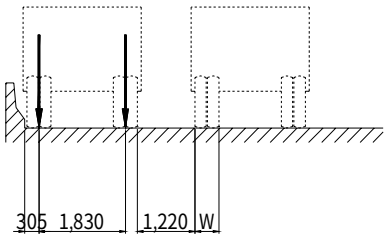
$qd = (9{,}476.671 - 1{,}070.329) \times 1/10.900 = 771.224$ (kN/m)

2) Live Load

a.Class A Load affect on effective width

$$i = \frac{15.24}{38 + L} = \frac{15.24}{38 + 4.450} = 0.359$$

i : impact coefficient



Class of Loading	Axle Load	Ground Contact Area	
		B	W
	kN	mm	mm
A	111	254	508
	67	203	381
	27	152	203

b.Class A Loading affected beyond effective width

The posision of bearing assumed as support. The force due to outlying Class A Loading diffuded from web, which consider as reaction force affect on web or distribution load affect on slab girder.

$\Sigma Rl = 1414.609$ (kN)

Concentrate load

$Pl = (\Sigma Rl - \Sigma Wl) / nw$

Distribution load

$ql = (\Sigma Rl - \Sigma Wl) / B$

where

ΣRl : Reaction force due to dead load calculated by overall bridge model

ΣWl : Dead load affect on effective width directory

nw : Nos of web = 5 nos

B : Slab girder width = 10.900 m

Class A Loading one lane

$P = (1,414.609 - 144.300 \times 2) / 5 = 225.202$ (kN)

$q = (1,414.609 - 144.300 \times 2) / 10.900 = 103.304$ (kN/m)

Class A Loading two lane

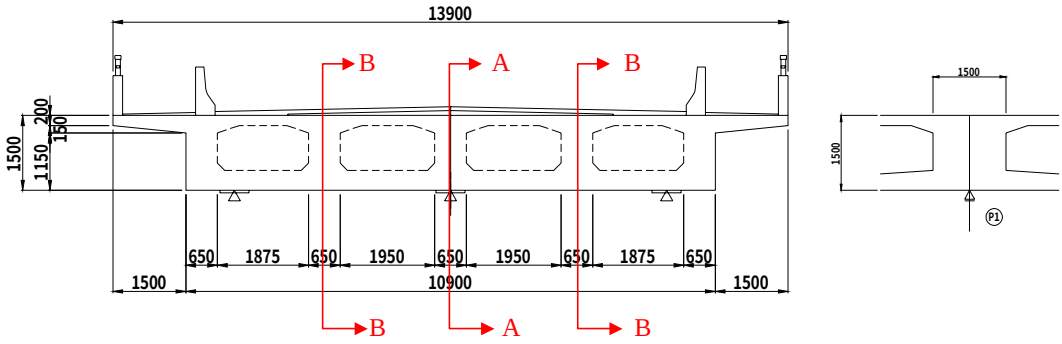
$P = (1,414.609 - 144.300 \times 4) / 5 = 167.482$ (kN)

$q = (1,414.609 - 144.300 \times 4) / 10.900 = 76.827$ (kN/m)

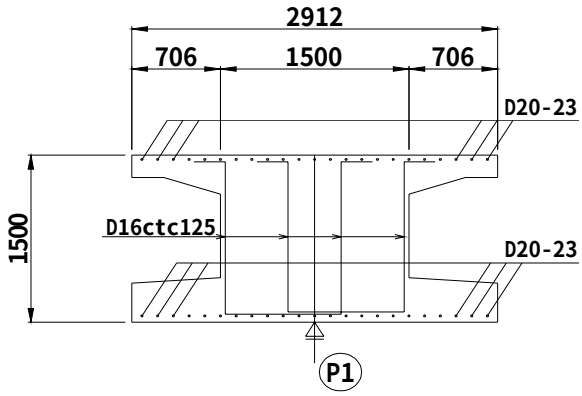
4.2.2 Calculation Result

Intermediate Cross Beam at P1

Section Profile



Reinforcement Arrangement



					Section-A (At Support)	Section-B (Mid Span)
Sectional Force	Bending Moment	Dead Load	D	(kN·m)	-1849.85	974.01
		Live Load	L	(kN·m)	-269.30	284.47
	Shear Force	Dead Load	D	(kN)	-2202.24	1292.01
		Live Load	L	(kN)	-277.97	231.54
Service Load Design	Group-I (D+L)	Design Moment		(kN·m)	-2119.15	1258.48
		Bar Arrangement		-	23-D20	23-D20
		Bending Stress	fc	(N/mm^2)	2.85	1.84
			fs	(N/mm^2)	151.64	126.24
		Allowable Stress	fca	(N/mm^2)	14.00	14.00
			fsa	(N/mm^2)	168.00	168.00
Load Factor Design	Group-I (D+L)	Factored Force	Mu	(kN·m)	-2989.5	1883.8
			Su	(kN)	-3466.4	2182.3
		Flexural Strength	Mrs	(kN·m)	-6173.6	4395.5
			Mrs / Mu		2.07	2.33
		Shear Reinforcement	Asreq	(cm^2/m)	58.4	44.4
			As	(cm^2/m)	D16@125=64.4	D16@125=64.4

Design Calculation of Substructure

1. DESIGN CONDITION

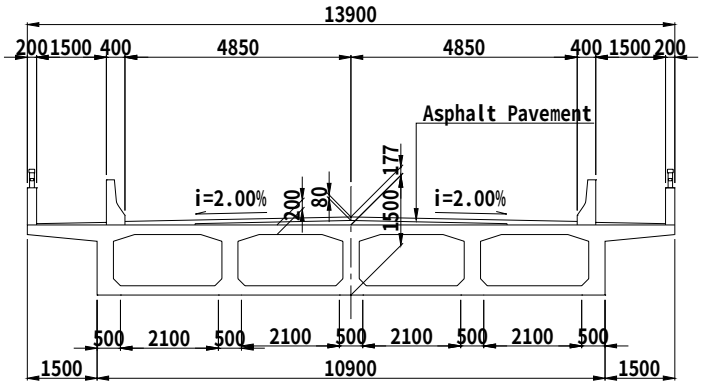
1.1 Design Criteria

Design criteria of East Side Approach Bridge shown as following.

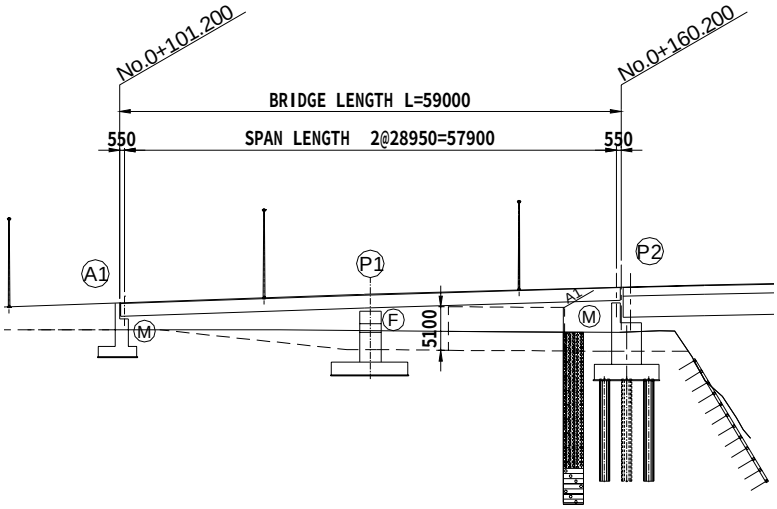
Superstructure	: 2Spans Continuous PC-Slab girder	
Bridge Length	: 59.000m	
Girder Length	: 58.800m	
Span Length	: 2@28.950	
Bridge Width	: 13.900m	
Effective Width	: Carriage Way	9.70m
	: Foot Way	2 x 1.50m
Live Load	: Class-A, Class-AA	
Curvature	: R=∞	
Gradient	: i=3.500% ↙ ～ 2.000% ↙	
Super Elecation	: i = 2.000% ↙ ↘	
Skew Angle	: θ = 90 deg	
Support Condition	: A1	Fixed support
	: P1, P2	Movable Support
Asphalt Pavemant	: Carriage Way	80mm～
	Foot Way	30mm～
Substructure	: A1	Inverted T shape type abutment
	P1	Column type pier
	P2	Column type pier (See Appendix-B)
Foundation	: A1	Spread Footing
	P1	do.
	P2	do.

1.2 Bridge Profile

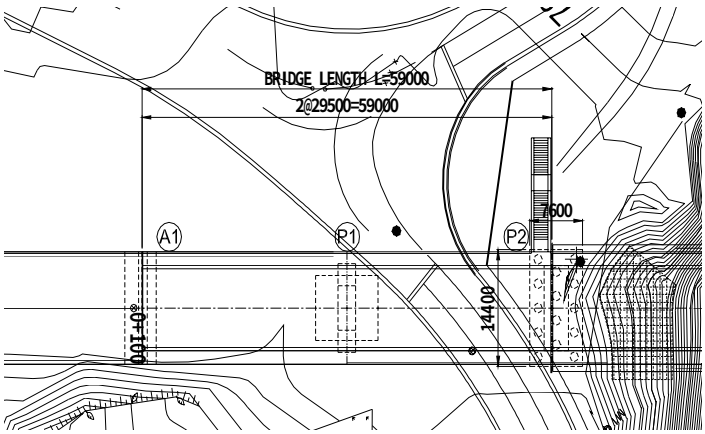
Typical Cross Section



Profile



Plan



1.3 Materials Property

1.3.1 Concrete

Table 1.3.1 Material Property of Concrete

Concrete (N/mm^2)

	Wall Column RC	Footing, Pilecap RC
Class	A1-1	A1-2
28Days Cylinder Strength	24	24
Modulus of Elasticity	2.50×10^4	2.50×10^4
Allowable Compression Stress	9.60	9.60
Allowable Tensile Stress	-2.45	-
Temperature coefficient	10×10^{-6}	10×10^{-6}
Allowable Shear Stress	0.39	0.39
Maximum Average Shear Stress	2.16	2.16

1.3.2 Reinforcement

Table 1.3.2 Material Property of Reinforcement

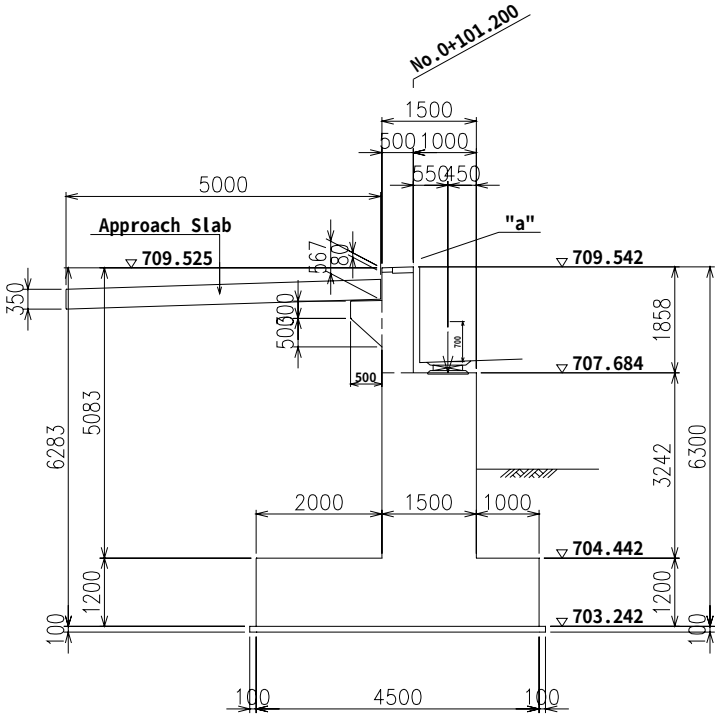
(N/mm^2)

Yield strength	420
Modulus of Elasticity （$\times10^5$）	2.0
Allowable Tensile Stress	168

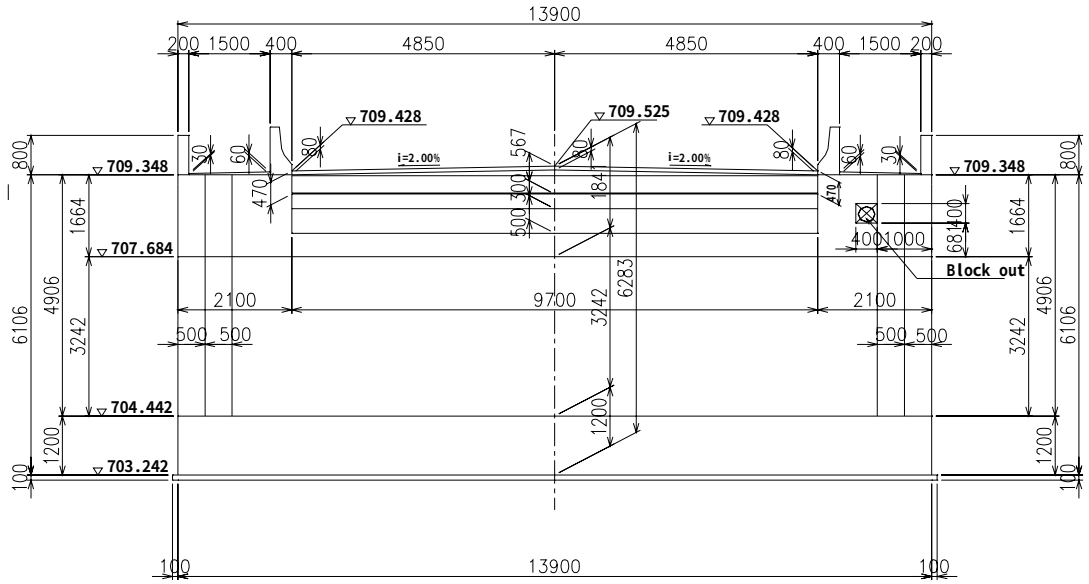
2 Design of A1 Abutment

2.1 General Arrangement

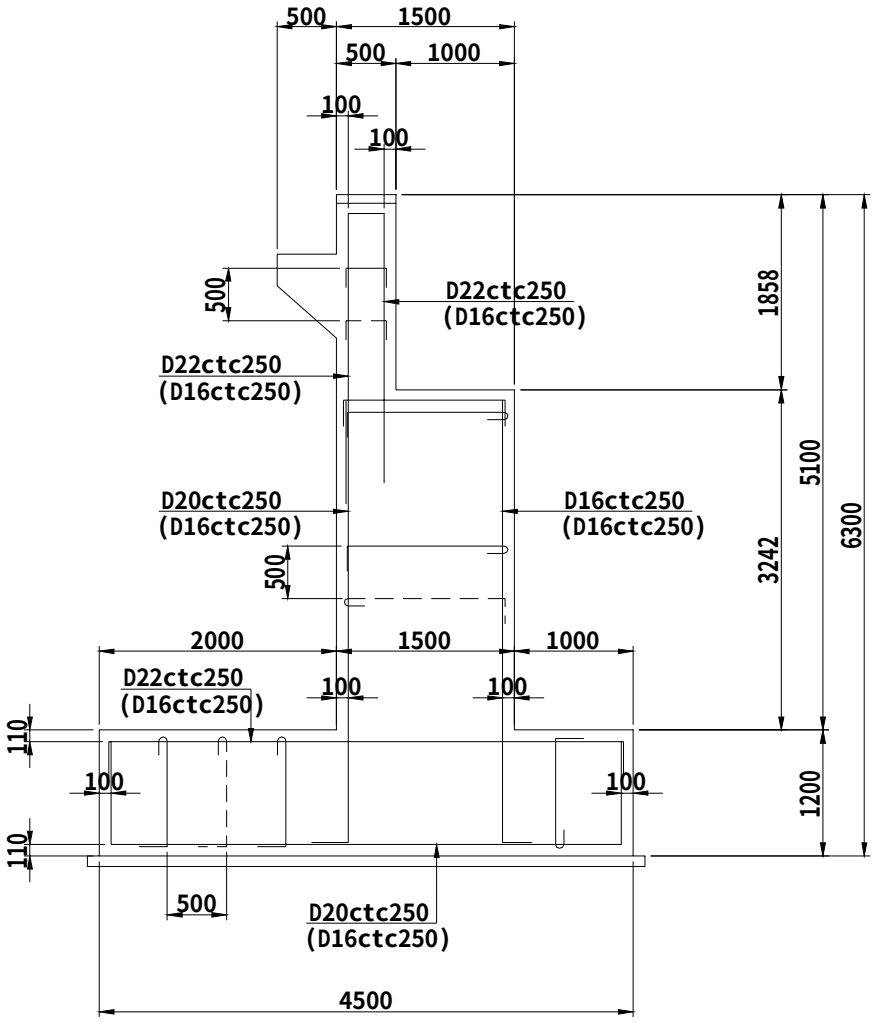
Side Elevation



FRONT ELEVATION



2.1.1 Reinforcement Bar Arrangement



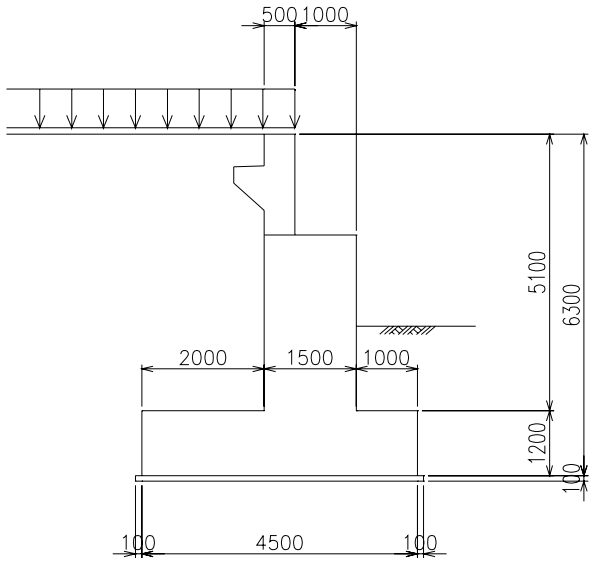
※( )Inside the reinforced concrete arrangement indicates of distribution direction

2.2 Loading Data

2.2.1 Type of Structure

・Reversed T Type Abutment

2.2.2 Configuration of Abutment



Transverse Width B (mm)	Left Projection length	Right Projection length
13900	————	————

2.2.3 Material

【Concrete】 Parapet: σck = 24 (N/mm^2)

Wall : σck = 24 (N/mm^2)

Footing : σck = 24 (N/mm^2)

Wing Wall: σck = 24 (N/mm^2)

【Reinforcement】 : Yield=420N/mm2

【Back Fill】 Internal Friction Angle φ = 30.00 °

2.2.4 Loadings

(1) Unit Weight

【Unit Weight】

(kN/m^3)

Concrete	24.5	
Water	10	
Soil	Wet Density	Saturated Density
Backfill(Front)	18.00	19.00
Backfill(Side)	19.00	20.00

(2) Superstruvture Reaction

1.Vertical Reaction

Loadings		A1 Rz(kN)
Self Weight of Girder	D	2660.000
Superimposed Dead Load	SD	720.000
A Loading Maximum	L	780.000
Shrinkage	S	0.000
Temperature	T	160.000

2. Horizontal Reaction for Longitudinal Direction

Loadings		A1 Rz(kN)
Shrinkage	S	0.000
Temparature	T	0.000
Longitudanl Force	LF	40.000
Centrifugal Force	CF	0.000
Earthquake	EQ	510.000

3. Horizontal Reaction for Transverse Direction

Loadings		A1 Rz(kN)
Centrifugal Force	CF	0.000

Combination Load Group			Reaction from Superstructure (kN)				
			Rd	Rex	RD=Rd+Rex	RL	RH
S.L.D	Ⅰ	1.0D+1.0SD+1.0L	3380.000	0.000	3380.000	780.000	0.000
	Ⅱ	1.0D+1.0SD	3380.000	0.000	3380.000	0.000	0.000
	Ⅲ	1.0D+1.0SD+1.0L+1.0LF	3380.000	0.000	3380.000	780.000	40.000
	Ⅳ	1.0D+1.0SD+1.0L+1.0CF+1.0S+1.0T	3380.000	0.000	3380.000	780.000	0.000
	Ⅴ	1.0D+1.0SD+1.0S+1.0T	3380.000	0.000	3380.000	0.000	0.000
	Ⅵ	1.0D+1.0SD+1.0L+1.0CF+1.0LF+1.0S+1.0T	3380.000	0.000	3380.000	780.000	40.000
	Ⅶ	1.0D+1.0SD+EQ	3380.000	0.000	3380.000	0.000	510.000
L.F.D	Ⅰ	(1.0D+1.0SD+1.67L)*1.3	4394.000	0.000	4394.000	1693.380	0.000
	Ⅱ	(1.0D+1.0SD)*1.3	4394.000	0.000	4394.000	0.000	0.000
	Ⅲ	(1.0D+1.0SD+1.0L+1.0CF+1.0LF)*1.3	3923.000	0.000	3923.000	1014.000	0.000
	Ⅳ	(1.0D+1.0SD+1.0L+1.0CF+1.0S+1.0T)*1.3	4394.000	0.000	4394.000	1014.000	50.000
	Ⅴ	(1.0D+1.0SD+1.0S+1.0T)*1.25	4225.000	0.000	4225.000	0.000	0.000
	Ⅵ	(1.0D+1.0SD+1.0L+1.0CF+1.0LF+1.0S+1.0T)*1.25	4225.000	0.000	4225.000	975.000	50.000
	Ⅶ	(1.0D+1.0SD+1.0EQ)*1.3	4394.000	0.000	4394.000	0.000	660.000

Rd : Dead Load

Rex : Other Dead Load

RD : Rd+Rex

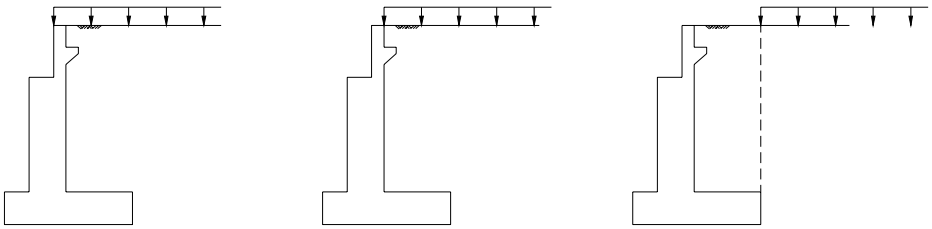
RL : Reaction of Live Load

RH : Horizontal Reaction

※The stability check and the calculation of the stress are done by combining the load about the coloring part.

(3) Surcharge Load

Combination Load Case		Surcharge Load (N/m^2)		Live Load Type		
		Dead Load Qd	Live Load Ql	a	b	c
S.L.D	Group Ⅰ	0.00	10	○		
	Group Ⅱ	0.00	10	○		
	Group Ⅲ	0.00	10	○		
	Group Ⅳ	0.00	10	○		
	Group Ⅴ	0.00	10	○		
	Group Ⅵ	0.00	10	○		
	Group Ⅶ	0.00	0.0	-		
L.F.D	Group Ⅰ	0.00	21.7	○		
	Group Ⅱ	0.00	13	○		
	Group Ⅲ	0.00	13	○		
	Group Ⅳ	0.00	13	○		
	Group Ⅴ	0.00	12.5	○		
	Group Ⅵ	0.00	12.5	○		
	Group Ⅶ	0.00	0.0	-		



TYPE A TYPE B TYPE C

2.2.5 Earth Pressure

(1) Coulomb's Formula

δ=0.8Φ=24.0°

$$K_A = \frac{\cos^2(\phi-\theta)}{\cos^2\theta\cos(\theta+\delta)\left\{1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\alpha)}{\cos(\theta+\delta)\cos(\theta-\alpha)}}\right\}^2}$$

$$= \frac{\cos^2(30.000-0.000)}{\cos^2 0.000\ \cos(0.000+30.000)\left\{1+\sqrt{\frac{\sin(30.000+30.000)\sin(30.000-(0.000))}{\cos(0.000+30.000)\cos(0.000-(0.000))}}\right\}^2}$$

$$= 0.297$$

δ=0.0°

$$K_A = \frac{\cos^2(\phi-\theta)}{\cos^2\theta\cos(\theta+\delta)\left\{1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\alpha)}{\cos(\theta+\delta)\cos(\theta-\alpha)}}\right\}^2}$$

$$= \frac{\cos^2(30.000-0.000)}{\cos^2 0.000\ \cos(0.000+0.000)\left\{1+\sqrt{\frac{\sin(30.000+0.000)\sin(30.000-(0.000))}{\cos(0.000+0.000)\cos(0.000-(0.000))}}\right\}^2}$$

$$= 0.333$$

2.2.6 Water Pressure

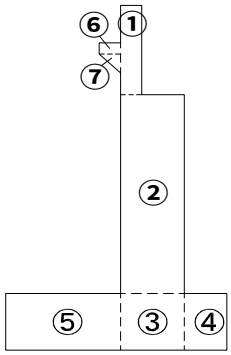
- The direction in the back hydraulic pressure where hydraulic pressure acts is made horizontal direction.

2.3 Calculation of acting force at footing bottom

(1) Block data that doesn't consider water level

1)Self Weight

a) Block dividing



b)Volum・Center of Grabity

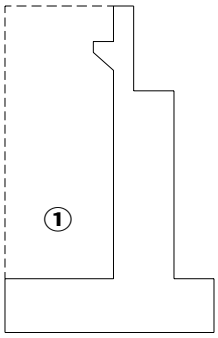
Division	Calculation formula Width × Height × Dept	Volume Vi(m^3)	Barycentric Position (m) Xi	Yi	Vi・Xi	Vi・Yi
1	0.500× 2.370× 17.410	20.631	2.25	7.985	46.419	164.737
2	1.500× 5.300× 17.410	138.410	1.750	4.150	242.217	574.399
3	1.500× 1.500× 17.410	39.172	1.750	0.750	68.552	29.379
4	1.000× 1.500× 17.410	26.115	0.500	0.750	13.057	19.586
5	2.700× 1.500× 17.410	70.510	3.850	0.750	271.465	52.883
6	0.500× 0.300× 16.010	2.402	2.750	8.375	6.604	20.113
7	1/2× 0.500× 0.500× 16.010	2.001	2.667	8.058	5.337	16.127
Σ		299.241	———	———	653.652	877.225

Barycentric Position XG = Σ(Vi･Xi)/ΣVi = 653.652/ 299.241 = 2.184 (m)

YG = Σ(Vi･Yi)/ΣVi = 877.225/ 299.241 = 2.931 (m)

2) Rear Backfill Soil

a) Block dividing



b)Volum・Center of Grabity

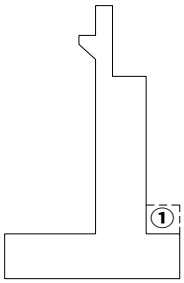
Division	Calculation Formula Width × Height × Dept	Volume $Vi(m^3)$	Barycentric Position (m) Xi	Yi	Vi・Xi	Vi・Yi
1	2.700× 7.670× 17.410	360.544	3.85	5.335	1388.093	1923.5
2	- 0.500× 0.300× 16.010	-2.402	2.75	8.375	-6.604	-20.113
3	-1/2× 0.500× 0.500× 16.010	-2.001	2.667	8.058	-5.337	-16.127
Σ		356.141	———	———	1376.152	1887.261

Barycentric Position XG = Σ(Vi・Xi)/ΣVi = 1376.152/ 356.141 = 3.864 (m)

YG = Σ(Vi・Yi)/ΣVi = 1887.261/ 356.141 = 5.299 (m)

3)Flont Backfill Soil

a) Block dividing



b)Volum・Center of Grabity

Division	Calculation Formula Width × Height × Dept	Volume $Vi(m^3)$	Barycentric Position (m) Xi	Yi	Vi・Xi	Vi・Yi
1	1.000× 0.500× 17.410	8.705	0.500	1.750	4.352	15.234
Σ		8.705	———	———	4.352	15.234

Barycentric Position XG = Σ(Vi・Xi)/ΣVi = 4.352/ 8.705 = 0.500 (m)

YG = Σ(Vi・Yi)/ΣVi = 15.225/ 8.700 = 1.750 (m)

(2) Vertical Force and Horizontal Force of Self-Weight, Buoyancy

1) Acting force by self-weight

Vertical Force = γ · V= 24.50 × 158.236 = 3876.789 (kN)
Poinit of appriction X = 2.044 (m)

2) Acting force by buoyancy of backfill soil

Vertical Force W = Wu + Wl (kN)
Wu = Vu (Volum of Above water of Above water) · γ (Wet density) (kN)
Wl = Vl(Volum of below water.) · γsat(Saturation density) (kN)
Poinit of appriction X = (Wu · Xu + Wl · Xl)/W (m)

Horizontal force H = W · Kh (kN)
Poinit of appriction Y = (Wu · Yu + Wl · Yl)/W (m)

a) S.L.D

Position	Total Volum、Barycentric Position			Volum of below water		
	Volume	Barycentric Position (m)		Volume	Barycentric Position (m)	
	$V(m^3)$	X	Y	$V(m^3)$	X	Y
Backfill(Rear)	139.113	3.515	3.718	0.000	0.000	0.000
Backfill(Flont)	25.020	0.500	2.100	0.000	0.000	0.000

Position	Volum of Above water		
	Volume	Barycentric Position (m)	
	$V(m^3)$	X	Y
Backfill(Rear)	139.113	3.515	3.718
Backfill(Flont)	25.020	0.500	2.100

Position	Weight of above water level Wu = Vu×γ (kN)	Weight of below waterlevel Wl = Vl×γsat (kN)
Backfill(Rear)	139.113 × 19.000 = 2643.138	0.000 × 20.000 = 0.000
Backfill(Flont)	25.020 × 19.000 = 450.360	0.000 × 20.000 = 0.000

Position	Vertical Force:W Wu+Wl (kN)	Poinit of appriction X(m)
Backfill(Rear)	2643.138 + 0.000 = 2643.138	3.515
Backfill(Flont)	450.360 + 0.000 = 450.360	0.500

b) L.F.D(Group Ⅰ～Ⅳ)

Position	Total Volum、Barycentric Position			Volum of below water		
	Volume	Barycentric Position (m)		Volume	Barycentric Position (m)	
	$V(m^3)$	X	Y	$V(m^3)$	X	Y
Backfill(Rear)	139.113	3.515	3.718	0.000	0.000	0.000
Backfill(Flont)	25.020	0.500	2.100	0.000	0.000	0.000

Position	Volum of Above water		
	Volume	Barycentric Position (m)	
	$V(m^3)$	X	Y
Backfill(Rear)	139.113	3.515	3.718
Backfill(Flont)	25.020	0.500	2.100

Position	Weight of above water level Wu = Vu×γ (kN)	Weight of below waterlevel Wl = Vl×γsat (kN)
Backfill(Rear)	139.113 × 19.00 = 2643.138	0.000 × 20.000 = 0.000
Backfill(Flont)	25.020 × 19.00 = 450.360	0.000 × 20.000 = 0.000

Position	Vertical Force:W Wu+Wl (kN)	Poinit of appication X(m)
Backfill(Rear)	2643.138 + 0.000 = 2643.138	3.515
Backfill(Flont)	450.360 + 0.000 = 450.360	0.500

c) L.F.D(Group Ⅰ～Ⅳ)

Position	Total Volum、Barycentric Position			Volum of below water		
	Volume	Barycentric Position (m)		Volume	Barycentric Position (m)	
	$V(m^3)$	X	Y	$V(m^3)$	X	Y
Backfill(Rear)	139.113	3.515	3.718	0.000	0.000	0.000
Backfill(Flont)	25.020	0.500	2.100	0.000	0.000	0.000

Position	Volum of Above water		
	Volume	Barycentric Position (m)	
	$V(m^3)$	X	Y
Backfill(Rear)	139.113	3.515	3.718
Backfill(Flont)	25.020	0.500	2.100

Position	Weight of above water level Wu = Vu×γ (kN)	Weight of below waterlevel Wl = Vl×γsat (kN)
Backfill(Rear)	139.113 × 24.700 =3436.091	0.000 × 20.000 = 0.000
Backfill(Flont)	25.020 × 24.700 = 617.994	0.000 × 20.000 = 0.000

Position	Vertical Force:W Wu+Wl (kN)	Poinit of appication X(m)
Backfill(Rear)	3436.091 + 0.000 = 3436.091	3.515
Backfill(Flont)	617.994 + 0.000 = 617.994	0.500

3) Calculation of buoyancy

Front water level	Hf =	1.200 (m)
Water level of the bac	Hr =	1.200 (m)

Hydraulic pressure strength in front of Footing Pf = 12.00 (kN/m^2)

Hydraulic pressure strength in the back of Footing Pr = 12.00 (kN/m^2)

$$U = \frac{Pf+Pr}{2} * Bj * Bc = 750.6 \text{ (kN)}$$

Poinit of apprication (From the front side of footing)

$$X = \frac{Pf+2*Pr}{3*(Pf+Pr)} * Bj = 2.250 \text{ (kN)}$$

Where

Bj : Footing width at longitudinal direction. Bj 4.500 (m)

Bc : Footing width at transvers direction. Bc = 13.900 (m)

(3) Surcharge load

Vertical Force

$$N = q \cdot L \cdot B$$

Poinit of aprication

in which,
q: Ground level surcharge load
qd : Ground level surcharge load(dead load)
ql : Ground level surcharge load(live load)
B: Surchage load length at transvers direction, B = 24.800 (m)
Ls: Distance from design section to load action position
L: Length on which load acts(m)

Surcharge	q (kN/m^2)	Ls (m)	L (m)	Vertical Force N (kN)	Poinit of aprication X (m)
ql(a)	10.000	2.000	2.500	347.500	3.600

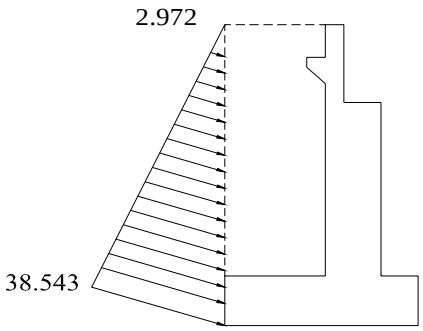
(4) Earth pressure and hydraulic pressure

1) Common data

Unit weight of water	$\gamma w(kN/m^3)$	9.800
Width of soil pressure action	Bc (m)	13.900
Height in which soil pressure is not considered	hr (m)	0.000
Cohesion of soil	C (kN/m^2)	0.000

2) Earth pressure

a) Bouyancy is not taken into consideration.



Data for Earth pressure calculation- buoyancy not considered

Surchage load	q (kN/m^2)	10.000
Height from rear water level to top of abutment	H1 (m)	6.300
Height from rear water level to bottom of Footing	H2 (m)	0.000
Heightof rear water leve	Hs (m)	0.000

Calculation Result of Earth Puressure

Item			
Parameter	HU(m)	HU(m)	6.300
	HL(m)	HL(m)	0.000
	Height from water level of the back to the top	h1(m)	6.300
	Height from Water level of the back to the lower side of Footing	h2(m)	0.000
	Height of water level of the back	hs(m)	0.000
	Height in which soil pressure is not considered	hr(m)	0.000
	Intersection angle of abutment wall and vertical	θ (deg.)	0.000
	Friction angle of soil and wall	δ (deg.)	30.000
	Wet density of backfill soil (kN/m^3)	γt	19.000
	Saturation density of backfill soil (kN/m3)	γsat	20.000
	Action starting point of earth pressure (X-Coordinates)	Xp(m)	4.500
Coefficient of Earth Pressure	Coefficient of earth pressure above water level (upper)	Ku1	0.29717
	(lower)	Kl1	0.29717
	Coefficient of earth pressure below water level (upper)	Ku2	0.29717
	(lower)	Kl2	0.29717
Earth Pressure Strength	[1] Earth pressure strength abobe water level (uppet)		2.972
	[2] Earth pressure strength abobe water level (lower)		38.543
	[3] Earth pressure strength below water level (upper)		0.000
	[4] Earth pressure strength below water level (lower)		0.000
Earth Pressure Force	Pe1 = (1/2)・([1]+[2])・h1・Bc		1817.74
	Pe2 = (1/2)・([3]+[4])・h2・Bc		0.00
	Pe = Pe1+Pe2		1817.74
	Peh = Pe・cos(δ+θ) (Horizontal element of earth pressure)		1574.21
	Pev = Pe・sin(δ+θ) (Vertical element of earth pressure)		908.87
Poinit of appication	Y1 = (2・[1]+[2])・h1/{3・([1]+[2])}+h2+HL+hr		2.250
	Y2 = (2・[3]+[4])・h2/{3・([3]+[4])}+HL+hr		0.000
	Y = (Pe1・Y1+Pe2・Y2)/Pe		2.250
	X = Xp - Y tanθ		4.500

・Poinit of appication

$$X=\frac{\Sigma(Pev*X)}{\Sigma Pev}=\quad 4.500 \quad (m)$$

$$Y=\frac{\Sigma(Peh*Y)}{\Sigma Peh}=\quad 2.250 \quad (m)$$

・Earth Pressure Force

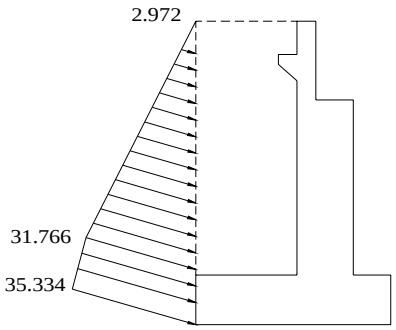
Vertical Force

Pv = ΣPev = 908.87 (kN)

Horizontal Force

Ph = ΣPeh = 1574.21 (kN)

b) Buoyancy is taken into consideration.



Data for Earth pressure calculation- buoyancy not considered

Surchage load	q (kN/m^2)	10.000
Height from rear water level to top of abutment	H1 (m)	5.100
Height from rear water level to bottom of Footing	H2 (m)	1.200
Heightof rear water leve	Hs (m)	1.200

Calculation Result of Earth Puressure

Item			
Parameter	HU(m)	HU(m)	6.300
	HL(m)	HL(m)	0.000
	Height from water level of the back to the top	h1(m)	5.100
	Height from Water level of the back to the lower side of Footing	h2(m)	1.200
	Height of water level of the back	hs(m)	1.200
	Height in which soil pressure is not considered	hr(m)	0.000
	Intersection angle of abutment wall and vertical	θ (deg.)	0.000
	Friction angle of soil and wall	δ (deg.)	30.000
	Wet density of backfill soil (kN/m^3)	γt	19.000
	Saturation density of backfill soil (kN/m3)	γsat	20.000
	Action starting point of earth pressure (X-Coordinates)	Xp(m)	4.500
Coefficient of Earth Pressure	Coefficient of earth pressure above water level (upper)	Ku1	0.2917
	(lower)	Kl1	0.2917
	Coefficient of earth pressure below water level (upper)	Ku2	0.2917
	(lower)	Kl2	0.2917
Earth Pressure Strength	[1] Earth pressure strength abobe water level (uppet)		2.972
	[2] Earth pressure strength abobe water level (lower)		31.768
	[3] Earth pressure strength below water level (upper)		31.768
	[4] Earth pressure strength below water level (lower)		35.334
Earth Pressure Force	Pe1 = (1/2)・([1]+[2])・h1・Bc		1231.34
	Pe2 = (1/2)・([3]+[4])・h2・Bc		559.63
	Pe = Pe1+Pe2		1790.97
	Peh = Pe・cos(δ+θ) (Horizontal element of earth pressure)		1551.03
	Pev = Pe・sin(δ+θ) (Vertical element of earth pressure)		895.49
Poinit of apprication	Y1 = (2・[1]+[2])・h1/{3・([1]+[2])}+h2+HL+hr		3.045
	Y2 = (2・[3]+[4])・h2/{3・([3]+[4])}+HL+hr		0.589
	Y = (Pe1・Y1+Pe2・Y2)/Pe		2.278
	X = Xp - Y tanθ		4.500

・Poinit of appication

$$X=\frac{\Sigma(Pev*X)}{\Sigma Pev}=\quad 4.500\quad (m)$$

$$Y=\frac{\Sigma(Peh*Y)}{\Sigma Peh}=\quad 2.278\quad (m)$$

・Earth Pressure Force

Vertical Force

Pv = ΣPev = 895.49 (kN)

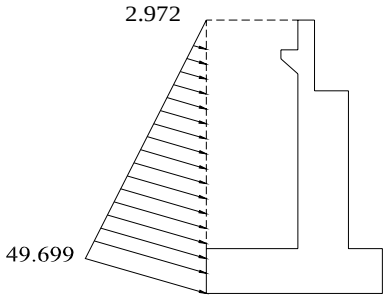
Horizontal Force

Ph = ΣPeh = 1551.03 (kN)

Hydraulic Pressure Force

		Front Water Level	Rear Water Level
Height in which hydraulic pressure is calculated h (m)		1.200	1.200
Hydraulic pressure strength (kN/m^2)	[1] γw・h	12.000	12.000
Hydraulic pressure force (kN)	Pw = (1/2)・[1]・h・Bc	100.08	100.08
Height of hydraulic pressure force (m	Yw = h/3	0.400	0.400

c) During Earthquake-Bouyancy is not taken into consideration.



Data for Earth pressure calculation- buoyancy not considered

Surchage load	q (kN/m^2)	0.000
Height from rear water level to top of abutment	H1 (m)	6.300
Height from rear water level to bottom of Footing	H2 (m)	0.000
Heightof rear water leve	Hs (m)	0.000

Calculation Result of Earth Puressure

Item			
Parameter	HU(m)	HU(m)	6.300
	HL(m)	HL(m)	0.000
	Height from water level of the back to the top	h1(m)	6.300
	Height from Water level of the back to the lower side of Footing	h2(m)	0.000
	Height of water level of the back	hs(m)	0.000
	Height in which soil pressure is not considered	hr(m)	0.000
	Intersection angle of abutment wall and vertical	θ (deg.)	0.000
	Friction angle of soil and wall	δ (deg.)	15.000
	Wet density of backfill soil (kN/m^3)	γt	19.000
	Saturation density of backfill soil (kN/m3)	γsat	20.000
	Action starting point of earth pressure (X-Coordinates)	Xp(m)	4.500
Coefficient of Earth Pressure	Coefficient of earth pressure above water level (upper)	Ku1	0.4152
	(lower)	Kl1	0.4152
	Coefficient of earth pressure below water level (upper)	Ku2	0.4152
	(lower)	Kl2	0.4152
Earth Pressure Strength	[1] Earth pressure strength abobe water level (uppet)		0.000
	[2] Earth pressure strength abobe water level (lower)		49.699
	[3] Earth pressure strength below water level (upper)		0.000
	[4] Earth pressure strength below water level (lower)		0.000
Earth Pressure Force	Pe1 = (1/2)・([1]+[2])・h1・Bc		2176.09
	Pe2 = (1/2)・([3]+[4])・h2・Bc		0.00
	Pe = Pe1+Pe2		2176.09
	Peh = Pe・cos(δ+θ) (Horizontal element of earth pressure)		2101.94
	Pev = Pe・sin(δ+θ) (Vertical element of earth pressure)		563.21
Poinit of apprication	Y1 = (2・[1]+[2])・h1/{3・([1]+[2])}+h2+HL+hr		2.100
	Y2 = (2・[3]+[4])・h2/{3・([3]+[4])}+HL+hr		0.000
	Y = (Pe1・Y1+Pe2・Y2)/Pe		2.100
	X = Xp - Y tanθ		4.500

・Poinit of appication

$$X = \frac{\Sigma(Pev*X)}{\Sigma Pev} = 4.500 \quad (m)$$

$$Y = \frac{\Sigma(Peh*Y)}{\Sigma Peh} = 2.100 \quad (m)$$

・Earth Pressure Force

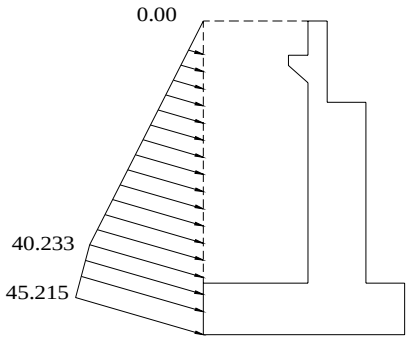
Vertical Force

Pv = ΣPev = 563.21 (kN)

Horizontal Force

Ph = ΣPeh = 2101.94 (kN)

d) During Earthquake-Buoyancy is taken into consideration.



Data for Earth pressure calculation- buoyancy not considered

Surchage load	q (kN/m^2)	10.000
Height from rear water level to top of abutment	H1 (m)	5.100
Height from rear water level to bottom of Footing	H2 (m)	1.200
Heightof rear water leve	Hs (m)	1.200

Calculation Result of Earth Puressure

Item			
Parameter	HU(m)	HU(m)	6.300
	HL(m)	HL(m)	0.000
	Height from water level of the back to the top	h1(m)	5.100
	Height from Water level of the back to the lower side of Footing	h2(m)	1.200
	Height of water level of the back	hs(m)	1.200
	Height in which soil pressure is not considered	hr(m)	0.000
	Intersection angle of abutment wall and vertical	θ (deg.)	0.000
	Friction angle of soil and wall	δ (deg.)	30.000
	Wet density of backfill soil (kN/m^3)	γt	19.000
	Saturation density of backfill soil (kN/m3)	γsat	20.000
	Action starting point of earth pressure (X-Coordinates)	Xp(m)	4.500
Coefficient of Earth Pressure	Coefficient of earth pressure above water level (upper)	Ku1	0.4152
	(lower)	Kl1	0.4152
	Coefficient of earth pressure below water level (upper)	Ku2	0.4152
	(lower)	Kl2	0.4152
Earth Pressure Strength	[1] Earth pressure strength abobe water level (uppet)		0.000
	[2] Earth pressure strength abobe water level (lower)		40.233
	[3] Earth pressure strength below water level (upper)		40.233
	[4] Earth pressure strength below water level (lower)		45.215
Earth Pressure Force	Pe1 = (1/2)・([1]+[2])・h1・Bc		1426.06
	Pe2 = (1/2)・([3]+[4])・h2・Bc		712.64
	Pe = Pe1+Pe2		2138.69
	Peh = Pe・cos(δ+θ) (Horizontal element of earth pressure)		2065.82
	Pev = Pe・sin(δ+θ) (Vertical element of earth pressure)		553.53
Poinit of apprication	Y1 = (2・[1]+[2])・h1/{3・([1]+[2])}+h2+HL+hr		2.900
	Y2 = (2・[3]+[4])・h2/{3・([3]+[4])}+HL+hr		0.588
	Y = (Pe1・Y1+Pe2・Y2)/Pe		2.130
	X = Xp - Y tanθ		4.500

・Poinit of apprication

$$X=\frac{\Sigma(Pev*X)}{\Sigma Pev}=\quad 4.500 \quad (m)$$

$$Y=\frac{\Sigma(Peh*Y)}{\Sigma Peh}=\quad 2.130 \quad (m)$$

・Earth Pressure Force

Vertical Force

Pv = ΣPev = 553.53 (kN)

Horizontal Force

Ph = ΣPeh = 2065.82 (kN)

Hydraulic Pressure Force

		Front Water Level	Rear Water Level
Height in which hydraulic pressure is calculated h (m)		1.200	1.200
Hydraulic pressure strength (kN/m^2)	[1] γw・h	12.000	12.000
Hydraulic pressure force (kN)	Pw = (1/2)・[1]・h・Bc	100.08	100.08
Height of hydraulic pressure force (m)	Yw = h/3	0.400	0.400

(6) Summary of Acting Force

1) Total Acting Force at Bottom of Footing

[1] S.L.D Group Ⅰ

Loadings	Vertical Force	Horizontal Force	Arm Length		Rotation Moment(kN.m)	
	V_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M_{xi}= V_i \cdot X_i$	$M_{yi}= H_i \cdot Y_i$
Self Weight	3876.789	0.000	2.044	0.000	7924.157	0.000
Front Backfill	450.350	0.000	0.500	0.000	225.175	0.000
Side Backfill	0.000	0.000	0.000	0.000	0.000	0.000
The back Soil	2643.138	0.000	3.515	0.000	9290.630	0.000
Backfill Total	3093.488	0.000	3.784	0.000	9515.805	0.000
Superstruture Reaction	4160.000	0.000	1.450	4.442	6032.000	0.000
Surcharge D	0.000	0.000	3.600	6.300	0.000	0.000
Surcharge L	278.000	0.000	3.500	6.300	973.000	0.000
Other Load	0.000	0.000	0.000	0.000	0.000	0.000
Earth Pressure	895.485	1551.026	4.500	2.278	4029.683	3533.237
Back Hydraulic Pressure	0.000	100.080	0.000	0.400	0.000	40.032
Flont Hydraulic Pressure	0.000	-100.080	0.000	0.400	0.000	-40.032
Buoyancy	-750.600	0.000	2.250	0.000	-1688.850	0.000
Total	11553.162	1551.026	——	——	26785.794	3533.237

[2]S.L.D Group Ⅲ

Loadings	Vertical Force	Horizontal Force	Arm Length		Rotation Moment(kN.m)	
	V_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M_{xi}= V_i \cdot X_i$	$M_{yi}= H_i \cdot Y_i$
Self Weight	3876.789	0.000	2.044	0.000	7924.157	0.000
Front Backfill	450.350	0.000	0.500	0.000	225.175	0.000
Side Backfill	0.000	0.000	0.000	0.000	0.000	0.000
The back Soil	2643.138	0.000	3.515	0.000	9290.630	0.000
Backfill Total	3093.488	0.000	3.784	0.000	9515.805	0.000
Superstruture Reaction	4160.000	40.000	1.450	4.442	6032.000	177.680
Surcharge D	0.000	0.000	3.600	6.300	0.000	0.000
Surcharge L	278.000	0.000	3.500	6.300	973.000	0.000
Other Load	0.000	0.000	0.000	0.000	0.000	0.000
Earth Pressure	895.485	1551.026	4.500	2.278	4029.683	3533.237
Back Hydraulic Pressure	0.000	100.080	0.000	0.400	0.000	40.032
Flont Hydraulic Pressure	0.000	-100.080	0.000	0.400	0.000	-40.032
Buoyancy	-750.600	0.000	2.250	0.000	-1688.850	0.000
Total	11553.162	1591.026	——	——	26785.794	3710.917

[3]S.L.D Group Ⅶ

Loadings	Vertical Force	Horizontal Force	Arm Length		Rotation Moment(kN.m)	
	V_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M_{xi}= V_i \cdot X_i$	$M_{yi}= H_i \cdot Y_i$
Self Weight	3876.789	775.358	2.044	2.020	7924.157	1566.223
Front Backfill	450.360	0.000	0.500	0.000	225.180	0.000
Side Backfill	0.000	0.000	0.000	0.000	0.000	0.000
The back Soil	2643.138	422.902	3.515	3.718	9290.630	1572.350
Backfill Total	3093.498	422.902	3.784	0.000	9515.810	1572.350
Superstruture Reaction	3380.000	510.000	1.450	4.442	4901.000	2265.420
Surcharge D	0.000	0.000	0.000	0.000	0.000	0.000
Surcharge L	0.000	0.000	0.000	0.000	0.000	0.000
Other Load	0.000	0.000	0.000	0.000	0.000	0.000
Earth Pressure	553.534	2065.818	4.500	2.130	2490.903	4400.192
Back Hydraulic Pressure	0.000	100.080	0.000	0.400	0.000	40.032
Flont Hydraulic Pressure	0.000	-100.080	0.000	0.400	0.000	-40.032
Buoyancy	-750.600	0.000	2.250	0.000	-1688.850	0.000
Total	10153.221	3774.078	——	——	23143.020	9804.185

[4]L.F.D Group Ⅰ

Loadings	Vertical Force	Horizontal Force	Arm Length		Rotation Moment(kN.m)	
	V_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M_{xi}= V_i \cdot X_i$	$M_{yi}= H_i \cdot Y_i$
Self Weight	5039.826	0.000	2.044	0.000	10301.404	0.000
Front Backfill	585.468	0.000	0.500	0.000	292.734	0.000
Side Backfill	0.000	0.000	0.000	0.000	0.000	0.000
The back Soil	3436.079	0.000	3.515	3.718	12077.818	0.000
Backfill Total	4021.547	0.000	3.076	0.000	12370.552	0.000
Superstruture Reaction	6087.400	0.000	1.450	4.442	8826.730	0.000
Surcharge D	0.000	0.000	0.000	6.300	0.000	0.000
Surcharge L	451.750	0.000	3.250	6.300	1468.188	0.000
Other Load	0.000	0.000	0.000	0.000	0.000	0.000
Earth Pressure	1168.146	2023.287	4.500	2.272	5256.657	4596.908
Back Hydraulic Pressure	0.000	130.104	0.000	0.400	0.000	52.042
Flont Hydraulic Pressure	0.000	-130.104	0.000	0.400	0.000	-52.042
Buoyancy	-975.780	0.000	0.000	0.000	0.000	0.000
Total	15792.889	2023.287	——	——	38223.531	4596.908

[5]L.F.D Group Ⅲ

Loadings	Vertical Force	Horizontal Force	Arm Length		Rotation Moment(kN.m)	
	V_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M_{xi}= V_i \cdot X_i$	$M_{yi}= H_i \cdot Y_i$
Self Weight	5039.826	0.000	2.044	2.020	10301.404	0.000
Front Backfill	585.468	0.000	0.500	0.000	292.734	0.000
Side Backfill	0.000	0.000	0.000	0.000	0.000	0.000
The back Soil	3436.079	0.000	3.515	3.718	12077.818	0.000
Backfill Total	4021.547	0.000	3.076	0.000	12370.552	0.000
Superstruture Reaction	5408.000	50.000	1.450	4.442	7841.600	222.100
Surcharge D	0.000	0.000	0.000	0.000	0.000	0.000
Surcharge L	451.750	0.000	3.250	6.300	1468.188	0.000
Other Load	0.000	0.000	0.000	0.000	0.000	0.000
Earth Pressure	1168.146	2023.287	4.500	2.272	5256.657	4596.908
Back Hydraulic Pressure	0.000	130.104	0.000	0.400	0.000	52.042
Flont Hydraulic Pressure	0.000	-130.104	0.000	0.400	0.000	-52.042
Buoyancy	-975.780	0.000	2.250	0.000	-2195.505	0.000
Total	15113.489	2073.287	——	——	35042.896	4819.008

[6]L.F.D Group Ⅶ

Loadings	Vertical Force	Horizontal Force	Arm Length		Rotation Moment(kN.m)	
	V_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M_{xi}= V_i \cdot X_i$	$M_{yi}= H_i \cdot Y_i$
Self Weight	5039.826	1007.965	2.044	2.020	10301.404	2036.090
Front Backfill	585.468	0.000	0.500	0.000	292.734	0.000
Side Backfill	0.000	0.000	0.000	0.000	0.000	0.000
The back Soil	3436.079	422.902	3.515	3.718	12077.818	1572.350
Backfill Total	4021.547	422.902	3.784	0.000	12370.552	1572.350
Superstruture Reaction	4394.000	660.000	1.450	4.442	6371.300	2931.720
Surcharge D	0.000	0.000	0.000	0.000	0.000	0.000
Surcharge L	0.000	0.000	0.000	0.000	0.000	0.000
Other Load	0.000	0.000	0.000	0.000	0.000	0.000
Earth Pressure	722.498	2696.401	4.500	2.123	3251.241	5724.459
Back Hydraulic Pressure	0.000	130.104	0.000	0.400	0.000	52.042
Flont Hydraulic Pressure	0.000	-130.104	0.000	0.400	0.000	-52.042
Buoyancy	-975.780	0.000	2.250	0.000	-2195.505	0.000
Total	13202.091	4787.268	——	——	30098.992	12264.619

2) Total Force at Footing center

Vertical Force : $V_B = V_o$ (kN)
Horizontal Force : $H_B = H_o$ (kN)
Rotation Moment : $M_B = V_o \cdot B_j/2.0+M_o$ (kN.m)

Footing Length at Longitudanal Direction : B= 4.500 (m)

Load Case		V_B (kN)	H_B (kN)	M_B (kN.m)
S.L.S	Group Ⅰ	11553.16	1551.03	2742.06
	Group Ⅲ	11553.16	1591.03	2919.74
	Group Ⅶ	10153.22	3774.08	9505.91
L.F.D	Group Ⅰ	15792.89	2023.29	1907.38
	Group Ⅲ	15113.49	2073.29	3781.46
	Group Ⅶ	13202.09	4787.27	11870.33

2.4 Stability checking

1) Checking of the safety to fall

Load Case		Displacement Distance		
		$e_B=M_B/V_B$	Allowable Displacement distance	
S.L.D	Group I	0.237	≦	0.750
	Group III	0.253	≦	0.750
	Group VII	0.936	≦	1.500
L.F.D	Group I	0.121	≦	1.500
	Group III	0.250	≦	1.500
	Group VII	0.899	≦	1.500

2) Checking of the safety to Slide

$fs = H_U / H_B$

Load Case		Shear Resistance (kN)	Action horizontal force(kN)	Safety Foctoer	Required Safety	
S.L.D	Group I	5,799.7	1,551.0	3.739	≦	1.50
	Group III	5,799.7	1,591.0	3.645	≦	1.50
	Group VII	5,096.9	3,774.1	1.351	≦	1.20
L.F.D	Group I	7,928.0	2,023.3	3.918	≦	1.10
	Group III	7,587.0	2,073.3	3.659	≦	1.10
	Group VII	6,627.4	4,787.3	1.384	≦	1.10

$\tan\Phi_B$ = 0.502 [$\tan 26.667° (2/3\Phi)$]

3) Checking of subgrade reaction

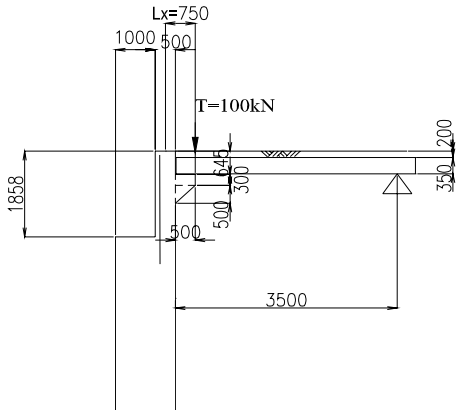
Load Case		Type of subgrade reaction	Subgrade Reaction		Allowable Reaction	
			qmin(kN)	qmax(kN)	(kN)	
S.L.D	Group I	Trapezoid	126.3	243.2	≦	400.0
	Group III	Trapezoid	122.5	246.9	≦	400.0
	Group VII	Triangle	-	370.7	≦	600.0
L.F.D	Group I	Trapezoid	211.8	293.1	≦	600.0
	Group III	Trapezoid	161.0	322.2	≦	600.0
	Group VII	Triangle	-	468.7	≦	600.0

L= 13.900 m

B= 4.500 m

2.5 Design of Parapet Wall

2.5.1 Calculation of Sectional Force



[unit:mm]

$M_f = Ru \cdot L_x =$ 71.617 (kN.m)

$Ru = R_f + T$ = 95.490 (kN)

Rf = 1/2*(W1+W2+q)*L = 22.762 (kN)

in which,

M_f : Sectinal Force at Base of Parapet (kN.m)

Ru : Total reaction on support (kN)

L_x : Distance from center of Parapet to reaction force action position (m), L_x = 0.750

T : Load of wheel (kN), T = 222/2.44=91.0 ⇒100.0

R_f : Reaction force that acts on approach-slab base (kN)

W_1 : Pavement weight on approach-slab (kN/m^2), W_1 = 4.432

W_2 : Self Weight of Approach-slab (kN/m^2), W_2 = 8.575

q : Surcharge Load (kN/m^2), q = 0.0

L : Design Span Length L = αL0 = 3.500

L0 : Approach Slab Length (m), L0 = 5.000

α : , Design span length coefficient α = 0.700

2.5.2 Calculation of Stress

(1) Calculation of Bending Stress

Calculation Formura

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As' \cdot \frac{(x-d') \cdot (h/2-d')}{x} + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

$$x^2 + \frac{2 \cdot n}{b} \left\{As' \cdot (x-d') + As \cdot (x-d)\right\} = 0.0$$

in which,

x : Distance from edge on compression side to neutral axis (mm)

h : Height of Member (mm), h = 500.000

b : Width in section (mm), b = 1000.000

d : Effective height (mm) = 415

d' : Concrete Cover (mm) =85

As : Sectional area of reinforcing bar arranged on tension side (mm^2) D16@125=1608.5

As': Sectional area of reinforcing bar arranged on compression side (mm^2) = D16@250=804.25

n : Elastic Modulus Ratio of Reinforce and Concrete , n = 15.00

e : Axis force eccentric distance (mm)

σc: Compressive Stress of Concrete (N/mm^2)

σs: Tensile Stress of Reinforcing (N/mm^2)

M: Bending Moment (N.mm) =96.656

Calculation Result

x = 115.05mm

σc	= 3.44N/mm2	<	σca=0.4fcu=9.6 N/mm2	OK
σs	= 127.9 N/mm2	<	σsa=0.4fy=168 N/mm2	OK

2.6 Calculation of Calculation of Approach Slab Support

2.6.1 Calculation of Sectional Force

Mu = Ru・bu = 47.745 (kN.m)

Ru = Rf+T/3.00 = 95.490 (kN)

Rf = 1/2*(W1+W2+q)*L = 22.762 (kN)

Sectinal Force by Self Weight

	Calculation	Area Ai (m2)	Distance to center of gravity X (m)	Ai・Xi
①	0.500 × 0.300	0.150	0.250	0.038
②	1/2 × 0.500 × 0.500	0.125	0.167	0.021
Total		0.275	———	0.058

Self Weight Rg = ΣAi・γ = 0.275・24.500 = 6.738 (kN)

Poinit of appriction Xg = Σ(Ai・Yi)/ΣAi = 0.058/0.275 = 0.212 (m)

Bending Moment Mg = Rg・Xg = 6.875・0.212 = 1.429 (kN.m)

Total Bendibg Moment M = Mu+Mg = 47.745+1.429 = 49.174 (kN.m)

Shear Force S = Ru+Rg = 95.490+6.738 = 102.227 (kN)

2.6.2 Calculation of Stress

(1) Calculation of Bending Stress

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As' \cdot \frac{(x-d') \cdot (h/2-d')}{x} + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

$$x^2 + \frac{2 \cdot n}{b} \{As' \cdot (x-d') + As \cdot (x-d)\} = 0.0$$

Calculation Result

Reinforcement Bar: **D16@250**

x = 17.77mm

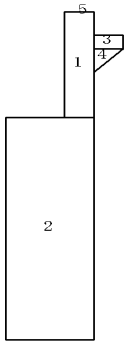
σc = 1.26N/mm2 < σca=0.4fcu=9.6 N/mm2 OK

σs = 93.69 N/mm2 < σsa=0.4fy=168 N/mm2 OK

2.7 Design of Abutment Wall

2.7.1 Block data that doesn't consider water level

(1)Block dividing



Division	Calculation formula Width × Height × Depth	Volume Vi(m^3)	Barycentric Position		Vi・Xi	Vi・Yi
			Xi	Yi		
1	0.500× 1.858× 13.900	12.913	1.250	4.171	16.141	53.861
2	1.500× 3.242× 13.900	67.596	0.750	1.621	50.697	109.573
3	0.500× 0.300× 9.700	1.455	1.750	4.383	2.546	6.377
4	1/2× 0.500× 0.500× 9.700	1.212	1.667	4.066	2.021	4.930
Σ		83.176	——	——	71.405	174.741

Center of gravity XG = Σ(Vi・Xi)/ΣVi = 71.405/ 83.176 = 0.858 (m)

YG = Σ(Vi・Yi)/ΣVi = 174.741/ 83.176 =2.101 (m)

2.7.2 Sectionnal force from self weight,superstructure

(1) Self Weight

Vertical Force W = γ ・ V = 200 × 83.176 = 2037.819 (kN)

Poinit of appriction X = 0.858 (m)

(2) Superstructure Reaction

[1]S.L.D Group Ⅰ

Vertical Force Rv = 4160 (kN)

Poinit of appriction X = 0.300 (m)

Horizontal Force RH = 0.000(kN).

Poinit of appriction Y = 3.242 (m)

$$X=\frac{B}{2}\ (BR-XR)=\ 0.750-0.450=0.300\ \ m$$

where

B : Thickness of wall

BR: Distance from the front side of wall to the front side of parapet

XR: Distance from the front side of parapet to action position

Action position horizontal force

Y = YZ+YR = 3.242+0.000 = 3.242 (m)

where

YZ: Height of wall

YR: Height of horizontal force acting position

[2]S.L.D Group III

Rv = 4160.000 (kN)

X = 0.300 (m)

RH = 40.000 (kN)

Y = 3.242 (m)

[3]S.L.D Group VII

Rv = 3380.000 (kN)

X = 0.300 (m)

RH = 510.000 (kN)

Y = 3.242 (m)

[4]L.F.D Group I

Rv = 6088 (kN)

X = 0.300 (m)

RH = 0.000 (kN)

Y = 3.242 (m)

[5]L.F.D Group III

Rv = 5408 (kN)

X = 0.300 (m)

RH = 50.000 (kN)

Y = 3.242 (m)

[6]L.F.D Group VII

Rv = 4394 (kN)

X = 0.300 (m)

RH = 660.000 (kN)

Y = 3.242 (m)

2.7.3 Earth pressure and hydraulic pressure

(1) General data

Unit Weight of Water : $\gamma w(kN/m^3)$	10.0
Width of soil pressure action : Bc (m)	13.9
Height in which soil pressure is not considered : hr (m)	0.000
cohesion of soil : C (kN/m^2)	0.000

(2) Earth pressure

[1]S.L.D Group Ⅰ、Ⅲ

1)Data for earthl pressure calculation

Surcharge : q (kN/m^2)	10.00
Height from back water level to top : H1 (m)	5.10
Height of back water level to bottom : H2 (m)	0.000
Height in which hydraulic pressure is calculated : Hs (m)	0.000

2) Calculation result of earthl pressure

	Item	Value
Parameter	Acting height (Upper section) HU(m)	5.100
	Acting height (Lower section) HL(m)	0.000
	rom water level of the back to the top h1	5.100
	Height from water level of the back to the lower side of Fo	0.000
	Height of water level of the back hs(m)	0.000
	Height in which soil pressure is not considered hr(m)	0.000
	Intersection angle of abutment wall and vertical (deg.) θ	0.000
	Friction angle of soil and wall (deg.)	10.000
	Wet density of backfill soil (kN/m^3)	19.000
	Saturation density of backfill soil	20.000
	Action starting point of earthl pressure (Xoordinates) (m)	2.500
Coefficient of earth pressure	Coefficient of earth pressure from water level of the back above(upper) Ku1	0.3085
	Coefficient of earth pressure from water level of the back above(lower) Ku11	0.3085
	Coefficient of earth pressure below from water level of the back (upper) Ku2	0.3085
	Coefficient of earth pressure below from water level of the back (lower) Ku22	0.3085
Earth pressure	[1] Earth pressure strength abobe water level (uppet)	3.085
	[2] Earth pressure strength abobe water level (lower)	32.975
	[3] Earth pressure strength below water level (upper)	0.000
	[4] Earth pressure strength below water level (lower)	0.000
Earth pressure force	Pe1 = (1/2)・([1]+[2])・h1・Bc	1278.134
	Pe2 = (1/2)・([3]+[4])・h2・Bc	0.000
	Pe = Pe1+Pe2	1278.134
	Peh = Pe・cos(δ+θ) (Horizontal element of earth pressure)	1258.717
Poinit of appricatio n	Y1 = (2・[1]+[2])・h1/{3・([1]+[2])}+h2+HL+hr	1.845
	Y2 = (2・[3]+[4])・h2/{3・([3]+[4])}+HL+hr	0.000
	Y = (Pe1・Y1+Pe2・Y2)/Pe	1.845

・Poinit of appricationn

$$Y=\frac{\Sigma(Peh*Y)}{\Sigma Peh} = 1.845 \text{ m}$$

・Earth pressur force

Horizontal Force

$$Ph=\Sigma Peh = 1258.72 \text{ kN}$$

[2]S.L.D Group Ⅶ

1)Data for earthl pressure calculation

Surcharge : q (kN/m^2)	0.00
Height from back water level to top : H1 (m)	5.10
Height of back water level to bottom : H2 (m)	0.000
Height in which hydraulic pressure is calculated : Hs (m)	0.000

2) Calculation result of earthl pressure

	Item	Value
Parameter	Acting height (Upper section) HU(m)	5.100
	Acting height (Lower section) HL(m)	0.000
	rom water level of the back to the top h1	5.100
	Height from water level of the back to the lower side of Fo	0.000
	Height of water level of the back hs(m)	0.000
	Height in which soil pressure is not considered hr(m)	0.000
	Intersection angle of abutment wall and vertical (deg.) θ	0.000
	Friction angle of soil and wall (deg.)	10.000
	Wet density of backfill soil (kN/m^3)	19.000
	Saturation density of backfill soil	20.000
	Action starting point of earthl pressure (Xoordinates) (m)	2.500
Coefficient of earth pressure	Coefficient of earth pressure from water level of the back above(upper) Ku1	0.4128
	Coefficient of earth pressure from water level of the back above(lower) Ku11	0.4128
	Coefficient of earth pressure below from water level of the back (upper) Ku2	0.4128
	Coefficient of earth pressure below from water level of the back (lower) Ku22	0.4128
Earth pressure	[1] Earth pressure strength abobe water level (uppet)	0.000
	[2] Earth pressure strength abobe water level (lower)	40.000
	[3] Earth pressure strength below water level (upper)	0.000
	[4] Earth pressure strength below water level (lower)	0.000
Earth pressure force	Pe1 = (1/2)・([1]+[2])・h1・Bc	1417.811
	Pe2 = (1/2)・([3]+[4])・h2・Bc	0.000
	Pe = Pe1+Pe2	1417.811
	Peh = Pe・cos(δ+θ) (Horizontal element of earth pressure)	1417.811
Poinit of appricatio n	Y1 = (2・[1]+[2])・h1/{3・([1]+[2])}+h2+HL+hr	1.700
	Y2 = (2・[3]+[4])・h2/{3・([3]+[4])}+HL+hr	0.000
	Y = (Pe1・Y1+Pe2・Y2)/Pe	1.700

・Poinit of appricationn

$$Y=\frac{\Sigma(Peh*Y)}{\Sigma Peh} = 1.700 \text{ m}$$

・Earth pressur force

Horizontal Force

$$Ph = \Sigma Peh = 1417.81 \text{ kN}$$

[3]L.F.D Group Ⅰ～Ⅲ

1)Data for earthl pressure calculation

Surcharge : q (kN/m^2)	13.00
Height from back water level to top : H1 (m)	5.10
Height of back water level to bottom : H2 (m)	0.000
Height in which hydraulic pressure is calculated : Hs (m)	0.000

2) Calculation result of earthl pressure

	Item	Value
Parameter	Acting height (Upper section) HU(m)	5.100
	Acting height (Lower section) HL(m)	0.000
	rom water level of the back to the top h1	5.100
	Height from water level of the back to the lower side of Fo	0.000
	Height of water level of the back hs(m)	0.000
	Height in which soil pressure is not considered hr(m)	0.000
	Intersection angle of abutment wall and vertical (deg.) θ	0.000
	Friction angle of soil and wall (deg.)	10.000
	Wet density of backfill soil (kN/m^3)	19.000
	Saturation density of backfill soil	20.000
	Action starting point of earthl pressure (Xoordinates) (m)	2.500
Coefficient of earth pressure	Coefficient of earth pressure from water level of the back above(upper) Ku1	0.3085
	Coefficient of earth pressure from water level of the back above(lower) Ku11	0.3085
	Coefficient of earth pressure below from water level of the back (upper) Ku2	0.3085
	Coefficient of earth pressure below from water level of the back (lower) Ku22	0.3085
Earth pressure	[1] Earth pressure strength abobe water level (uppet)	4.010
	[2] Earth pressure strength abobe water level (lower)	42.867
	[3] Earth pressure strength below water level (upper)	0.000
	[4] Earth pressure strength below water level (lower)	0.000
Earth pressure force	Pe1 = (1/2)・([1]+[2])・h1・Bc	1661.575
	Pe2 = (1/2)・([3]+[4])・h2・Bc	0.000
	Pe = Pe1+Pe2	1661.575
	Peh = Pe・cos(δ+θ) (Horizontal element of earth pressure)	1636.332
Poinit of appricatio n	Y1 = (2・[1]+[2])・h1/{3・([1]+[2])}+h2+HL+hr	1.845
	Y2 = (2・[3]+[4])・h2/{3・([3]+[4])}+HL+hr	0.000
	Y = (Pe1・Y1+Pe2・Y2)/Pe	1.845

・Poinit of appricatio

$$Y=\frac{\Sigma(Peh*Y)}{\Sigma Peh} = 1.845 \text{ m}$$

・Earth pressur force

Horizontal Force

$$Ph=\Sigma Peh = 1636.33 \text{ kN}$$

[4]L.F.D Group Ⅶ

1)Data for earthl pressure calculation

Surcharge : q (kN/m^2)	0.00
Height from back water level to top : H1 (m)	5.10
Height of back water level to bottom : H2 (m)	0.000
Height in which hydraulic pressure is calculated : Hs (m)	0.000

2) Calculation result of earthl pressure

	Item	Value
Parameter	Acting height (Upper section) HU(m)	5.100
	Acting height (Lower section) HL(m)	0.000
	rom water level of the back to the top h1	5.100
	Height from water level of the back to the lower side of Fo	0.000
	Height of water level of the back hs(m)	0.000
	Height in which soil pressure is not considered hr(m)	0.000
	Intersection angle of abutment wall and vertical (deg.) θ	0.000
	Friction angle of soil and wall (deg.)	10.000
	Wet density of backfill soil (kN/m^3)	19.000
	Saturation density of backfill soil	20.000
	Action starting point of earthl pressure (Xoordinates) (m)	2.500
Coefficient of earth pressure	Coefficient of earth pressure from water level of the back above(upper) Ku1	0.4128
	Coefficient of earth pressure from water level of the back above(lower) Ku11	0.4128
	Coefficient of earth pressure below from water level of the back (upper) Ku2	0.4128
	Coefficient of earth pressure below from water level of the back (lower) Ku22	0.4128
Earth pressure	[1] Earth pressure strength abobe water level (uppet)	0.000
	[2] Earth pressure strength abobe water level (lower)	52.000
	[3] Earth pressure strength below water level (upper)	0.000
	[4] Earth pressure strength below water level (lower)	0.000
Earth pressure force	Pe1 = (1/2)・([1]+[2])・h1・Bc	1843.155
	Pe2 = (1/2)・([3]+[4])・h2・Bc	0.000
	Pe = Pe1+Pe2	1843.155
	Peh = Pe・cos(δ+θ) (Horizontal element of earth pressure)	1843.155
Poinit of appricatio n	Y1 = (2・[1]+[2])・h1/{3・([1]+[2])}+h2+HL+hr	1.700
	Y2 = (2・[3]+[4])・h2/{3・([3]+[4])}+HL+hr	0.000
	Y = (Pe1・Y1+Pe2・Y2)/Pe	1.700

・Poinit of appricationn

$$Y=\frac{\Sigma(Peh*Y)}{\Sigma Peh} = 1.700 \text{ m}$$

・Earth pressur force

Horizontal Force

$$Ph = \Sigma Peh = 1843.16 \text{ kN}$$

2.7.4 Summary of Sectional Force

(1) Service Load Design

[1]S.L.D Group I

Loadings	N_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M = M_{xi} + M_{yi}$ (kN.m)
Self Weight	2037.819	0.000	-0.108	0.000	-220.084
Superstruture Reaction	4160.000	0.000	0.300	3.242	1248.000
Other Load	0.000	0.000	0.100	0.000	0.000
Earth Pressure	0.000	1258.717	0.000	1.845	2322.333
Back Hydraulic Pressure(back)	0.000	0.000	0.000	0.000	0.000
Back Hydraulic Pressure(flont)	0.000	0.000	0.000	0.000	0.000
Total	6197.819	1258.717	————	————	3350.248
unit width	445.886	90.555	————	————	241.025

[2]S.L.D Group III

Loadings	N_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M = M_{xi} + M_{yi}$ (kN.m)
Self Weight	2037.819	0.000	-0.108	0.000	-220.084
Superstruture Reaction	4160.000	40.000	0.300	3.242	1377.680
Other Load	0.000	0.000	0.100	0.000	0.000
Earth Pressure	0.000	1258.717	0.000	1.845	2322.333
Back Hydraulic Pressure(back)	0.000	0.000	0.000	0.000	0.000
Back Hydraulic Pressure(flont)	0.000	0.000	0.000	0.000	0.000
Total	6197.819	1298.717	————	————	3479.928
unit width	445.886	93.433	————	————	250.355

[3]S.L.D Group VII

Loadings	N_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M = M_{xi} + M_{yi}$ (kN.m)
Self Weight	2037.819	407.564	-0.108	2.101	636.207
Superstruture Reaction	3380.000	510.000	0.300	3.242	2667.420
Other Load	0.000	0.000	0.100	0.000	0.000
Earth Pressure	0.000	1417.811	0.000	1.700	2410.279
Back Hydraulic Pressure(back)	0.000	0.000	0.000	0.000	0.000
Back Hydraulic Pressure(flont)	0.000	0.000	0.000	0.000	0.000
Total	5417.819	2335.375	————	————	5713.906
unit width	389.771	168.013	————	————	411.072

(2) Load Factor Design

[4]L.F.D Group Ⅰ

Loadings	N_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M = M_{xi} + M_{yi}$ (kN.m)
Self Weight	2649.165	0.000	-0.108	0.000	-286.110
Superstruture Reaction	5408.000	0.000	0.300	3.242	1622.400
Other Load	0.000	0.000	0.100	0.000	0.000
Earth Pressure	0.000	1636.332	0.000	1.845	3019.033
Back Hydraulic Pressure(back)	0.000	0.000	0.000	0.000	0.000
Back Hydraulic Pressure(flont)	0.000	0.000	0.000	0.000	0.000
Total	8057.165	1636.332	————	————	4355.323
unit width	579.652	117.722	————	————	313.333

[5]L.F.D Group Ⅲ

Loadings	N_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M = M_{xi} + M_{yi}$ (kN.m)
Self Weight	2649.165	0.000	-0.108	0.000	-286.110
Superstruture Reaction	5408.000	50.000	0.300	3.242	1784.500
Other Load	0.000	0.000	0.100	0.000	0.000
Earth Pressure	0.000	1636.332	0.000	1.845	3019.033
Back Hydraulic Pressure(back)	0.000	0.000	0.000	0.000	0.000
Back Hydraulic Pressure(flont)	0.000	0.000	0.000	0.000	0.000
Total	8057.165	1686.332	————	————	4517.423
unit width	579.652	121.319	————	————	324.994

[6]L.F.D Group Ⅰ、Ⅲ

Loadings	N_i (kN)	H_i (kN)	X_i (m)	Y_i (m)	$M = M_{xi} + M_{yi}$ (kN.m)
Self Weight	2649.165	529.833	-0.108	2.101	827.069
Superstruture Reaction	4394.000	660.000	0.300	3.242	3457.920
Other Load	0.000	0.000	0.000	0.000	0.000
Earth Pressure	0.000	1843.155	0.000	1.700	3133.364
Back Hydraulic Pressure(back)	0.000	0.000	0.000	0.000	0.000
Back Hydraulic Pressure(flont)	0.000	0.000	0.000	0.000	0.000
Total	7043.165	3032.988	————	————	7418.353
unit width	506.703	218.201	————	————	533.694

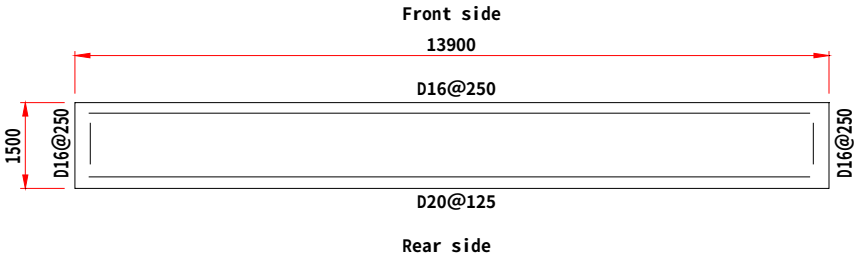
2.7.5 Calculation of Stress

(1) Reinforcement Arrangement

Nos. of Reinforcement Bars　　4 Nos (Rear：@250、Front@250、Side：@250)

Total area of bars

Rear：	4-D20 (@250)	314.2×4＝	1256.8	mm^2
Front：	4-D16 (@250)	201.1× 4＝	804.4	mm^2
Side：	10-D16 (@250)	201.1× 10＝	2011.0	mm^2



(2) Calculation of Stress

$$\sigma_c = \frac{N}{\frac{b \cdot x}{2} - n \cdot As \cdot \frac{d-x}{x} + n \cdot As' \cdot \frac{x-d'}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

$$x^3 - 3 \cdot \left(\frac{h}{2} - e\right) \cdot x^2 - \frac{6n}{b} \left\{As' \cdot \left(\frac{h}{2} - d' - e\right) + As \cdot \left(\frac{h}{2} - d - e\right)\right\} \cdot x + \frac{6n}{b} \left\{As' \cdot d' \cdot \left(\frac{h}{2} - d' - e\right) + As \cdot d \cdot \left(\frac{h}{2} - d - e\right)\right\} = 0.0$$

in which,

x : Distance from edge on compression side to neutral axis (mm)

h : Height of Member (mm), h = 500.000

b : Width in section (mm), b = 1000.000

d : Effective height (mm) = 415

d' : Concrete Cover (mm) =85

As : Sectional area of reinforcing bar arranged on tension side (mm^2) = D25@125

As': Sectional area of reinforcing bar arranged on compression side (mm^2) = D25@250

n : Elastic Modulus Ratio of Reinforce and Concrete , n = 15.00

e : Axis force eccentric distance (mm)

σc: Compressive Stress of Concrete (N/mm^2)

σs: Tensile Stress of Reinforcing (N/mm^2)

N: Axial Force (kN)

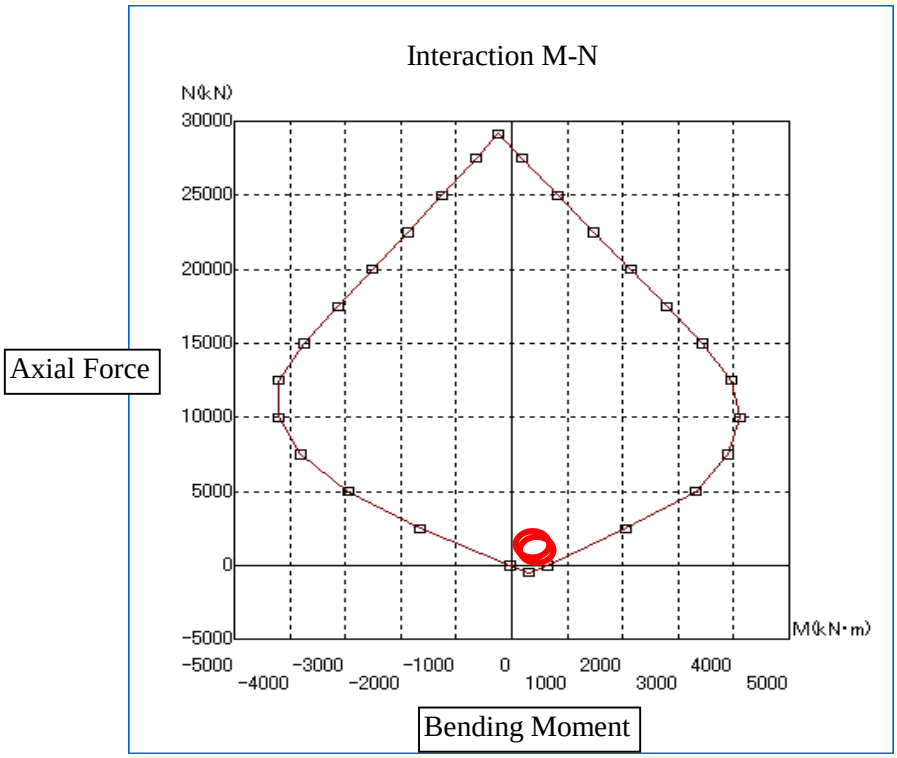
Calculation Result

Load Case	M	N	x	σc	σs	σca	σsa
S.L.D GRoup I	241.0	445.9	762.900	1.22	15.2	9.6	168.0
S.L.D GRoup III	250.4	445.9	725.700	1.29	17.9	12.0	210.0
S.L.D GRoup VII	411.1	389.8	382.400	2.78	114.5	12.8	223.4

(3) Checking of Flexural Strength

List of Sectinal Force at Base of Wall

Load Case	M (kN.m)	N (kN.)	S (kN.)
L.F.D GRoup I	313.3	579.7	117.7
L.F.D GRoup III	325.0	579.7	121.3
L.F.L GRoup VII	533.7	506.703	218.2



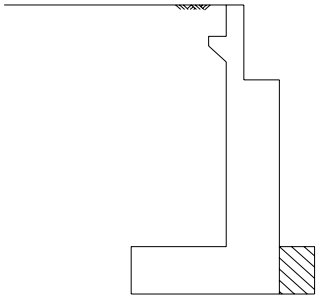
N(kN)	Mr(kN·m	N(kN)	Mr(kN·m
27500	195.211	0	-36.997
25000	843.888	2500	-1672.05
22500	1491.273	5000	-2950.325
20000	2139.408	7500	-3800.319
17500	2786.853	10000	-4217.841
15000	3434.778	12500	-4201.77
12500	3963.703	15000	-3754.716
10000	4111.096	17500	-3133.537
7500	3901.996	20000	-2512.018
5000	3333.959	22500	-1890.307
2500	2075.14	25000	-1269.737
0	631.593	27500	-648.494
-475.07	308.81	29161.96	-235.274

2.8 Design of Flont Footing

2.8.1 Block data that doesn't consider water level

(1) Self Weight

1) Block dividing



2) Self-respect and center of gravity

Division	Calculation formula	Volume V1	Barycentric Position	Vi・Xi
	Width × Height × Depth	Vi(m^3)	Xi(m)	
1	1.000× 1.200× 13.9	16.68	0.5	13.057
Σ		16.68	———	13.057

Barycentric Position XG = Σ(Vi・Xi)/ΣVi = 13.057/26.115 = 0.500 (m)

2.8.2 Vertical force by self-weight , backfill soil,buoyancy and other load

(1) Self Weight

Vertical Force $W = \gamma \cdot V =$ $24.50 \times 16.680 = 408.660$ (kN)

Poinit of appication $X =$ 0.500 (m)

(2) Backfill soil and buoyancy

1) Backfill

Weight of Backfill 1.000*1.800*13.9*18 Wb = 450.360 (kN)

Poinit of appication Xi= 0.500 (m)

2) buoyancy

Front water level Hf = 1.200(m)

Water level of the back Hr = 1.200 (m)

Hydraulic pressure in flont of footing Pf = 12.000 (kN/m^2)

Hydraulic pressure in flont of footing Pr = 12.000 (kN/m^2)

Uplift pressure

$$Pu = \frac{Pf+Pr}{2} \quad Bj*Bc = \quad 166.8 \quad (kN)$$

Poinit of appication

$$Xu = \frac{Pf+2 \cdot Pr}{3 \cdot (Pf+Pr)} \quad \cdot Bj = \quad 0.500 \quad (kN)$$

where,

Bj : Footing Width at longitudinal direction Bj = 1.000 (m)

Bc : Footing Width at transvese direction Bc = 13.900 (m)

2.8.3 Subgrade Reaction

Vertical Force
V = (q1+q2)/2*L

Poinit of apprication:Xi

$$X = \frac{(2q1+q2)}{(q1+q2)} \times L/3$$

in which
q1,q2 : Subgrade Reaction (kN/m^2)
X : Arm Length (m)
L : Front footing Length (m)

Load Case		Subgrade Reaction		Virtical Force	X	ΣVXi
		q1(kN/m^2)	q2(kN/m^2)	(kN)	(m)	(kN·m)
S.L.S	Group I	243.2	217.2	3199.3	0.509	1629.7
	Group III	246.9	219.3	3240.2	0.510	1652.2
	Group VII	406.5	293.4	4863.8	0.527	2562.9
L.F.D	Group I	293.1	275.1	3949.1	0.505	1995.5
	Group III	322.2	286.4	4230.0	0.510	2156.5
	Group VII	512.6	374.3	6164.0	0.526	3242.2

2.8.4 Summary of Secsinal Force

[1] S.L.D Group- Ⅰ

Loadings	V (kN)	X (m)	M =N_i · X_i (kN.m)
Self Weight	-408.660	0.500	-204.330
Flont Backfill Soil	-450.360	0.500	-225.180
Side Backfill Soil	0.000	0.000	0.000
Total of backfill Soil	-450.360	0.500	-225.180
Buoyancy	166.800	0.500	83.400
Subgrade Reaction	3199.284	0.509	1629.733
Total	2507.064	——	1283.623
unit width	180.364	——	92.347

[2] S.L.D Group-Ⅲ

Loadings	V (kN)	X (m)	M =N_i · X_i (kN.m)
Self Weight	-408.660	0.500	-204.330
Flont Backfill Soil	-450.360	0.500	-225.180
Side Backfill Soil	0.000	0.000	0.000
Total of backfill Soil	-450.360	0.500	-225.180
Buoyancy	166.800	0.500	83.400
Subgrade Reaction	3240.231	0.510	1652.156
Total	2548.011	——	1306.046
unit width	183.310	——	93.960

[3] S.L.D Group-Ⅶ

Loadings	V (kN)	X (m)	M =N_i · X_i (kN.m)
Self Weight	-408.660	0.500	-204.330
Flont Backfill Soil	-450.360	0.500	-225.180
Side Backfill Soil	0.000	0.000	0.000
Total of backfill Soil	-450.360	0.500	-225.180
Buoyancy	166.800	0.500	83.400
Subgrade Reaction	4863.845	0.527	2562.917
Total	4171.625	——	2216.807
unit width	300.117	——	159.483

[4] L.F.D Group- Ⅰ

Loadings	V (kN)	X (m)	M =N_i · X_i (kN.m)
Self Weight	-408.660	0.500	-204.330
Flont Backfill Soil	-450.360	0.500	-225.180
Side Backfill Soil	0.000	0.000	0.000
Total of backfill Soil	-450.360	0.500	-225.180
Buoyancy	166.800	0.500	83.400
Subgrade Reaction	3949.091	0.505	1995.477
Total	3256.871	——	1649.367
unit width	234.307	——	118.659

[5] L.F.D Group-Ⅲ

Loadings	V (kN)	X (m)	$M = N_i \cdot X_i$ (kN.m)
Self Weight	-408.660	0.500	-204.330
Flont Backfill Soil	-450.360	0.500	-225.180
Side Backfill Soil	0.000	0.000	0.000
Total of backfill Soil	-450.360	0.500	-225.180
Buoyancy	166.800	0.500	83.400
Subgrade Reaction	4230.001	0.510	2156.498
Total	3537.781	——	1810.388
unit width	254.517	——	130.244

[6] L.F.D Group-Ⅶ

Loadings	V (kN)	X (m)	$M = N_i \cdot X_i$ (kN.m)
Self Weight	-408.660	0.500	-204.330
Flont Backfill Soil	-450.360	0.500	-225.180
Side Backfill Soil	0.000	0.000	0.000
Total of backfill Soil	-450.360	0.500	-225.180
Buoyancy	166.800	0.500	83.400
Subgrade Reaction	6164.007	0.526	3242.243
Total	5471.787	——	2896.133
unit width	393.654	——	208.355

2.8.5 Calculation of Stress

(1)Serviceability Limit State

Stress and Crack Width checked with the Load Case S-Lc.4-2

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2}-\frac{x}{3}\right)+n \cdot As' \cdot \frac{(x-d') \cdot (h/2-d')}{x}+n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

$$x^2+ \frac{2 \cdot n}{b} \left\{As' \cdot (x-d')+As \cdot (x-d)\right\}=0.0$$

in which,

x : Distance from edge on compression side to neutral axis (mm)

h : Height of Member (mm), h = 1200

b : Width in section (mm), b = 1000

d : Effective height (mm) = 1090

d' : Concrete Cover (mm) =110

As : Sectional area of reinforcing bar arranged on tension side (mm^2) D20@250

As': Sectional area of reinforcing bar arranged on compression side (mm^2) = D22@250

n : Elastic Modulus Ratio of Reinforce and Concrete , n = 15.00

σc: Compressive Stress of Concrete (N/mm^2)

σs: Tensile Stress of Reinforcing (N/mm^2)

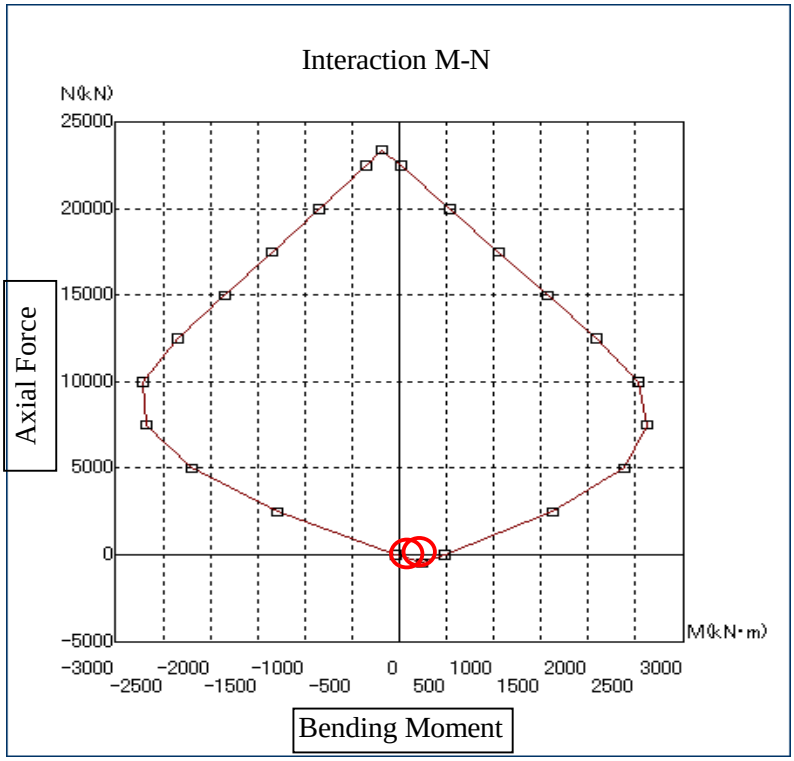
M: Bending Moment (kN.m)

Calculation Result

Load Case	M (kNm/m)	S (kN)	σc (N/mm^2)	σs (N/mm^2)	σca (N/mm^2)	σsa (N/mm^2)
S.L.D-Group Ⅰ	92.3	180.36	1.00	71.4	9.6	168.0
S.L.D-Group Ⅲ	94.0	183.31	1.00	72.7	12.0	210.0
S.L.D-Group Ⅶ	159.5	300.12	1.70	123.4	12.8	223.4

(2) Load Factor Design

Load Case	M (kN.m)	N (kN.)	S (kN.)
L.F.D GRoup Ⅰ	118.7	-	234.3
L.F.D GRoup Ⅲ	130.2	-	254.5
L.F.L GRoup Ⅶ	208.4	-	393.7

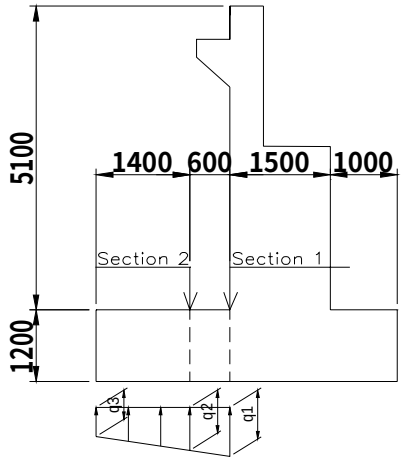


N(kN)	Mr(kN·m
22500	9.826
20000	530.286
17500	1050.304
15000	1570.488
12500	2090.805
10000	2534.269
7500	2622.629
5000	2385.136
2500	1618.384
0	488.575

2.9 Design of Rear Footing

2.9.1 Block data

(1) Self Weight,Backfill , Buoyancy and Subgrade Reaction



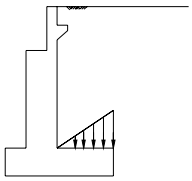
1) Section-①

Load Comb.	Self Weight (kN)	Backfill (kN)	Buoyancy (kN)	ΣW (kN)	Subgrade Reaction			
					q1 (kN/m2)	q3 (kN/m2)	q(kN)	x(m)
S.L.S Group Ⅰ	-817.320	-2693.820	333.600	-3177.540	178.2	126.3	4232.004	0.943
S.L.S Group Ⅲ	-817.320	-2693.820	333.600	-3177.540	177.8	122.5	4173.508	0.939
S.L.S Group Ⅶ	-817.320	-2693.820	333.600	-3177.540	123.7	0.0	940.983	0.365
L.F.D Group Ⅰ	-817.320	-2693.820	333.600	-3177.540	248.0	211.8	6391.118	0.974
L.F.D Group Ⅲ	-817.320	-2693.820	333.600	-3177.540	232.7	161.0	5472.180	0.939
L.F.D Group Ⅶ	-817.320	-2693.820	333.600	-3177.540	166.8	0.0	1397.466	0.402

2) Section-②

Load Comb.	Self Weight (kN)	Backfill (kN)	Buoyancy (kN)	ΣW (kN)	Subgrade Reaction			
					q2 (kN/m2)	q3 (kN/m2)	q(kN)	x(m)
S.L.S Group Ⅰ	-572.124	-1885.674	233.520	-2224.278	162.6	126.3	2810.743	0.671
S.L.S Group Ⅲ	-572.124	-1885.674	233.520	-2224.278	161.2	122.5	2759.969	0.668
S.L.S Group Ⅶ	-572.124	-1885.674	233.520	-2224.278	55.9	0.0	191.944	0.165
L.F.D Group Ⅰ	-572.124	-1885.674	233.520	-2224.278	237.1	211.8	4368.288	0.687
L.F.D Group Ⅲ	-572.124	-1885.674	233.520	-2224.278	211.2	161.0	3621.379	0.669
L.F.D Group Ⅶ	-572.124	-1885.674	233.520	-2224.278	83.8	0.0	352.631	0.202

(2) Earth Pressure



Vertical element of earth pressure

$$Ew = \frac{Pev}{L \cdot B}$$

$$N = (qr+qf) \cdot L \cdot \frac{B}{2.0}$$

Poinit of appication

$$X = \frac{2.0 \cdot qr+qf}{3 \cdot (qr+qf)}$$

in which
Pev: Vertical element of earth pressure
qf : Distribution load strength of rear end earth pressure vertical element
qr : Distribution load of earthl pressure vertical element of design position
L: Rear footing length. L=2.000 (m)
B: Width of earth pressure action B = 13.90 (m)

Section	Load Case	Ew (kN/m)	qf (kN/m2)	qr (kN/m2)	N (kN)	X (m)	M=N·x (kN·m)
①	S.L.S Group Ⅰ,Ⅲ	-64.423	0.000	-64.423	-895.485	1.333	-1193.682
①	S.L.S Group Ⅶ	-39.823	0.000	-39.823	-553.534	1.333	-737.861
①	L.F.D Group Ⅰ,Ⅲ	-83.750	0.000	-83.750	-1164.131	1.333	-1551.786
①	L.F.D Group Ⅶ	-51.770	0.000	-51.770	-719.594	1.333	-959.219
②	S.L.S Group Ⅰ,Ⅲ	-64.423	-19.327	-64.423	-814.891	0.826	-673.100
②	S.L.S Group Ⅶ	-39.823	-11.947	-39.823	-503.716	0.826	-416.069
②	L.F.D Group Ⅰ,Ⅲ	-83.750	-25.125	-83.750	-1059.358	0.826	-875.030
②	L.F.D Group Ⅶ	-51.770	-15.531	-51.770	-654.831	0.826	-540.890

(3) Surcharge

Poinit of apprication

where
q: Surcharge load
qd : Surcharge load strength (dead load)
ql : Surcharge load strength (live load)
B: Surchage load length at transvers direction, B = 13.900 (m)
Ls: Distance from design section to load action position
L: Length on which load acts(m)

Section	Load Case	q (kN/m^2)	Ls (m)	L (m)	Vertical N (kN)	Poinit of X (m)	M=N·x (kN・m)
①	S.L.S Group Ⅰ,Ⅲ	-10.000	0.000	2.000	-278.000	1.000	-278.000
①	L.F.D Group Ⅰ,Ⅲ	-13.000	0.000	2.000	-361.400	1.000	-361.400
②	S.L.S Group Ⅰ,Ⅲ	-10.000	0.000	1.400	-194.600	0.700	-136.220
②	L.F.D Group Ⅰ,Ⅲ	-13.000	0.000	1.400	-252.980	0.700	-177.086

(4) Summary of Sectional Force for Service Limit State

a) Section ①

Bending Moment

(unit:kN·m)

Load Case	Self Weight,Backfill, Buoyancy	Earth pressurer	Surcharge	Subgrade Reaction	Total Moment	unit width
S.L.S Group Ⅰ	-3177.540	-1193.682	-278.000	3991.274	-657.947	-47.334
S.L.S Group Ⅲ	-3177.540	-1193.682	-278.000	3917.180	-732.041	-52.665
S.L.S Group Ⅶ	-3177.540	-737.861	0.000	343.202	-3572.199	-256.993
L.F.D Group Ⅰ	-3177.540	-1551.786	-361.400	6223.667	1132.941	81.507
L.F.D Group Ⅲ	-3177.540	-1551.786	-361.400	5140.200	49.474	3.559
L.F.D Group Ⅶ	-3177.540	-959.219	0.000	561.604	-3575.155	-257.205

B) Section ②

Bending Moment

(unit:kN·m)

Load Case	Self Weight,Backfill, Buoyancy	Earth pressurer	Surcharge	Subgrade Reaction	Total Moment	unit width
S.L.S Group Ⅰ	-1556.995	-673.100	-136.220	1884.950	-481.365	-34.631
S.L.S Group Ⅲ	-1556.995	-673.100	-136.220	1844.058	-522.257	-37.572
S.L.S Group Ⅶ	-1556.995	-416.069	0.000	31.618	-1941.446	-139.672
L.F.D Group Ⅰ	-1556.995	-875.030	-177.086	3000.366	391.255	28.148
L.F.D Group Ⅲ	-1556.995	-875.030	-177.086	2421.096	-188.015	-13.526
L.F.D Group Ⅶ	-1556.995	-540.890	0.000	71.187	-2026.698	-145.806

Shearing Force

(unit:kN)

Load Case	Self Weight,Backfill, Buoyancy	Earth pressurer	Surcharge	Subgrade Reaction	Total Shearing Force	unit width
S.L.S Group Ⅰ	-572.124	-814.891	-194.600	2810.743	1229.128	88.426
S.L.S Group Ⅲ	-572.124	-814.891	-194.600	2759.969	1178.354	84.774
S.L.S Group Ⅶ	-572.124	-503.716	0.000	191.944	-883.896	-63.590
L.F.D Group Ⅰ	-572.124	-1059.358	-252.980	4368.288	2483.826	178.693
L.F.D Group Ⅲ	-572.124	-1059.358	-252.980	3621.379	1736.916	124.958
L.F.D Group Ⅶ	-572.124	-654.831	0.000	352.631	-874.324	-62.901

2.9.2 Calculation of Stress
(1)Service Load Design

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As' \cdot \frac{(x-d') \cdot (h/2-d')}{x} + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

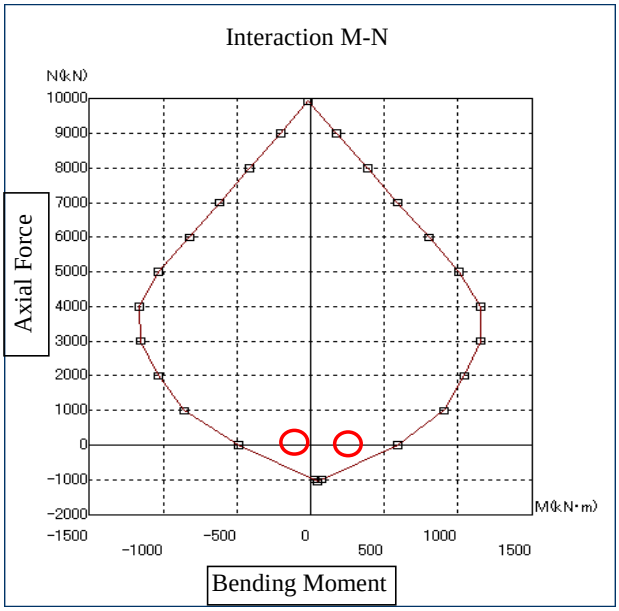
b : Width in section (mm), b = 1000
d : Effective height (mm) = 1426
d' : Concrete Cover (mm) =74
As : Sectional area of reinforcing bar arranged on tension side (mm^2) D22@250
As': Sectional area of reinforcing bar arranged on compression side (mm^2) = D20@250
n : Elastic Modulus Ratio of Reinforce and Concrete , n = 15.00
σc: Compressive Stress of Concrete (N/mm^2)
σs: Tensile Stress of Reinforcing (N/mm^2)
M: Bending Moment (kN.m)

Calculation Result
Section ①

Load Case	M (kNm/m)	X (m)	σc (N/mm^2)	σs (N/mm^2)	σca (N/mm^2)	σsa (N/mm^2)
S.L.D-Group Ⅰ	47.3	0.194	0.40	30.5	9.6	168.0
S.L.D-Group Ⅲ	52.7	0.194	0.50	33.9	12.0	210.0
S.L.D-Group Ⅶ	257.0		2.50	165.4	12.8	223.4

(2) Load Factor Design

Load Case	M (kNm/m)
L.F.D Group Ⅰ	-81.5
L.F.D Group Ⅲ	-3.6
L.F.D Group Ⅶ	257.2



N(kN)	Mr(kN·m
9933.251	-15.517
9000	178.537
8000	386.13
7000	593.863
6000	801.536
5000	1009.227
4000	1149.448
3000	1150.933
2000	1043.89
1000	901.931
0	587.251

(3) Calculation of Shearing Stress

Shear Strength "Vn" is Calculated as follows.

Vn= Vc + Vs

In Which

Vc : Normal Shear Strength provided by the Concrete

Vc = vc x bw x d (vc=0.08 √ f'c)

= 0.08 √ f'c x bw x d)

f'c : 28days Cylinder Strength

bw : Width of Section

d : Effective Height of Section

Vs : Normal Shear Strength provided by the Shear Reinforcement

Vs = Av x fy x d / s

Av : Area of Shear Reinforcement within a distancees.

fy : Yeild Strength of Shear Reinforcement

d : Effective Height of Section

s : Calculated Distance.

Factored Shear Force for Load Factor Design

		Longitudinal Direction
Load Factor Design	Group-I	178.7 kN
	Group-III	125.0 kN
	Group-VII	-62.9 kN

Calculation of Shear Strength

vc = 0.08 √ f'c = 0.08 √ (24) = 0.39N/mm^2 -> 390kN/m^2

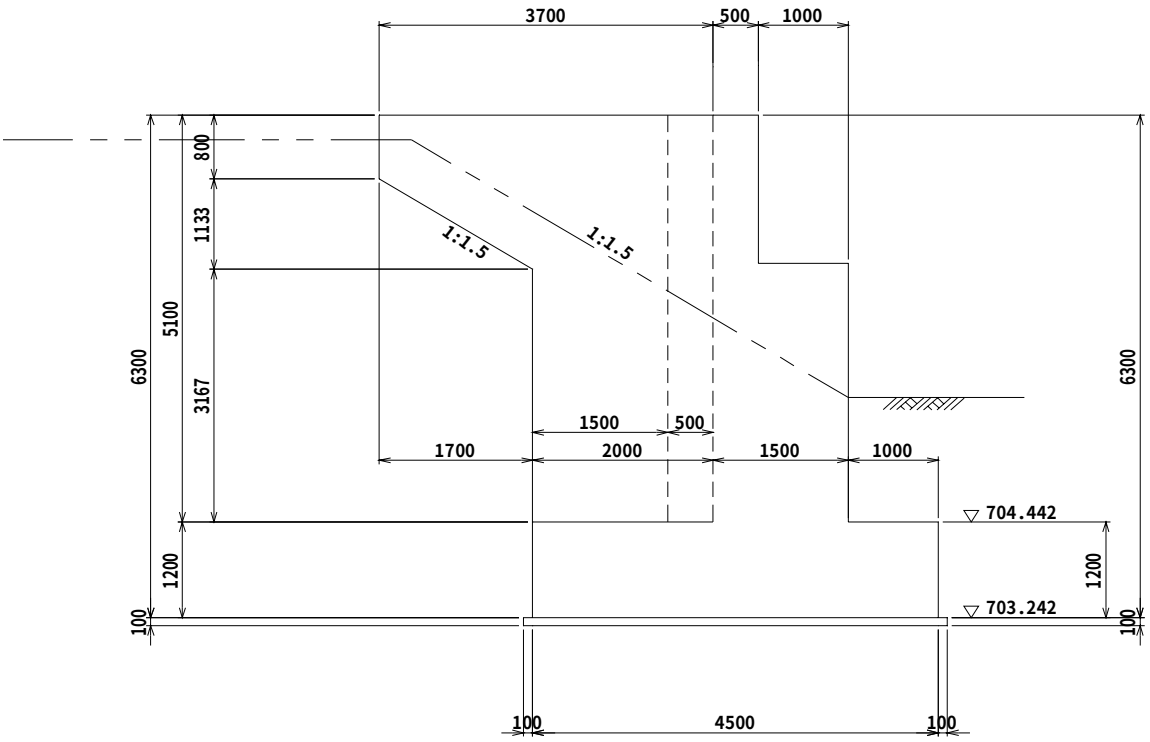
fy = 420 N/mm^2 -> 420000 kN/m^2

s = 0.500 m

		Su(kN)	bw(m)	d(m)	Vc(kN)	Vsreq(kN)	Asreq(mm^2/m)
Load Factor Design	Group-I	178.7	1.000	1.090	425.10	0.00	0.0
	Group-III	125.0	1.000	1.090	425.10	0.00	0.0
	Group-VI	-62.9	1.000	1.090	425.10	0.00	0.0

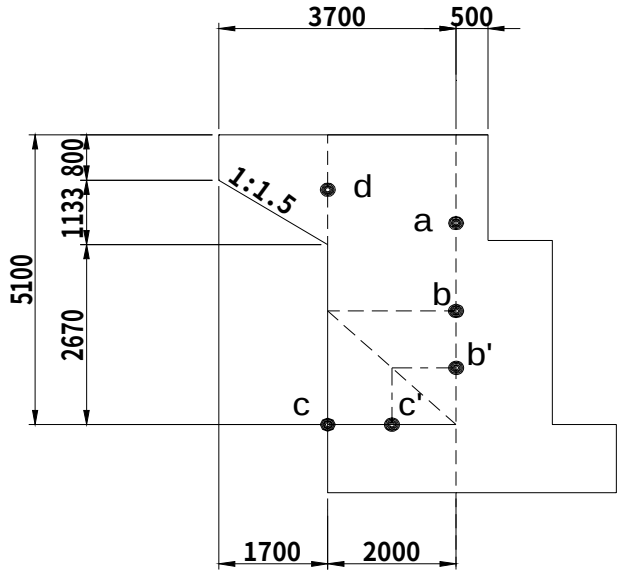
2.10 Design of Wing Wall

2.10.1 Configuration of Wing



Side Elevation of Wing Wall(Right,Left)

2.10.2 Caliculation of Sectinal Force



Thickness:700mm

(1) Service Load Design: Group Ⅰ

1) Sectional Force at Section "a"

Shear and Bending Moment due to Earth Pressure

Shear Firce

$$Sa = \frac{SA+SD}{h1} = 29.370 \quad (kN/m)$$

$$SA = \frac{1}{2} \cdot (Pa+Pb) \cdot h1 \cdot l1 = 74.301 \quad (kN)$$

$$Pa = q \cdot Ka \cdot \cos\delta = 3.038 \quad (kN/m^2)$$

Bending Moment

$$Ma = \frac{MA+SD \cdot l1+MD}{h1} = 38.402 \quad (kN.m/m)$$

$$MA = SA \cdot \frac{l1}{2} = 74.301 \quad (kN.m)$$

2) Sectional Force at Section “b”

Shear and Bending Moment due to Earthpressure

Shear Firce

$$Sb = Pb \cdot l1 = 41.861 \quad (kN/m)$$

Bending Moment

$$Mb = Sb \cdot \frac{l1}{2} = 41.861 \quad (kN.m/m)$$

$$Pb = (q+\gamma s \cdot h1) \cdot Ka \cdot \cos\delta = 20.930$$

3) Sectional Force at Section “b’”

Shear and Bending Moment due to Earthpressure

Shear Firce

$$Sb' = Pb' \cdot \frac{l1}{2} = 26.702 \quad (kN/m)$$

Bending Moment

$$Mb' = Sb' \cdot \frac{l1}{4} = 13.351 \quad (kN \cdot m)$$

$$Pb' = \left\{q+\gamma s \cdot \left(h1+\frac{h2}{2}\right)\right\} \cdot Ka \cdot \cos\delta = 26.702$$

4) Sectional Force at Section " c "

Shear and Bending Moment due to Earth Pressure

Shear Firce $Sc = \frac{1}{2} \cdot (Pb+Pc) \cdot 11 = 53.404$ (kN/m)

Bending Moment $Mc = Sc \cdot \frac{2 \cdot Pb+Pc}{3 \cdot (Pb+Pc)} \cdot 11 = \frac{1}{6} \cdot (2 \cdot Pb+Pc) \cdot 11^2$

$= 49.557$ (kN. m/m)

$Pc = \{q+\gamma s \cdot (h1+h2)\} \cdot Ka \cdot \cos\delta = 32.474$ (kN/m²)

5) Sectional Force at Section " c '"

Shear and Bending Moment due to Earth Pressure

Shear Firce $Sc' = \frac{1}{2} \cdot (Pb'+Pc') \cdot \frac{11}{2} = 29.588$ (kN/m)

Bending Moment $Mc' = Sc' \cdot \frac{2 \cdot Pb'+Pc'}{3 \cdot (Pb'+Pc')} \cdot \frac{11}{2} = \frac{1}{6} \cdot (2 \cdot Pb'+Pc') \cdot \left(\frac{11}{2}\right)^2$

$= 14.313$ (kN. m/m)

$Pc' = \{q+\gamma s \cdot (h1+h2)\} \cdot Ka \cdot \cos\delta = 32.474$ (kN/m²)

6) Sectional Force at Section " d "

Shear and Bending Moment due to Earth Pressure

Shear Firce $Sd = \frac{SD}{h4} = 8.662$ (kN/m)

$SD = Pd = Pd1+Pd2 = 16.746$ (kN)

$Pd1 = q \cdot \left(h3 \cdot 12 + \frac{12^2}{2 \cdot n}\right) \cdot Ka \cdot \cos\delta$

$= 7.058$ (kN)

$Pd2 = \frac{1}{2} \cdot \gamma s \cdot \left(h3^2 \cdot 12 + \frac{h3 \cdot 12^2}{n} + \frac{12^3}{3 \cdot n^2}\right) \cdot Ka \cdot \cos\delta$

$= 9.689$ (kN)

Bending Moment

$$Md = \frac{MD}{h4} = 5.820 \quad (kN.m/m)$$

$$MD = Pd \cdot ld = Pd1+Pd2 = 11.252 \quad (kN.m)$$

$$Pd1 = q \cdot \left(\frac{h3 \cdot 12^2}{2} + \frac{12^3}{6 \cdot n} \right) \cdot Ka \cdot \cos \delta$$

$$= 5.170 \quad (kN.m)$$

$$Pd2 = \frac{1}{2} \cdot \gamma s \cdot \left(\frac{h3^2 \cdot 12^2}{2} + \frac{h3 \cdot 12^3}{3 \cdot n} + \frac{12^4}{12 \cdot n^2} \right) \cdot Ka \cdot \cos \delta$$

$$= 6.082 \quad (kN.m)$$

in which

h1 : Height of fixed part at upper side (m) , h1 = 3.100
h2 : Height of fixed part at upper side (m) , h2 = 2.000
h3 : Height of the tip of cantilever (m) , h3 = 0.800
h4 : Height of the basal part of cantilever (m), h4 = 1.933
l1 : Width of fixed part (m) , l1 = 2.000
l2 : Width of the cantilever section (m) , l2 = 1.700
n : Incline of lower side , n = 1.500
td : Thickness of Wing Wall (m) , td = 0.700
q : Surcharge Load (kN/m^2)
q = 10.00
Ka : Coefficient of Earth pressure
Ka = 0.3085
δ : Angle of wall friction (deg)
δ = 12.50 (kN/m^2)
γs: Unit weight of soil(kN/m^3) , γs = 19.000
γc: Unit weight of Reinforced Concrete (kN/m^3) , γc = 24.500

Section	Load Type	M (kN.m)	S (kN)
a	Earth Pressure	38.402	29.37
b	Earth Pressure	41.861	41.861
b’	Earth Pressure	13.351	26.702
c	Earth Pressure	49.557	53.404
c’	Earth Pressure	14.313	29.588
d	Earth Pressure	5.820	8.662

⑵ Service Load Design: Group Ⅶ

1) Sectional Force at Section "a"

Shear and Bending Moment due to Earth Pressure, Seismic nertia force

$Sa = 28.561$ (kN/m)

$Ma = 35.474$ (kN. m/m)

$$Sa = \frac{SA+SD}{h1} = 6.736 \quad (kN/m)$$

$$Ma = \frac{MA+SD \cdot l1+MD}{h1} = 9.917 \quad (kN.\ m/m)$$

$$SA = h1 \cdot l1 \cdot td \cdot \gamma c \cdot Kh = 15.190 \quad (kN)$$

$$MA = SA \cdot \frac{l1}{2} = 15.190 \quad (kN.\ m)$$

2) Sectional Force at Section “b”

Shear and Bending Moment due to Earth Pressure, Seismic nertia force

$Sb = Pb \cdot l1 = 48.628$ (kN/m)

$Mb = Sb \cdot \frac{l1}{2} = 48.628$ (kN. m/m)

20.930

$Sb = l1 \cdot td \cdot \gamma c \cdot Kh = 4.900$ (kN/m)

$Mb = Sb \cdot \frac{l1}{2} = 4.900$ (kN. m/m)

3) Sectional Force at Section “b’”

Shear and Bending Moment due to Earth Pressure, Seismic nertia force

$Sb' = 32.157$ (kN/m)

$Mb' = 16.079$ (kN. m/m)

$$Sb' = \frac{l1}{2} \cdot td \cdot \gamma c \cdot Kh = 2.450 \quad (kN/m)$$

$$Mb' = Sb' \cdot \frac{l1}{4} = 1.225 \quad (kN.\ m/m)$$

4) Sectional Force at Section “ C ”

Shear and Bending Moment due to Earth Pressure, Seismic nertia force

$Sc = 64.314$ (kN/m)

$Mc = 59.085$ (kN. m/m)

$$Sc = l1 \cdot td \cdot \gamma c \cdot Kh = 4.900 \quad (kN/m)$$

$$Mc = Sc \cdot \frac{l1}{2} = 4.900 \quad (kN.\ m/m)$$

5) Sectional Force at Section "c'"

Shear and Bending Moment due to Earth Pressure, Seismic nertia force

$Sc' = 36.079$ (kN/m)

$Mc' = 17.386$ (kN.m/m)

$$Sc' = \frac{11}{2} \cdot td \cdot \gamma c \cdot Kh = 2.450 \quad (kN/m)$$

$$Mc' = Sc' \cdot \frac{11}{4} = 1.225 \quad (kN.m/m)$$

6) Sectional Force at Section "d"

Shear and Bending Moment due to Earth Pressure, Seismic nertia force

$Sd = 6.810$ (kN/m)

$Md = 4.275$ (kN.m/m)

$$Sd = \frac{SD}{h4}$$

$$= 2.944 \quad (kN/m)$$

$$SD = \left(h3 \cdot 12 + \frac{12^2}{2 \cdot n}\right) \cdot td \cdot \gamma c \cdot Kh$$

$$= 5.692 \quad (kN)$$

$$Md = \frac{MD}{h4}$$

$$= 2.157 \quad (kN.m/m)$$

$$MD = \left(\frac{h3 \cdot 12^2}{2} + \frac{12^3}{6 \cdot n}\right) \cdot td \cdot \gamma c \cdot Kh$$

$$= 4.170 \quad (kN.m)$$

Section	Load Type	M (kN.m)	S (kN)
a	S.L.D Group Ⅶ	45.391	35.297
b	S.L.D Group Ⅶ	53.528	53.528
b'	S.L.D Group Ⅶ	17.304	34.607
c	S.L.D Group Ⅶ	63.985	69.214
c'	S.L.D Group Ⅶ	18.611	38.529
d	S.L.D Group Ⅶ	6.432	9.754

(3) Load Factor Design

Group Ⅰ

Section	Load Type	M (kN.m)	S (kN)
a	L.F.D Group Ⅰ	49.923	38.181
b	L.F.D Group Ⅰ	54.419	54.419
b’	L.F.D Group Ⅰ	17.356	34.713
c	L.F.D Group Ⅰ	64.424	69.425
c’	L.F.D Group Ⅰ	18.607	38.464
d	L.F.D Group Ⅰ	8.362	11.183

Group Ⅶ

Section	Load Type	M (kN.m)	S (kN)
a	L.F.D Group Ⅶ	59.008	45.886
b	S.L.D Group Ⅶ	69.586	69.586
b’	S.L.D Group Ⅶ	22.495	44.989
c	S.L.D Group Ⅶ	83.181	89.978
c’	S.L.D Group Ⅶ	24.194	50.088
d	S.L.D Group Ⅶ	8.362	12.680

2.10.3 Calculation of Stress

(1) Calculation of Stress

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As' \cdot \frac{(x-d') \cdot (h/2-d')}{x} + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

$$x^2 + \frac{2 \cdot n}{b} \left\{As' \cdot (x-d') + As \cdot (x-d)\right\} = 0.0$$

b : Width in section (mm), b = 1000

d : Effective height (mm)

d' : Concrete Cover (mm) =74

As : Sectional area of reinforcing bar arranged on tension side (mm^2) D25@125=3926.99

As': Sectional area of reinforcing bar arranged on compression side (mm^2) = D16@250=804.25

n : Elastic Modulus Ratio of Reinforce and Concrete , n = 15.00

σc: Compressive Stress of Concrete (N/mm^2)

σs: Tensile Stress of Reinforcing (N/mm^2)

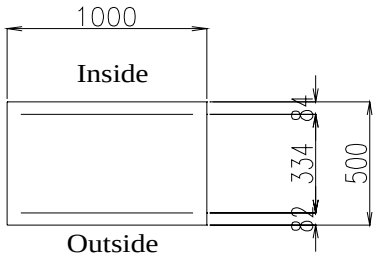
M: Bending Moment (kN.m)

S.L.D Group Ⅰ

Section	Reinforcement-bar Arranngement		Calculation Result		
	Inside (mm^2)	Outside (mm2)	x (mm)	σc (N/mm2)	σs (N/mm^2)
a	D16-4Nos.=804.25	D16-4Nos.=804.25	89.100	2.2	123.1
b	D16-4Nos.=804.25	D16-4Nos.=804.25	89.100	2.4	134.2
b'	D16-4Nos.=804.25	D16-4Nos.=804.25	89.100	0.8	42.8
c	D20-4Nos.=804.25	D16-4Nos.=1256.6	105.300	3.4	108.1
c'	D16-4Nos.=804.25	D16-4Nos.=804.25	105.300	0.7	31.2
d	D16-4Nos.=804.25	D16-4Nos.=804.25	89.100	0.3	18.7
		allowable stress		σca=9.6	σsa=168

S.L.D Group Ⅶ

Section	Reinforcement-bar Arranngement		Calculation Result		
	Inside (mm^2)	Outside (mm2)	x (mm)	σc (N/mm2)	σs (N/mm^2)
a	D16-4Nos.=804.25	D16-4Nos.=804.25	89.100	2.6	145.3
b	D16-4Nos.=804.25	D16-4Nos.=804.25	89.100	3.1	171.4
b'	D16-4Nos.=804.25	D16-4Nos.=804.25	89.100	1.0	55.4
c	D20-4Nos.=804.25	D16-4Nos.=1256.6	105.300	3.6	152.7
c'	D16-4Nos.=804.25	D16-4Nos.=804.25	105.300	1.0	40.6
d	D16-4Nos.=804.25	D16-4Nos.=804.25	89.100	0.4	20.6
		allowable stress		σca=12.8	σsa=223

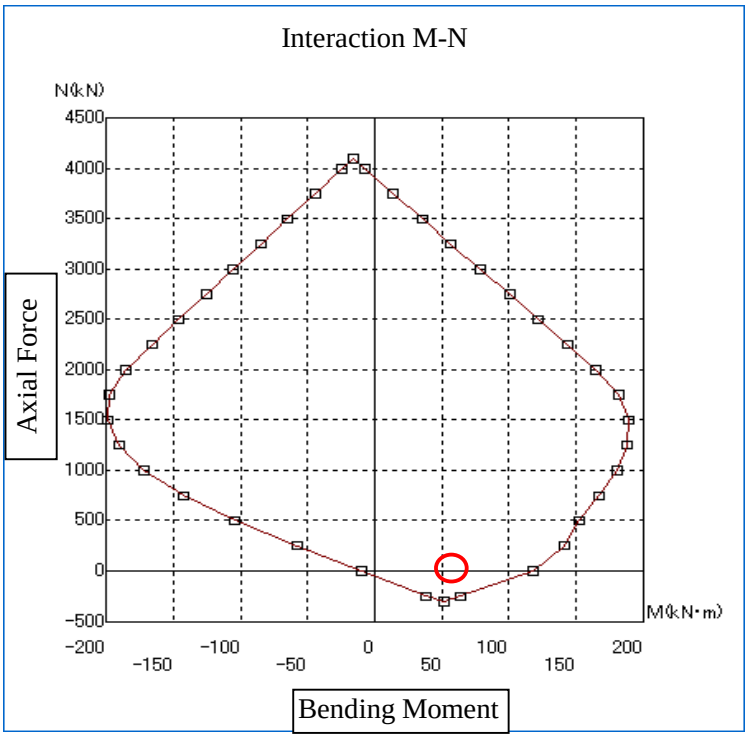


Unit:mm

2.10.4 Checking of Flexural Strength

Reinfocement Bar 4-D16

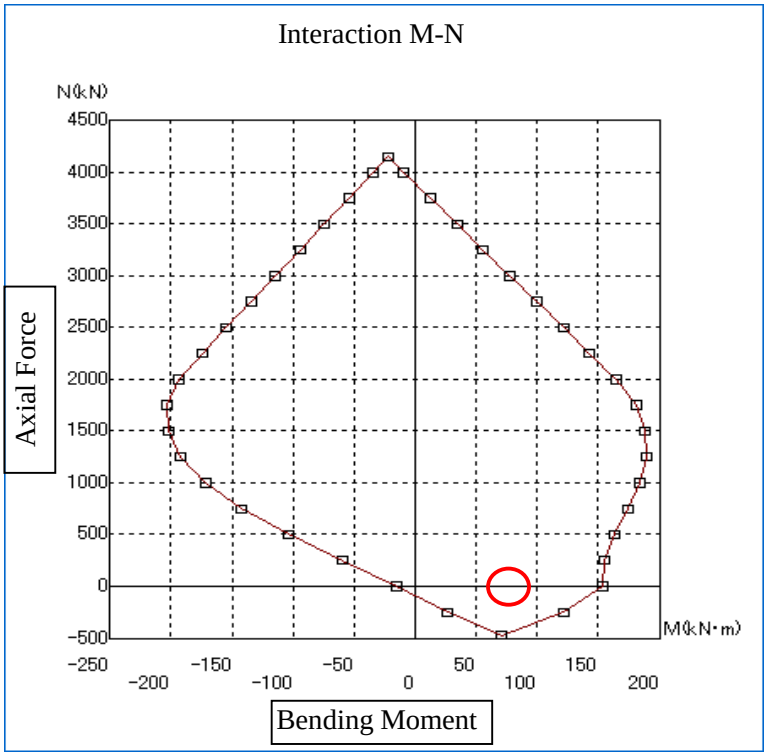
L.F.D Group Ⅰ、Ⅶ



N(kN)	Mr(kN·m
4000	-7.855
3750	13.772
3500	35.476
3250	57.122
3000	78.762
2750	100.404
2250	143.714
2000	165.353
1750	181.777
1500	189.228
1250	188.423
1000	180.543
750	167.587
500	152.88
250	141.366
0	118.042

Reinfocement Bar 4-D20

L.F.D Group Ⅰ、Ⅶ

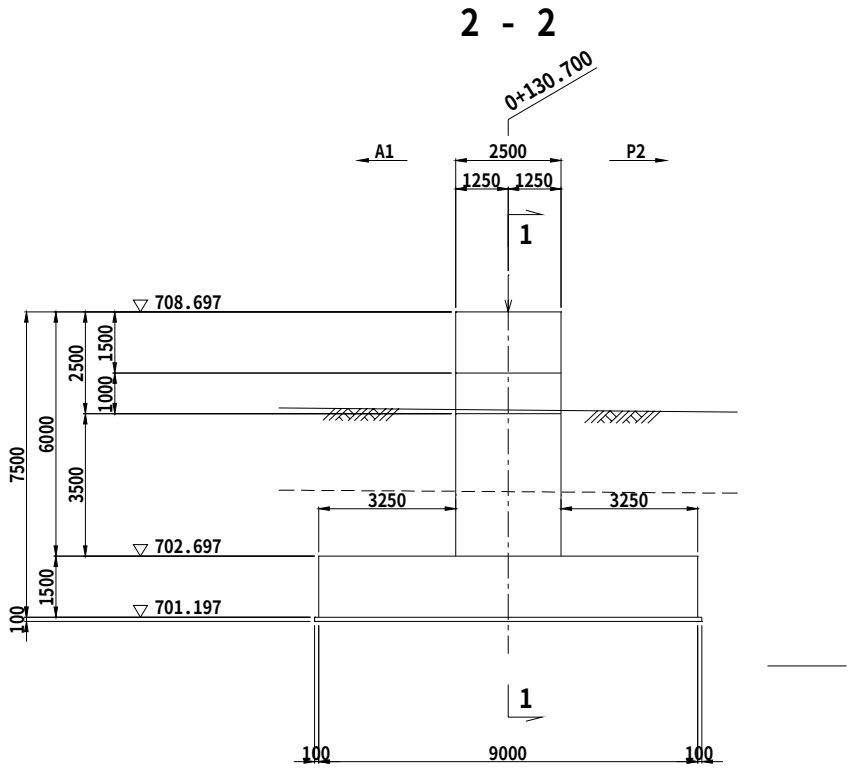


N(kN)	Mr(kN·m
4150.792	-22.619
4000	-9.458
3750	12.285
3500	34.083
3250	55.873
3000	77.64
2750	99.419
2500	121.205
2250	143.006
2000	164.696
1750	180.982
1500	188.857
1250	189.215
1000	183.449
750	173.689
500	163.006
250	155.22
0	153.81

3. Design of P1 Pier

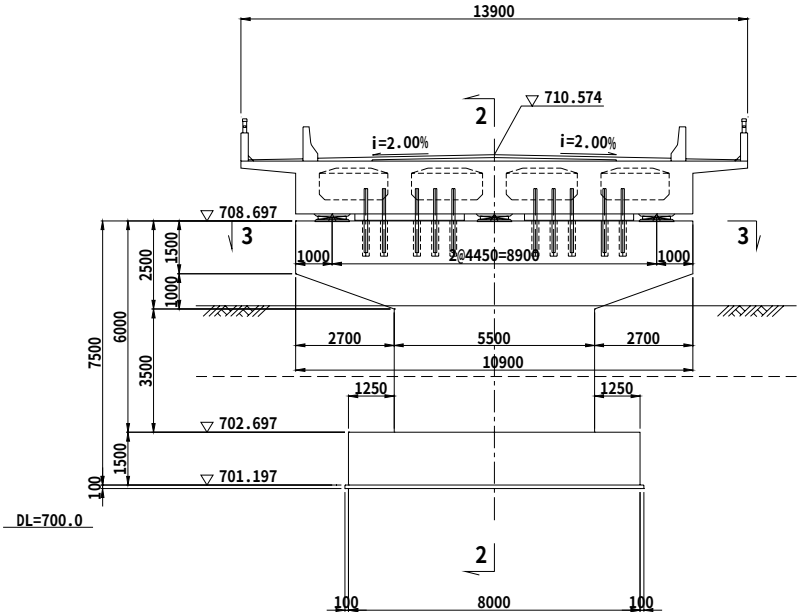
3.1 General Arrangement

Side Elevation



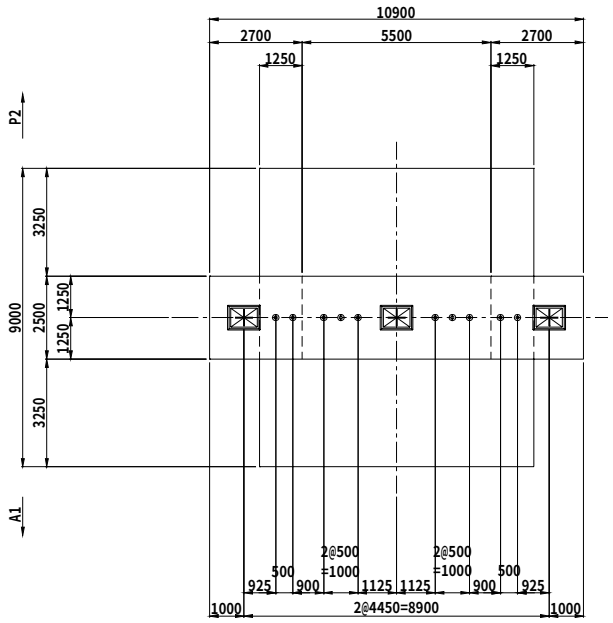
Front Elevation

1 - 1

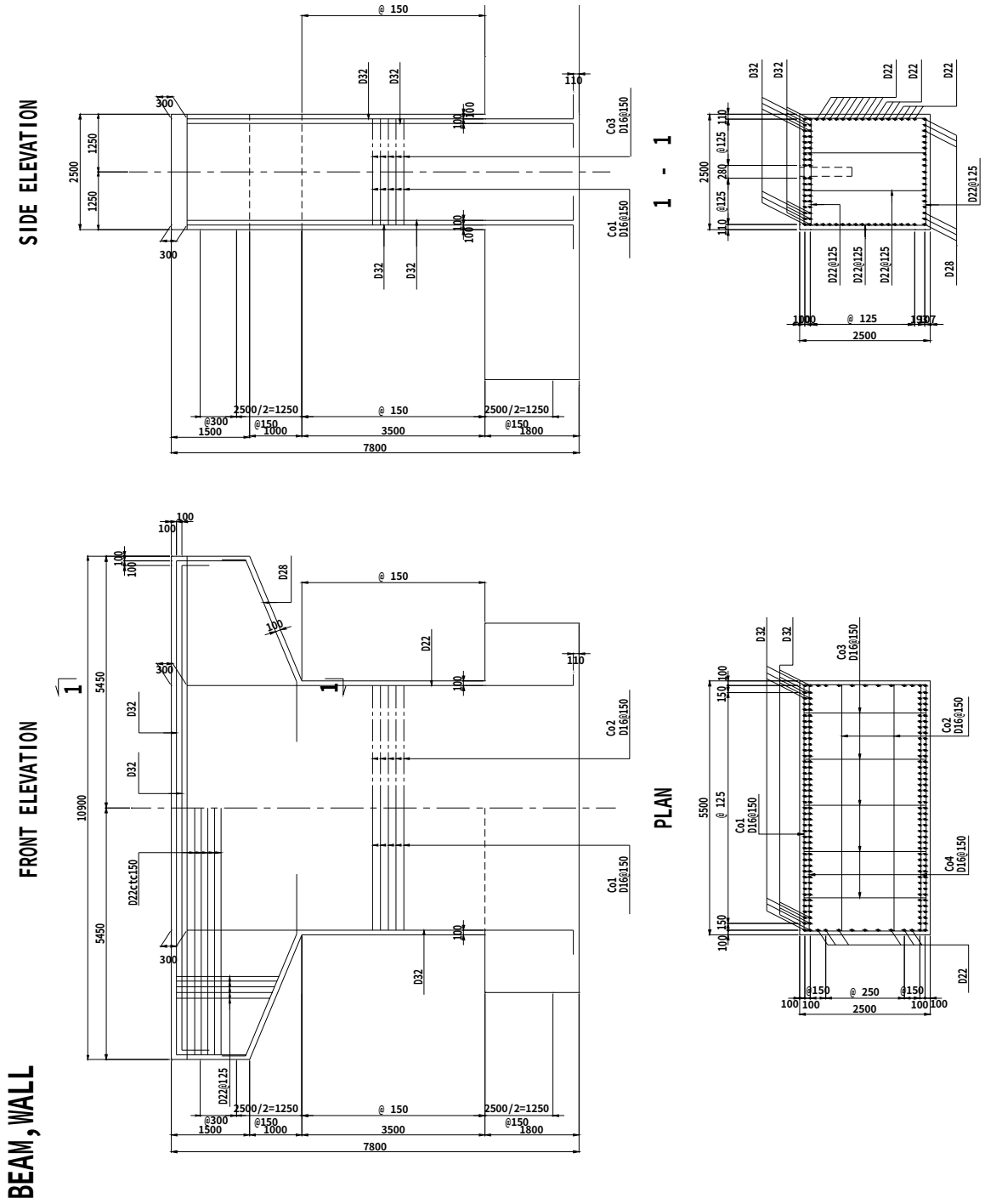


Plan

3 - 3

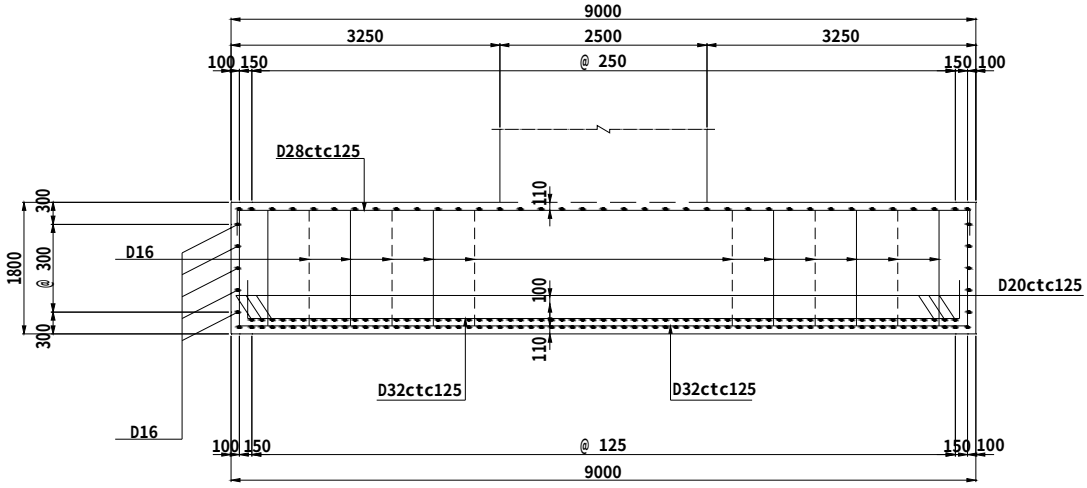


3.2 Bar Arrangement

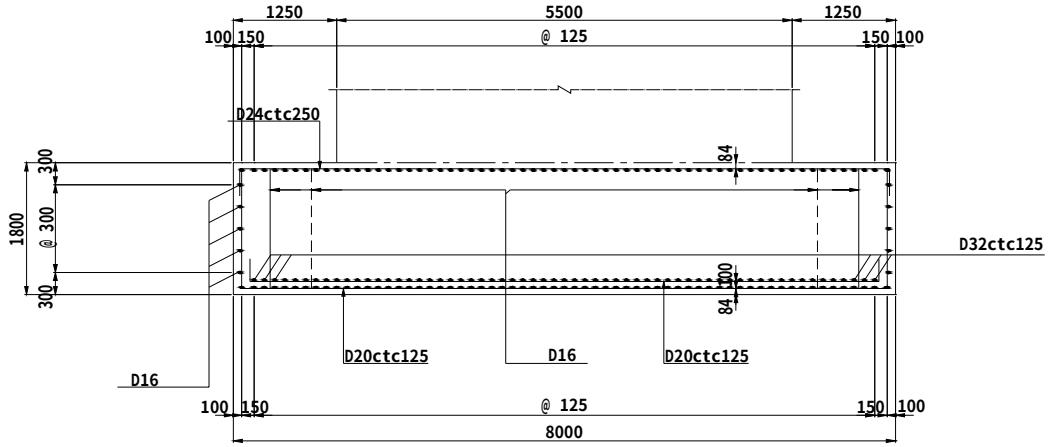


FOOTING

LONGITUDINAL DIRECTION

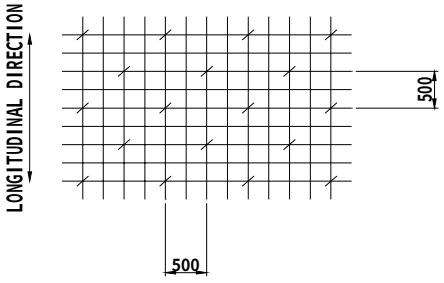


TRANSVERSE DIRECTION



ARRANGEMENT OF STIRRUP

TRANSVERSE DIRECTION



3.3.Design Seismic Coefficient

The design seismic coefficient for P1 Pier is given by the following formula

$$Kh = \frac{Cs}{R}$$

$$Cs = \frac{1.2*A*S}{T^{2/3}}$$

in which,

Kh : Design Seismic Coefficient

Cs : Elastic Seismic Response Coefficient

R : Response Modifications Factor

Wall-type pier	R=2	← P1 Pier
Reinforced concrete pile bents		
a. Vertical piles only	R=3	
b. One or more batter piles	R=2	
Single columns	R=3	
Multiple column bent	R=5	

A : Acceleration Coefficient

A= 0.35

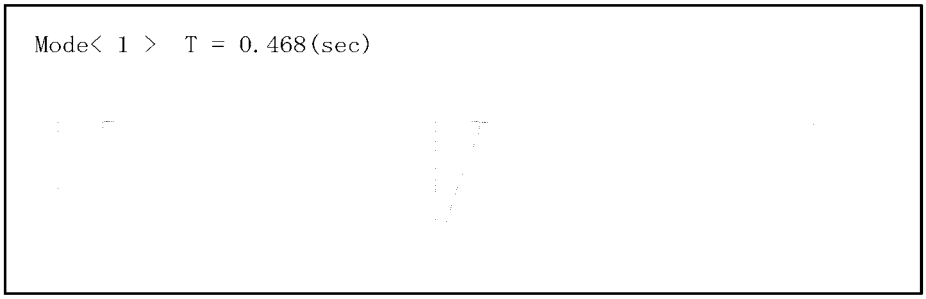
S : dimensionless coefficient for the soil profile characteristics of the site

Soil Profile Type		
Ⅰ	S=1.0	← P1 Pier
Ⅱ	S=1.2	
Ⅲ	S=1.5	
Ⅳ	S=2.0	

T : Period of the bridge(sec)

(1) Longitudinal Direction

R=2, A=0.35, S=1.0, T=0.47sec



Mode< 2 > T = 0.371(sec)

Mode< 3 > T = 0.317(sec)

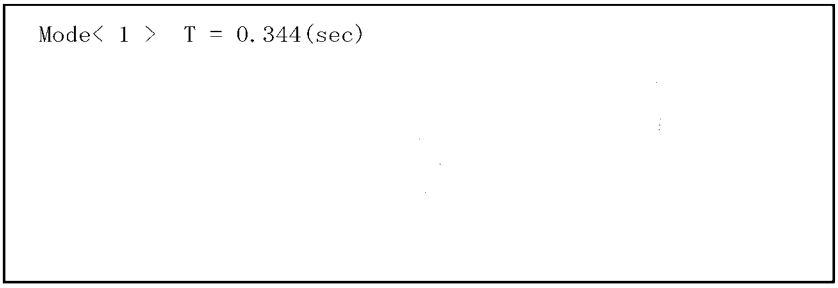
Mode< 4 > T = 0.202(sec)

$$Cs = \frac{1.2*A*S}{T^{2/3}} = \frac{1.2*0.35*1.0}{(0.47)^{2/3}} = 0.695$$

$$Kh = \frac{Cs}{R} = \frac{0.695}{2} = 0.347 \rightarrow \underline{0.35}$$

(2) Transverse Direction

R=2, A=0.35, S=1.0, T=0.34sec



Mode< 2 > T = 0.270(sec)

Mode< 3 > T = 0.124(sec)

Mode< 4 > T = 0.079(sec)

$$Cs = \frac{1.2*A*S}{T^{2/3}} = \frac{1.2*0.35*1.0}{(0.34)^{2/3}} = 0.862$$

$$Kh = \frac{Cs}{R} = \frac{0.862}{2} = 0.431 \rightarrow \underline{0.43}$$

(3) Calculation Result of Design Seismic Coefficient

	Design Seismic Coefficient
Longitudinal Direction	Kh = 0.35
Transverse Direction	Kh = 0.43

3.4 Loading Data

3.4.1 Reaction from Superstructure

(1)Vertical Force

Loadings		Rv (kN)	Remarks
Mark	Type of Loading		
D	Self Weight of Girder	7480	
	Prestress	-330	
	Creep Effect	0	
	Total	7150	
SD	Surfacing	2330	
L	CLASS-A Loading Maximum	690	
	Impuct Factor	30	
	Footway Load	320	
	Total	1040	
S	Shrinkage	0	
T	Temparature Change (Rise)	0	
T	Temparature Difference	-310	

(2)Horizontal Force

1)Longitudinal Direction

Loadings		Rh [Fix] (kN)	Remarks
Mark	Type of Loading		
S	Shrinkage	0	
T	Temparature Change (Rise)	0	
T	Temparature Difference	0	
LF	Longitudanl Force	40	
EQ	Seismic Force	5680	

2)Transverse Direction

Loadings		Rh [Fix] (kN)	Remarks
Mark	Type of Loading		
CF	Centrifugal Force	0	
EQ	Seismic Force	4080	

3.4.2 Force at Bottom of Wall

(1)Concrete Volume and Self Weight of Substructure

Division	Calculation formula Width × Height × Depth	Volume Vi(m^3)	Gravity y(m)	Vi x y
1	1.500 x 2.700 x 2.500 x 2	20.250	5.250	106.313
2	2.700 x 1.000 / 2 x 2.500 x 2	6.750	4.167	28.125
3	5.500 x 2.500 x 6.000	82.500	3.000	247.500
4				
Σ		109.500	3.488	381.938

Self Weight of Substructure 24.5 x ΣV = 2682.750 kN

(2) Buoyancy

Division	Calculation formula Width × Height × Depth	Volume Vi(m^3)
1		-
2		-
3		-
4		-
Σ		0.000

Buoyancy -10 x ΣV = 0.000 kN

(3) Superstructure Reaction

Load		V (kN)	H (kN)	yi (m)
Self Weight of Girder	D	7150.0	0.0	6.000
Surfacing	SD	2330.0	0.0	6.000
Shrinkage	S	0.0	0.0	6.000
Live Load (CLASS-A)	L	1040.0	0.0	6.000
Longitidinal Force	LF	0.0	40.0	9.710
Centrifugal Force	CF	0.0	0.0	9.710
Temparature Change	T	0.0	0.0	6.000
Temparature Difference	T	-310.0	0.0	6.000
Longitidinal Seismic Force	EQ	0.0	5680.0	6.000
Longitidinal Seismic Force	EQ	0.0	4080.0	6.000

(4) Summary of Force For Service Load Design

1) Longitudinal Direction

Group-I	D+SD+L+CF+E+B				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Live Load CLASS-A	L	1040.0	0.0	6.000	0.0
Centrifugal Force	CF	0.0	0.0	9.710	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Total		13202.8	0.0	-	0.0

Group-II	D+SD+E+B+W				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Wind Load	W	0.0	0.0	0.000	0.0
Total		12162.8	0.0	-	0.0

Group-III	D+SD+L+CF+E+B+0.3W+WL+LF				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Live Load CLASS-A	L	1040.0	0.0	6.000	0.0
Centrifugal Force	CF	0.0	0.0	9.710	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Wind Load	0.3W	0.0	0.0	0.000	0.0
Wind Load on Live Load	WL	0.0	0.0	0.000	0.0
Longitidinal Force	LF	0.0	40.0	9.710	388.4
Total		13202.8	40.0	-	388.4

Group-IV	D+SD+L+CF+E+B+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Live Load CLASS-A	L	1040.0	0.0	6.000	0.0
Centrifugal Force	CF	0.0	0.0	9.710	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Shrinkage	S	0.0	0.0	6.000	0.0
Temparature Change	T	0.0	0.0	6.000	0.0
Temparature Difference	T	-310.0	0.0	6.000	0.0
Total		12892.8	0.0	-	0.0

Group-V	D+SD+E+B+W+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Wind Load	W	0.0	0.0	0.000	0.0
Shrinkage	S	0.0	0.0	6.000	0.0
Temparature Change	T	0.0	0.0	6.000	0.0
Temparature Difference	T	-310.0	0.0	6.000	0.0
Total		11852.8	0.0	-	0.0

Group-VI	D+SD+L+CF+E+B+0.3W+WL+LF+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Live Load CLASS-A	L	1040.0	0.0	6.000	0.0
Centrifugal Force	CF	0.0	0.0	9.710	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Wind Load	0.3W	0.0	0.0	0.000	0.0
Wind Load on Live Load	WL	0.0	0.0	0.000	0.0
Longitidinal Force	LF	0.0	40.0	9.710	388.4
Shrinkage	S	0.0	0.0	6.000	0.0
Temparature Change	T	0.0	0.0	6.000	0.0
Temparature Difference	T	-310.0	0.0	6.000	0.0
Total		12892.8	40.0	-	388.4

Group-VII	D+SD+E+B+EQ				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	939.0	3.488	3275.1
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Seismic Force	EQ	0.0	5680.0	6.000	34080.0
Total		12162.8	6619.0	-	37355.1

2) Transvers Direction

Group-I	D+SD+L+CF+E+B				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Live Load CLASS-A	L	1040.0	0.0	6.000	0.0
Centrifugal Force	CF	0.0	0.0	9.710	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Total		13202.8	0.0	-	0.0

Group-II	D+SD+E+B+W				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Wind Load	W	0.0	0.0	0.000	0.0
Total		12162.8	0.0	-	0.0

Group-III	D+SD+L+CF+E+B+0.3W+WL+LF				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Live Load CLASS-A	L	1040.0	0.0	6.000	0.0
Centrifugal Force	CF	0.0	0.0	9.710	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Wind Load	0.3W	0.0	0.0	0.000	0.0
Wind Load on Live Load	WL	0.0	0.0	0.000	0.0
Longitidinal Force	LF	0.0	0.0	9.710	0.0
Total		13202.8	0.0	-	0.0

Group-IV	D+SD+L+CF+E+B+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Live Load CLASS-A	L	1040.0	0.0	6.000	0.0
Centrifugal Force	CF	0.0	0.0	9.710	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Shrinkage	S	0.0	0.0	6.000	0.0
Temparature Change	T	0.0	0.0	6.000	0.0
Temparature Difference	T	-310.0	0.0	6.000	0.0
Total		12892.8	0.0	-	0.0

Group-V	D+SD+E+B+W+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Wind Load	W	0.0	0.0	0.000	0.0
Shrinkage	S	0.0	0.0	6.000	0.0
Temparature Change	T	0.0	0.0	6.000	0.0
Temparature Difference	T	-310.0	0.0	6.000	0.0
Total		11852.8	0.0	-	0.0

Group-VI	D+SD+L+CF+E+B+0.3W+WL+LF+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	0.0	3.488	0.0
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Live Load CLASS-A	L	1040.0	0.0	6.000	0.0
Centrifugal Force	CF	0.0	0.0	9.710	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Wind Load	0.3W	0.0	0.0	0.000	0.0
Wind Load on Live Load	WL	0.0	0.0	0.000	0.0
Longitidinal Force	LF	0.0	0.0	9.710	0.0
Shrinkage	S	0.0	0.0	6.000	0.0
Temparature Change	T	0.0	0.0	6.000	0.0
Temparature Difference	T	-310.0	0.0	6.000	0.0
Total		12892.8	0.0	-	0.0

Group-VII	D+SD+E+B+EQ				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	2682.8	1153.6	3.488	4023.7
Self Weight of Girder	D(Super)	7150.0	0.0	6.000	0.0
Surfacing	SD	2330.0	0.0	6.000	0.0
Earth Pressure	E	0.0	0.0	0.000	0.0
Buoyancy	B	0.0	0.0	0.000	0.0
Seismic Force	EQ	0.0	4080.0	6.000	24480.0
Total		12162.8	5233.6	-	28503.7

(5) Summary of Force For Load Factor Design

1) Longitudinal Direction

Group-I	γ(D+SD+1.67L+CF+E+B)					
Loadings		γ x β	$\gamma \cdot \beta \cdot V_i$ (kN)	$\gamma \cdot \beta \cdot H_i$ (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Live Load CLASS-A	L	2.171	2257.8	0.0	6.000	0.0
Centrifugal Force	CF	1.300	0.0	0.0	9.710	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Total			18069.4	0.0	-	0.0

Group-II	γ(D+SD+E+B+W)					
Loadings		γ x β	$\gamma \cdot \beta \cdot V_i$ (kN)	$\gamma \cdot \beta \cdot H_i$ (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Wind Load	W	1.300	0.0	0.0	0.000	0.0
Total			15811.6	0.0	-	0.0

Group-III	γ(D+SD+L+CF+E+B+0.3W+WL+LF)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Live Load CLASS-A	L	1.300	1352.0	0.0	6.000	0.0
Centrifugal Force	CF	1.300	0.0	0.0	9.710	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Wind Load	0.3W	0.390	0.0	0.0	0.000	0.0
Wind Load on Live Load	WL	1.300	0.0	0.0	0.000	0.0
Longitidinal Force	LF	1.300	0.0	52.0	9.710	504.9
Total			17163.6	52.0	-	504.9

Group-IV	γ(D+SD+L+CF+E+B+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Live Load CLASS-A	L	1.300	1352.0	0.0	6.000	0.0
Centrifugal Force	CF	1.300	0.0	0.0	9.710	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Shrinkage	S	1.300	0.0	0.0	6.000	0.0
Temparature Change	T	1.300	0.0	0.0	6.000	0.0
Temparature Difference	T	1.300	-403.0	0.0	6.000	0.0
Total			16760.6	0.0	-	0.0

Group-V	γ(D+SD+E+B+W+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.250	3353.4	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.250	8937.5	0.0	6.000	0.0
Surfacing	SD	1.250	2912.5	0.0	6.000	0.0
Earth Pressure	E	1.250	0.0	0.0	0.000	0.0
Buoyancy	B	1.250	0.0	0.0	0.000	0.0
Wind Load	W	1.250	0.0	0.0	0.000	0.0
Shrinkage	S	1.250	0.0	0.0	6.000	0.0
Temparature Change	T	1.250	0.0	0.0	6.000	0.0
Temparature Difference	T	1.250	-387.5	0.0	6.000	0.0
Total			14815.9	0.0	-	0.0

Group-VI	γ(D+SD+L+CF+E+B+0.3W+WL+LF+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.250	3353.4	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.250	8937.5	0.0	6.000	0.0
Surfacing	SD	1.250	2912.5	0.0	6.000	0.0
Live Load CLASS-A	L	1.250	1300.0	0.0	6.000	0.0
Centrifugal Force	CF	1.250	0.0	0.0	9.710	0.0
Earth Pressure	E	1.250	0.0	0.0	0.000	0.0
Buoyancy	B	1.250	0.0	0.0	0.000	0.0
Wind Load	0.3W	1.250	0.0	0.0	0.000	0.0
Wind Load on Live Load	WL	1.250	0.0	0.0	0.000	0.0
Longitidinal Force	LF	1.250	0.0	50.0	9.710	485.5
Shrinkage	S	1.250	0.0	0.0	6.000	0.0
Temparature Change	T	1.250	0.0	0.0	6.000	0.0
Temparature Difference	T	1.250	-387.5	0.0	6.000	0.0
Total			16115.9	50.0	-	485.5

Group-VII	γ(D+SD+E+B+EQ)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Seismic Force	EQ	1.300	0.0	7384.0	6.000	44304.0
Total			15811.6	7384.0	-	44304.0

2) Transvers Direction

Group-I	γ(D+SD+1.67L+CF+E+B)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Live Load CLASS-A	L	2.171	2257.8	0.0	6.000	0.0
Centrifugal Force	CF	1.300	0.0	0.0	9.710	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Total			18069.4	0.0	-	0.0

Group-II	γ(D+SD+E+B+W)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Wind Load	W	1.300	0.0	0.0	0.000	0.0
Total			15811.6	0.0	-	0.0

Group-III	γ(D+SD+L+CF+E+B+0.3W+WL+LF)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Live Load CLASS-A	L	1.300	1352.0	0.0	6.000	0.0
Centrifugal Force	CF	1.300	0.0	0.0	9.710	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Wind Load	0.3W	0.390	0.0	0.0	0.000	0.0
Wind Load on Live Load	WL	1.300	0.0	0.0	0.000	0.0
Longitidinal Force	LF	1.300	0.0	0.0	9.710	0.0
Total			17163.6	0.0	-	0.0

Group-IV	γ(D+SD+L+CF+E+B+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Live Load CLASS-A	L	1.300	1352.0	0.0	6.000	0.0
Centrifugal Force	CF	1.300	0.0	0.0	9.710	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Shrinkage	S	1.300	0.0	0.0	6.000	0.0
Temparature Change	T	1.300	0.0	0.0	6.000	0.0
Temparature Difference	T	1.300	-403.0	0.0	6.000	0.0
Total			16760.6	0.0	-	0.0

Group-V	γ(D+SD+E+B+W+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.250	3353.4	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.250	8937.5	0.0	6.000	0.0
Surfacing	SD	1.250	2912.5	0.0	6.000	0.0
Earth Pressure	E	1.250	0.0	0.0	0.000	0.0
Buoyancy	B	1.250	0.0	0.0	0.000	0.0
Wind Load	W	1.250	0.0	0.0	0.000	0.0
Shrinkage	S	1.250	0.0	0.0	6.000	0.0
Temparature Change	T	1.250	0.0	0.0	6.000	0.0
Temparature Difference	T	1.250	-387.5	0.0	6.000	0.0
Total			14815.9	0.0	-	0.0

Group-VI	γ(D+SD+L+CF+E+B+0.3W+WL+LF+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.250	3353.4	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.250	8937.5	0.0	6.000	0.0
Surfacing	SD	1.250	2912.5	0.0	6.000	0.0
Live Load CLASS-A	L	1.250	1300.0	0.0	6.000	0.0
Centrifugal Force	CF	1.250	0.0	0.0	9.710	0.0
Earth Pressure	E	1.250	0.0	0.0	0.000	0.0
Buoyancy	B	1.250	0.0	0.0	0.000	0.0
Wind Load	0.3W	1.250	0.0	0.0	0.000	0.0
Wind Load on Live Load	WL	1.250	0.0	0.0	0.000	0.0
Longitidinal Force	LF	1.250	0.0	0.0	9.710	0.0
Shrinkage	S	1.250	0.0	0.0	6.000	0.0
Temparature Change	T	1.250	0.0	0.0	6.000	0.0
Temparature Difference	T	1.250	-387.5	0.0	6.000	0.0
Total			16115.9	0.0	-	0.0

Group-VII	γ(D+SD+E+B+EQ)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Self Weight of Substructure	D(Sub)	1.300	3487.6	0.0	3.488	0.0
Self Weight of Girder	D(Super)	1.300	9295.0	0.0	6.000	0.0
Surfacing	SD	1.300	3029.0	0.0	6.000	0.0
Earth Pressure	E	1.300	0.0	0.0	0.000	0.0
Buoyancy	B	1.300	0.0	0.0	0.000	0.0
Seismic Force	EQ	1.300	0.0	5304.0	6.000	31824.0
Total			15811.6	5304.0	-	31824.0

(5) Summary of Force at Bottom of Wall

		Longitudinal Direction			Transverse Direction		
		V(kN)	H(kN)	M(kNm)	V(kN)	H(kN)	M(kNm)
Service Load Design	Group-I	13202.8	0.0	0.0	13202.8	0.0	0.0
	Group-II	12162.8	0.0	0.0	12162.8	0.0	0.0
	Group-III	13202.8	40.0	388.4	13202.8	0.0	0.0
	Group-IV	12892.8	0.0	0.0	12892.8	0.0	0.0
	Group-V	11852.8	0.0	0.0	11852.8	0.0	0.0
	Group-VI	12892.8	40.0	388.4	12892.8	0.0	0.0
	Group-VII	12162.8	6619.0	37355.1	12162.8	5233.6	28503.7
Load Factor Design	Group-I	18069.4	0.0	0.0	18069.4	0.0	0.0
	Group-II	15811.6	0.0	0.0	15811.6	0.0	0.0
	Group-III	17163.6	52.0	504.9	17163.6	0.0	0.0
	Group-IV	16760.6	0.0	0.0	16760.6	0.0	0.0
	Group-V	14815.9	0.0	0.0	14815.9	0.0	0.0
	Group-VI	16115.9	50.0	485.5	16115.9	0.0	0.0
	Group-VII	15811.6	7384.0	44304.0	15811.6	5304.0	31824.0

3.5 Design of Spread Footing

3.5.1 Calculation of Stability

(1)Concrete Volume and Self Weight of Spread Footing

Division	Calculation formula Width × Height × Depth	Volume $Vi(m^3)$	Gravity y(m)	Vi x y
1	8.000 x 9.000 x 1.800	129.60	0.900	116.640
Σ		129.60	0.900	116.640

Self Weight of Substructure 24.5 x ΣV = 3175.20 kN

(2) Backfill Soil Covering on Footing

Division	Calculation formula Width × Height × Depth	Volume $Vi(m^3)$
1	(8.000 x 9.000 - 5.500 x 2.500)x 2.500	145.63
Σ		145.63

Weight of Soil on Spread Footing 19 x ΣV = 2766.88 kN

(3) Buoyancy

Division	Calculation formula Width × Height × Depth	Volume $Vi(m^3)$
1	8.000 x 9.000 x 0.000	0.00
Σ		0.00

Buoyancy -10 x ΣV = 0.00 kN

(4) Summary of Force at Bottom of Footing for Service Load Design

1) Longitudinal Direction

Group-I	D+SD+L+CF+E+B				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		13202.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		19144.8	0.0	-	0.0

Group-II	D+SD+E+B+W				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		12162.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		18104.8	0.0	-	0.0

Group-III	D+SD+L+CF+E+B+0.3W+WL+LF				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		13202.8	40.0	11.510	460.4
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		19144.8	40.0	-	460.4

Group-IV	D+SD+L+CF+E+B+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		12892.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		18834.8	0.0	-	0.0

Group-V	D+SD+E+B+W+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		11852.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		17794.8	0.0	-	0.0

Group-VI	D+SD+L+CF+E+B+0.3W+WL+LF+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		12892.8	40.0	11.510	460.4
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		18834.8	40.0	-	460.4

Group-VII	D+SD+E+B+EQ				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		12162.8	6619.0	7.444	49269.2
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Seicmic Force	EQ	0.0	4257.0	0.900	3831.3
Total		18104.8	6619.0	-	53100.5

2) Transvers Direction

Group-I	D+SD+L+CF+E+B				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		13202.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		19144.8	0.0	-	0.0

Group-II	D+SD+E+B+W				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		12162.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		18104.8	0.0	-	0.0

Group-III	D+SD+L+CF+E+B+0.3W+WL+LF				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		13202.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		19144.8	0.0	-	0.0

Group-IV	D+SD+L+CF+E+B+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		12892.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		18834.8	0.0	-	0.0

Group-V	D+SD+E+B+W+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		11852.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		17794.8	0.0	-	0.0

Group-VI	D+SD+L+CF+E+B+0.3W+WL+LF+S+T				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		12892.8	0.0	0.000	0.0
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Total		18834.8	0.0	-	0.0

Group-VII	D+SD+E+B+EQ				
Loadings		V_i (kN)	H_i (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall		12162.8	5233.6	7.246	37924.2
Self Weight of Footing	D	3175.2	0.0	0.900	0.0
Backfill Soil Covering on Footing	D	2766.9	0.0	2.750	0.0
Buoyancy	B	0.0	0.0	0.900	0.0
Seismic Force	EQ	0.0	1365.3	0.900	1228.8
Total		18104.8	6598.9	-	39153.0

(5) Summary of Force at Bottom of Footing for Load Factor Design

1) Longitudinal Direction

Group-I	γ(D+SD+1.67L+CF+E+B)					
Loadings			γ x β	$\gamma \cdot \beta \cdot V_i$ (kN)	$\gamma \cdot \beta \cdot H_i$ (kN)	Yi(m)	$M_{yi}= H_i \cdot Y_i$
Force at Bottom of Wall			-	18069.4	0.0	0.000	0.0
Self Weight of Footing	D		1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D		1.300	3596.9	0.0	2.750	0.0
Buoyancy	B		1.300	0.0	0.0	0.900	0.0
Total				25794.1	0.0	-	0.0

Group-II	γ(D+SD+E+B+W)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	15811.6	0.0	0.000	0.0
Self Weight of Footing	D	1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D	1.300	3596.9	0.0	2.750	0.0
Buoyancy	B	1.300	0.0	0.0	0.900	0.0
Total			23536.3	0.0	-	0.0

Group-III	γ(D+SD+L+CF+E+B+0.3W+WL+LF)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	17163.6	52.0	11.510	598.5
Self Weight of Footing	D	1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D	1.300	3596.9	0.0	2.750	0.0
Buoyancy	B	1.300	0.0	0.0	0.900	0.0
Total			24888.3	52.0	-	598.5

Group-IV	γ(D+SD+L+CF+E+B+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	16760.6	0.0	0.000	0.0
Self Weight of Footing	D	1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D	1.300	2766.9	0.0	2.750	0.0
Buoyancy	B	1.300	0.0	0.0	0.900	0.0
Total			23655.2	0.0	-	0.0

Group-V	γ(D+SD+E+B+W+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	14815.9	0.0	0.000	0.0
Self Weight of Footing	D	1.250	3969.0	0.0	0.900	0.0
Backfill Soil	D	1.250	3458.6	0.0	2.750	0.0
Buoyancy	B	1.250	0.0	0.0	0.900	0.0
Total			22243.5	0.0	-	0.0

Group-VI	γ(D+SD+L+CF+E+B+0.3W+WL+LF+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	16115.9	50.0	11.510	575.5
Self Weight of Footing	D	1.250	3969.0	0.0	0.900	0.0
Backfill Soil	D	1.250	3458.6	0.0	2.750	0.0
Buoyancy	B	1.250	0.0	0.0	0.900	0.0
Total			23543.5	50.0	-	575.5

Group-VII	γ(D+SD+E+B+EQ)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	15811.6	7384.0	7.800	57595.2
Self Weight of Footing	D	1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D	1.300	3596.9	0.0	2.750	0.0
Buoyancy	B	1.300	0.0	0.0	0.900	0.0
Seismic Force	EQ	1.300	0.0	2307.4	0.900	2076.7
Total			23536.3	9691.4	-	59671.9

2) Transvers Direction

Group-I	γ(D+SD+1.67L+CF+E+B)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	18069.4	0.0	0.000	0.0
Self Weight of Footing	D	1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D	1.300	3596.9	0.0	2.750	0.0
Buoyancy	B	1.300	0.0	0.0	0.900	0.0
Total			25794.1	0.0	-	0.0

Group-II	γ(D+SD+E+B+W)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	15811.6	0.0	0.000	0.0
Self Weight of Footing	D	1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D	1.300	3596.9	0.0	2.750	0.0
Buoyancy	B	1.300	0.0	0.0	0.900	0.0
Total			23536.3	0.0	-	0.0

Group-III	γ(D+SD+L+CF+E+B+0.3W+WL+LF)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	17163.6	0.0	0.000	0.0
Self Weight of Footing	D	1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D	1.300	3596.9	0.0	2.750	0.0
Buoyancy	B	1.300	0.0	0.0	0.900	0.0
Total			24888.3	0.0	-	0.0

Group-IV	γ(D+SD+L+CF+E+B+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	16760.6	0.0	0.000	0.0
Self Weight of Footing	D	1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D	1.300	3596.9	0.0	2.750	0.0
Buoyancy	B	1.300	0.0	0.0	0.900	0.0
Total			24485.3	0.0	-	0.0

Group-V	γ(D+SD+E+B+W+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	14815.9	0.0	0.000	0.0
Self Weight of Footing	D	1.250	3969.0	0.0	0.900	0.0
Backfill Soil	D	1.250	3458.6	0.0	2.750	0.0
Buoyancy	B	1.250	0.0	0.0	0.900	0.0
Total			22243.5	0.0	-	0.0

Group-VI	γ(D+SD+L+CF+E+B+0.3W+WL+LF+S+T)					
Loadings		γ x β	γ·β·V_i (kN)	γ·β·H_i (kN)	Yi(m)	M_{yi}= H_i · Y_i
Force at Bottom of Wall		-	16115.9	0.0	0.000	0.0
Self Weight of Footing	D	1.250	3969.0	0.0	0.900	0.0
Backfill Soil	D	1.250	3458.6	0.0	2.750	0.0
Buoyancy	B	1.250	0.0	0.0	0.900	0.0
Total			23543.5	0.0	-	0.0

Group-VII	γ(D+SD+E+B+EQ)					
Loadings		γ x β	$\gamma \cdot \beta \cdot V_i$ (kN)	$\gamma \cdot \beta \cdot H_i$ (kN)	Yi(m)	$M_{yi} = H_i \cdot Y_i$
Force at Bottom of Wall		-	15811.6	5304.0	7.800	41371.2
Self Weight of Footing	D	1.300	4127.8	0.0	0.900	0.0
Backfill Soil	D	1.300	3596.9	0.0	2.750	0.0
Buoyancy	B	1.300	0.0	0.0	0.900	0.0
Seismic Force	EQ	1.300	0.0	2307.4	0.900	2076.7
Total			23536.3	7611.4	-	43447.9

(5) Summary of Force at Bottom of Footing

		Longitudinal Direction			Transverse Direction		
		V(kN)	H(kN)	M(kNm)	V(kN)	H(kN)	M(kNm)
Service Load Design	Group-I	19144.8	0.0	0.0	19144.8	0.0	0.0
	Group-II	18104.8	0.0	0.0	18104.8	0.0	0.0
	Group-III	19144.8	40.0	460.4	19144.8	0.0	0.0
	Group-IV	18834.8	0.0	0.0	18834.8	0.0	0.0
	Group-V	17794.8	0.0	0.0	17794.8	0.0	0.0
	Group-VI	18834.8	40.0	460.4	18834.8	0.0	0.0
	Group-VII	18104.8	6619.0	53100.5	18104.8	6598.9	39153.0
Load Factor Design	Group-I	25794.1	0.0	0.0	25794.1	0.0	0.0
	Group-II	23536.3	0.0	0.0	23536.3	0.0	0.0
	Group-III	24888.3	52.0	598.5	24888.3	0.0	0.0
	Group-IV	23655.2	0.0	0.0	24485.3	0.0	0.0
	Group-V	22243.5	0.0	0.0	22243.5	0.0	0.0
	Group-VI	23543.5	50.0	575.5	23543.5	0.0	0.0
	Group-VII	23536.3	9691.4	59671.9	23536.3	7611.4	43447.9

(6) Calculation of Stability on Service Load Design

Stability of Footing is checked as follows.

*1) Eccentric Distance from Center of Footing to Vertical Force

$e = M / V - B/2$

e : Eccentric Distance
M : Moment at Bottom of Footing
V : Vertical Force at Bottom of Footing
B : Width of Footing on Checking Direction

*2) Safety Factor for Horizontal Force

$S.F = V*\tan\theta / H$

S.F : Safety Factor
V : Vertical Force at Bottom of Footing
$\tan\theta$: 0.6
H : Horizontal Force at Bottom of Footing

*3) Ground Reaction

$q = V/DB \pm 6M/DB^2$ $(e < B/6)$
$q = 2V / Dx$ $(e \geqq B/6)$

q : Ground Reaction
V : Vertical Force at Bottom of Footing
M : Moment at Bottom of Footing
D : Length of Footing
B : Width of Footing on Checking Direction
x : 3(B/2 - e)

Calculation Result of Stability

1) Longitudinal Direction

Dimension of Footing B= 9.000 m
D= 8.000 m

Eccentric Distance from Center of Footing to Vertical Force

	V (kN)	H (kN)	M (kN)	e (m)
Group-I	19144.8	0.0	0.0	0.000
Group-II	18104.8	0.0	0.0	0.000
Group-III	19144.8	40.0	460.4	0.024
Group-IV	18834.8	0.0	0.0	0.000
Group-V	17794.8	0.0	0.0	0.000
Group-VI	18834.8	40.0	460.4	0.024
Group-VII	18104.8	6619.0	53100.5	2.933

Eccentric Distance for Load Factor Design

	V (kN)	H (kN)	M (kN)	e (m)
Group-I	25794.1	0.0	0.0	0.000
Group-II	23536.3	0.0	0.0	0.000
Group-III	24888.3	52.0	598.5	0.024
Group-IV	23655.2	0.0	0.0	0.000
Group-V	22243.5	0.0	0.0	0.000
Group-VI	23543.5	50.0	575.5	0.024
Group-VII	23536.3	9691.4	59671.9	2.535

Safety Factor for Horizontal Force

	V (kN)	H (kN)	M (kN)	S.F	Limit of S.F	
Group-I	19144.8	0.0	0.0	-	1.500	OK
Group-II	18104.8	0.0	0.0	-	1.500	OK
Group-III	19144.8	40.0	460.4	287.172	1.500	OK
Group-IV	18834.8	0.0	0.0	-	1.500	OK
Group-V	17794.8	0.0	0.0	-	1.500	OK
Group-VI	18834.8	40.0	460.4	282.522	1.500	OK
Group-VII	18104.8	6619.0	53100.5	1.641	1.200	OK

Ground Reaction

	V (kN)	H (kN)	M (kN)	x (m)	qmax (kN/m^2)	qmin (kN/m^2)	qa (kN/m^2)	
Group-I	19144.8	0.0	0.0	9.000	265.90	265.90	700	OK
Group-II	18104.8	0.0	0.0	9.000	251.46	251.46	700	OK
Group-III	19144.8	40.0	460.4	9.000	270.16	261.64	700	OK
Group-IV	18834.8	0.0	0.0	9.000	261.59	261.59	700	OK
Group-V	17794.8	0.0	0.0	9.000	247.15	247.15	700	OK
Group-VI	18834.8	40.0	460.4	9.000	265.86	257.33	700	OK
Group-VII	18104.8	6619.0	53100.5	4.701	962.79	0.00	1050	OK

Ground Reaction for Load Factor Design

	V (kN)	H (kN)	M (kN)	x (m)	qmax (kN/m^2)	qmin (kN/m^2)
Group-I	25794.1	0.0	0.0	9.000	358.25	358.25
Group-II	23536.3	0.0	0.0	9.000	326.89	326.89
Group-III	24888.3	52.0	598.5	9.000	351.21	340.13
Group-IV	23655.2	0.0	0.0	9.000	328.54	328.54
Group-V	22243.5	0.0	0.0	9.000	308.94	308.94
Group-VI	23543.5	50.0	575.5	9.000	332.32	321.66
Group-VII	23536.3	9691.4	59671.9	5.894	998.31	0.00

2) Transverse Direction

Dimension of Footing B= 8.000 m

D= 9.000 m

Eccentric Distance from Center of Footing to Vertical Force

	V (kN)	H (kN)	M (kN)	e (m)
Group-I	19144.8	0.0	0.0	0.000
Group-II	18104.8	0.0	0.0	0.000
Group-III	19144.8	0.0	0.0	0.000
Group-IV	18834.8	0.0	0.0	0.000
Group-V	17794.8	0.0	0.0	0.000
Group-VI	18834.8	0.0	0.0	0.000
Group-VI	18104.8	6598.9	39153.0	2.163
Group-VII	25794.1	0.0	0.0	0.000

Eccentric Distance for Load Factor Design

	V (kN)	H (kN)	M (kN)	e (m)
Group-I	25794.1	0.0	0.0	0.000
Group-II	23536.3	0.0	0.0	0.000
Group-III	24888.3	0.0	0.0	0.000
Group-IV	24485.3	0.0	0.0	0.000
Group-V	22243.5	0.0	0.0	0.000
Group-VI	23543.5	0.0	0.0	0.000
Group-VII	23536.3	7611.4	43447.9	1.846

Safety Factor for Horizontal Force

	V (kN)	H (kN)	M (kN)	S.F	Limit of S.F	
Group-I	19144.8	0.0	0.0	-	1.500	OK
Group-II	18104.8	0.0	0.0	-	1.500	OK
Group-III	19144.8	0.0	0.0	-	1.500	OK
Group-IV	18834.8	0.0	0.0	-	1.500	OK
Group-V	17794.8	0.0	0.0	-	1.500	OK
Group-VI	18834.8	0.0	0.0	-	1.500	OK
Group-VII	18104.8	6598.9	39153.0	1.646	1.200	OK

Ground Reaction

	V (kN)	H (kN)	M (kN)	x (m)	qmax (kN/m^2)	qmin (kN/m^2)	qa (kN/m^2)	
Group-I	19144.8	0.0	0.0	8.000	265.90	265.90	700	OK
Group-II	18104.8	0.0	0.0	8.000	251.46	251.46	700	OK
Group-III	19144.8	0.0	0.0	8.000	265.90	265.90	700	OK
Group-IV	18834.8	0.0	0.0	8.000	261.59	261.59	700	OK
Group-V	17794.8	0.0	0.0	8.000	247.15	247.15	700	OK
Group-VI	18834.8	0.0	0.0	8.000	261.59	261.59	700	OK
Group-VII	18104.8	6598.9	39153.0	5.512	729.88	0.00	1050	OK

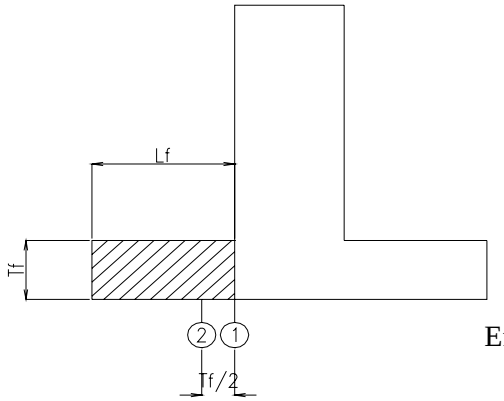
Ground Reaction for Load Factor Design

	V (kN)	H (kN)	M (kN)	x (m)	qmax (kN/m^2)	qmin (kN/m^2)
Group-I	25794.1	0.0	0.0	8.000	358.25	358.25
Group-II	23536.3	0.0	0.0	8.000	326.89	326.89
Group-III	24888.3	0.0	0.0	8.000	345.67	345.67
Group-IV	24485.3	0.0	0.0	8.000	340.07	340.07
Group-V	22243.5	0.0	0.0	8.000	308.94	308.94
Group-VI	23543.5	0.0	0.0	8.000	326.99	326.99
Group-VII	23536.3	7611.4	43447.9	6.462	809.39	0.00

3.5.2 Design of Spread Footing

(1) Block data that doesn't consider water level for Longitudinal Direction

1) Self Weight for Section-①



Lf= 3.250 m

Tf= 1.800 m

Pile Cap Length

L= 8.000 m

Effective Width= 8.000 m

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Position Xi(m)	Vi・Xi
1	3.25 x 1.8 x 8	46.8	1.625	76.050
Σ		46.8	---	76.050

Self Weight

Vertical Force W = γ x V = 24.5 x 46.8= 1146.60 kN

2) Backfill soil and buoyancy for Section-①

*) Buoyancy

Water level Hw= 0.00 m (equally Top of Footing)

Buoyancy

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Position Xi(m)	Vi・Xi
1	3.25 x 0 x 8	0.0	1.625	0.000
Σ		0.0	---	0.000

Buoyancy

Vertical Force W = γw x V = -10x 0= 0.00 kN

*) Backfill Soil

Backfill Soil Covering on Footing H= 2.500 m

Buoyancy

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Position Xi(m)	Vi・Xi
1	3.25 x 2.5 x 8	65.0	1.625	105.625
Σ		65.0	---	105.625

Backfill Soil

Vertical Force W = γs x V = 19x 65= 1235.00 kN

1) Self Weight for Section-②

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Position Xi(m)	Vi・Xi
1	2.35 x 1.8 x 8	33.8	1.175	39.762
Σ		33.8	---	39.762

Self Weight
Vertical Force W = γ x V = 24.5 x 33.8= 829.08 kN

2) Backfill soil and buoyancy for Section-②

*) Buoyancy

Water level Hw= 0.00 m (equally Top of Footing)
Buoyancy

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Position Xi(m)	Vi・Xi
1	2.35 x 0 x 8	0.0	1.175	0.000
Σ		0.0	---	0.000

Buoyancy
Vertical Force W = γw x V = -10x 0= 0.00 kN

*) Backfill Soil

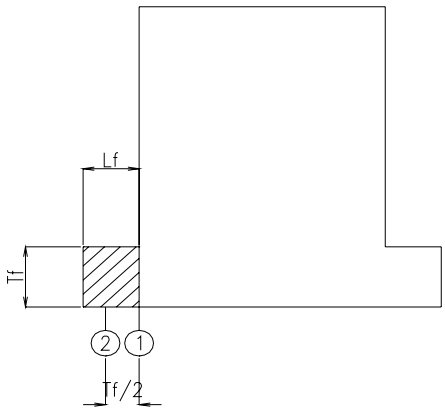
Backfill Soil Covering on Footing H= 2.500 m
Buoyancy

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Position Xi(m)	Vi・Xi
1	2.35 x 2.5 x 8	47.0	1.175	55.225
Σ		47.0	---	55.225

Backfill Soil
Vertical Force W = γs x V = 19x 47= 893.00 kN

(2) Block data that doesn't consider water level for Transverse Direction

1) Self Weight for Section-①



Lf= 1.250 m
Tf= 1.800 m
Pile Cap Length
L= 9.000 m

Effective Width= 5.330 m

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Xi(m)	Vi・Xi
1	1.25 x 1.8 x 9	20.3	0.625	12.656
Σ		20.3	---	12.656

Self Weight
Vertical Force W = γ x V = 24.5 x 20.3= 496.13 kN

2) Backfill soil and buoyancy for Section-①

*) Buoyancy

Water level Hw= 0.00 m (equally Top of Footing)

Buoyancy

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Xi(m)	Vi・Xi
1	1.25 x 0 x 9	0.0	0.625	0.000
Σ		0.0	---	0.000

Buoyancy
Vertical Force W = γw x V = -10x 0= 0.00 kN

*) Backfill Soil

Backfill Soil Covering on Footing H= 2.500 m

Buoyancy

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Xi(m)	Vi・Xi
1	1.25 x 2.5 x 9	28.1	0.625	17.578
Σ		28.1	---	17.578

Backfill Soil
Vertical Force W = γs x V = 19x 28.1= 534.38 kN

1) Self Weight for Section-②

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Xi(m)	Vi・Xi
1	0.35 x 1.8 x 9	5.7	0.175	0.992
Σ		5.7	---	0.992

Self Weight
Vertical Force W = γ x V = 24.5 x 5.7= 138.92 kN

2) Backfill soil and buoyancy for Section-②

*) Buoyancy

Water level Hw= 0.00 m (equally Top of Footing)

Buoyancy

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Xi(m)	Vi・Xi
1	0.35 x 0 x 9	0.0	0.175	0.000
Σ		0.0	---	0.000

Buoyancy Vertical Force W = γw x V = -10x 0= 0.00 kN

*) Backfill Soil

Backfill Soil Covering on Footing H= 2.500 m

Buoyancy

Division	Calculation formula Width × Height × Length	Volume V1 Vi(m^3)	Barycentric Xi(m)	Vi・Xi
1	0.35 x 2.5 x 9	7.9	0.175	1.378
Σ		7.9	---	1.378

Backfill Soil Vertical Force W = γs x V = 19x 7.9= 149.63 kN

(3) Summary of Sectional Force for Service Load Design

Longitudinal Direction at Section-①

Group-I	D+SD+L+CF+E+B			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1146.60	1.625	1863.2
Backfill Soil Covering on Footing	D	1235.00	1.625	2006.9
Buoyancy	B	0.00	1.625	0.0
Ground Reaction	-	-6913.41	1.625	-11234.3
Total		-4531.81		-7364.2
Per 1 meter		-566.48		-920.5

Group-II	D+SD+E+B+W			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1146.60	1.625	1863.2
Backfill Soil Covering on Footing	D	1235.00	1.625	2006.9
Buoyancy	B	0.00	1.625	0.0
Ground Reaction	-	-6537.85	1.625	-10624.0
Total		-4156.25		-6753.9
Per 1 meter		-519.53		-844.2

Group-III	D+SD+L+CF+E+B+0.3W+WL+LF			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1146.60	1.625	1863.2
Backfill Soil Covering on Footing	D	1235.00	1.625	2006.9
Buoyancy	B	0.00	1.625	0.0
Ground Reaction	-	-6984.22	1.628	-11371.0
Total		-4602.62		-7500.9
Per 1 meter		-575.33		-937.6

Group-IV	D+SD+L+CF+E+B+S+T			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1146.60	1.625	1863.2
Backfill Soil Covering on Footing	D	1235.00	1.625	2006.9
Buoyancy	B	0.00	1.625	0.0
Ground Reaction	-	-6801.46	1.625	-11052.4
Total		-4419.86		-7182.3
Per 1 meter		-552.48		-897.8

Group-V	D+SD+E+B+W+S+T			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1146.60	1.625	1863.2
Backfill Soil Covering on Footing	D	1235.00	1.625	2006.9
Buoyancy	B	0.00	1.625	0.0
Ground Reaction	-	-6425.91	1.625	-10442.1
Total		-4044.31		-6572.0
Per 1 meter		-505.54		-821.5

Group-VI	D+SD+L+CF+E+B+0.3W+WL+LF+S+T			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1146.60	1.625	1863.2
Backfill Soil Covering on Footing	D	1235.00	1.625	2006.9
Buoyancy	B	0.00	1.625	0.0
Ground Reaction	-	-6872.28	1.628	-11189.1
Total		-4490.68		-7319.0
Per 1 meter		-561.34		-914.9

Group-VII	D+SD+E+B+EQ			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1146.60	1.625	1863.2
Backfill Soil Covering on Footing	D	1235.00	1.625	2006.9
Buoyancy	B	0.00	1.625	0.0
Ground Reaction	-	-16379.73	1.911	-31303.9
Total		-13998.13		-27433.8
Per 1 meter		-1749.77		-3429.2

Transverse Direction at Section-①

Group-I	D+SD+L+CF+E+B			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	496.13	0.625	310.1
Backfill Soil Covering on Footing	D	534.38	0.625	334.0
Buoyancy	B	0.00	0.625	0.0
Ground Reaction	-	-2991.38	0.625	-1869.6
Total		-1960.88		-1225.5
Per 1 meter		-367.89		-229.9

Group-II	D+SD+E+B+W			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	496.13	0.625	310.1
Backfill Soil Covering on Footing	D	534.38	0.625	334.0
Buoyancy	B	0.00	0.625	0.0
Ground Reaction	-	-2828.88	0.625	-1768.1
Total		-1798.38		-1124.0
Per 1 meter		-337.41		-210.9

Group-III	D+SD+L+CF+E+B+0.3W+WL+LF			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	496.13	0.625	310.1
Backfill Soil Covering on Footing	D	534.38	0.625	334.0
Buoyancy	B	0.00	0.625	0.0
Ground Reaction	-	-2991.38	0.625	-1869.6
Total		-1960.88		-1225.5
Per 1 meter		-367.89		-229.9

Group-IV	D+SD+L+CF+E+B+S+T			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	496.13	0.625	310.1
Backfill Soil Covering on Footing	D	534.38	0.625	334.0
Buoyancy	B	0.00	0.625	0.0
Ground Reaction	-	-2942.94	0.625	-1839.3
Total		-1912.44		-1195.2
Per 1 meter		-358.81		-224.2

Group-V	D+SD+E+B+W+S+T			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	496.13	0.625	310.1
Backfill Soil Covering on Footing	D	534.38	0.625	334.0
Buoyancy	B	0.00	0.625	0.0
Ground Reaction	-	-2780.44	0.625	-1737.8
Total		-1749.94		-1093.7
Per 1 meter		-328.32		-205.2

Group-VI	D+SD+L+CF+E+B+0.3W+WL+LF+S+T			
		Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	496.13	0.625	310.1
Backfill Soil Covering on Footing	D	534.38	0.625	334.0
Buoyancy	B	0.00	0.625	0.0
Ground Reaction	-	-2942.94	0.625	-1839.3
Total		-1912.44		-1195.2
Per 1 meter		-358.81		-224.2

Group-VII	D+SD+E+B+EQ				
			Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing		D	496.13	0.625	310.1
Backfill Soil Covering on Footing		D	534.38	0.625	334.0
Buoyancy		B	0.00	0.625	0.0
Ground Reaction		-	-7280.12	0.652	-4744.0
Total			-6249.62		-4099.9
Per 1 meter			-1172.54		-769.2

(4) Summary of Sectional Force for Load Factor Design

Longitudinal Direction at Section-①

Group-I	γ(D+SD+1.67L+CF+E+B)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.300	1490.58	1.625	2422.2
Backfill Soil Covering on Footing	D	1.300	1605.50	1.625	2608.9
Buoyancy	B	1.300	0.00	1.625	0.0
Ground Reaction	-	-	-9314.54	1.625	-15136.1
Total			-6218.46		-10105.0
Per 1 meter			-777.31		-1263.1

Group-II	γ(D+SD+E+B+W)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.300	1490.58	1.625	2422.2
Backfill Soil Covering on Footing	D	1.300	1605.50	1.625	2608.9
Buoyancy	B	1.300	0.00	1.625	0.0
Ground Reaction	-	-	-8499.21	1.625	-13811.2
Total			-5403.13		-8780.1
Per 1 meter			-675.39		-1097.5

Group-III	γ(D+SD+L+CF+E+B+0.3W+WL+LF)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.300	1490.58	1.625	2422.2
Backfill Soil Covering on Footing	D	1.300	1605.50	1.625	2608.9
Buoyancy	B	1.300	0.00	1.625	0.0
Ground Reaction	-	-	-9079.49	1.628	-14782.4
Total			-5983.41		-9751.3
Per 1 meter			-747.93		-1218.9

Group-IV	γ(D+SD+L+CF+E+B+S+T)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.300	1490.58	1.625	2422.2
Backfill Soil Covering on Footing	D	1.300	1605.50	1.625	2608.9
Buoyancy	B	1.300	0.00	1.625	0.0
Ground Reaction	-	-	-8542.16	1.625	-13881.0
Total			-5446.08		-8849.9
Per 1 meter			-680.76		-1106.2

Group-V	γ(D+SD+E+B+W+S+T)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.250	1433.25	1.625	2329.0
Backfill Soil Covering on Footing	D	1.250	1543.75	1.625	2508.6
Buoyancy	B	1.250	0.00	1.625	0.0
Ground Reaction	-	-	-8032.39	1.625	-13052.6
Total			-5055.39		-8215.0
Per 1 meter			-631.92		-1026.9

Group-VI	γ(D+SD+L+CF+E+B+0.3W+WL+LF+S+T)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.250	1433.25	1.625	2329.0
Backfill Soil Covering on Footing	D	1.250	1543.75	1.625	2508.6
Buoyancy	B	1.250	0.00	1.625	0.0
Ground Reaction	-	-	-8590.35	1.628	-13986.4
Total			-5613.35		-9148.8
Per 1 meter			-701.67		-1143.6

Group-VII	γ(D+SD+E+B+EQ)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.300	1490.58	1.625	2422.2
Backfill Soil Covering on Footing	D	1.300	1605.50	1.625	2608.9
Buoyancy	B	1.300	0.00	1.625	0.0
Ground Reaction	-	-	-18799.85	1.831	-34426.0
Total			-15703.77		-29394.9
Per 1 meter			-1962.97		-3674.4

Longitudinal Direction at Section-②

Group-I	γ(D+SD+1.67L+CF+E+B)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	1077.80
Backfill Soil Covering on Footing	D	1.300	1160.90
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-6735.13
Total			-4496.43
Per 1 meter			-562.05

Group-II	γ(D+SD+E+B+W)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	1077.80
Backfill Soil Covering on Footing	D	1.300	1160.90
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-6145.58
Total			-3906.88
Per 1 meter			-488.36

Group-III	γ(D+SD+L+CF+E+B+0.3W+WL+LF)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	1077.80
Backfill Soil Covering on Footing	D	1.300	1160.90
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-6575.59
Total			-4336.89
Per 1 meter			-542.11

Group-IV	γ(D+SD+L+CF+E+B+S+T)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	1077.80
Backfill Soil Covering on Footing	D	1.300	1160.90
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-6176.64
Total			-3937.94
Per 1 meter			-492.24

Group-V	γ(D+SD+E+B+W+S+T)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.250	1036.35
Backfill Soil Covering on Footing	D	1.250	1116.25
Buoyancy	B	1.250	0.00
Ground Reaction	-	-	-5808.03
Total			-3655.43
Per 1 meter			-456.93

Group-VI	γ(D+SD+L+CF+E+B+0.3W+WL+LF+S+T)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.250	1036.35
Backfill Soil Covering on Footing	D	1.250	1116.25
Buoyancy	B	1.250	0.00
Ground Reaction	-	-	-6221.50
Total			-4068.90
Per 1 meter			-508.61

Group-VII	γ(D+SD+E+B+EQ)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	1077.80
Backfill Soil Covering on Footing	D	1.300	1160.90
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-15026.65
Total			-12787.95
Per 1 meter			-1598.49

Transverse Direction at Section-①

Group-I	γ(D+SD+1.67L+CF+E+B)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.300	644.96	0.625	403.1
Backfill Soil Covering on Footing	D	1.300	694.69	0.625	434.2
Buoyancy	B	1.300	0.00	0.625	0.0
Ground Reaction	-	-	-4030.33	0.625	-2519.0
Total			-2690.68		-1681.7
Per 1 meter			-504.82		-315.5

Group-II	γ(D+SD+E+B+W)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.300	644.96	0.625	403.1
Backfill Soil Covering on Footing	D	1.300	694.69	0.625	434.2
Buoyancy	B	1.300	0.00	0.625	0.0
Ground Reaction	-	-	-3677.54	0.625	-2298.5
Total			-2337.89		-1461.2
Per 1 meter			-438.63		-274.1

Group-III	γ(D+SD+L+CF+E+B+0.3W+WL+LF)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.300	644.96	0.625	403.1
Backfill Soil Covering on Footing	D	1.300	694.69	0.625	434.2
Buoyancy	B	1.300	0.00	0.625	0.0
Ground Reaction	-	-	-3888.79	0.625	-2430.5
Total			-2549.14		-1593.2
Per 1 meter			-478.26		-298.9

Group-IV	γ(D+SD+L+CF+E+B+S+T)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.300	644.96	0.625	403.1
Backfill Soil Covering on Footing	D	1.300	694.69	0.625	434.2
Buoyancy	B	1.300	0.00	0.625	0.0
Ground Reaction	-	-	-3825.82	0.625	-2391.1
Total			-2486.17		-1553.8
Per 1 meter			-466.45		-291.5

Group-V	γ(D+SD+E+B+W+S+T)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.250	620.16	0.625	387.6
Backfill Soil Covering on Footing	D	1.250	667.97	0.625	417.5
Buoyancy	B	1.250	0.00	0.625	0.0
Ground Reaction	-	-	-3475.55	0.625	-2172.2
Total			-2187.43		-1367.1
Per 1 meter			-410.40		-256.5

Group-VI	γ(D+SD+L+CF+E+B+0.3W+WL+LF+S+T)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.250	620.16	0.625	387.6
Backfill Soil Covering on Footing	D	1.250	667.97	0.625	417.5
Buoyancy	B	1.250	0.00	0.625	0.0
Ground Reaction	-	-	-3678.68	0.625	-2299.2
Total			-2390.56		-1494.1
Per 1 meter			-448.51		-280.3

Group-VII	γ(D+SD+E+B+EQ)				
		γ x β	Vi(kN)	Xi(m)	Mi(kNm)
Self Weight of Footing	D	1.250	620.16	0.625	387.6
Backfill Soil Covering on Footing	D	1.250	667.97	0.625	417.5
Buoyancy	B	1.250	0.00	0.625	0.0
Ground Reaction	-	-	-8224.94	0.647	-5324.1
Total			-6936.82		-4519.0
Per 1 meter			-1301.47		-847.8

Transverse Direction at Section-②

Group-I	γ(D+SD+1.67L+CF+E+B)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	180.59
Backfill Soil Covering on Footing	D	1.300	194.51
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-1128.49
Total			-753.39
Per 1 meter			-141.35

Group-II	γ(D+SD+E+B+W)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	180.59
Backfill Soil Covering on Footing	D	1.300	194.51
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-1029.71
Total			-654.61
Per 1 meter			-122.82

Group-III	γ(D+SD+L+CF+E+B+0.3W+WL+LF)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	180.59
Backfill Soil Covering on Footing	D	1.300	194.51
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-1088.86
Total			-713.76
Per 1 meter			-133.91

Group-IV	γ(D+SD+L+CF+E+B+S+T)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	180.59
Backfill Soil Covering on Footing	D	1.300	194.51
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-1071.23
Total			-696.13
Per 1 meter			-130.61

Group-V	γ(D+SD+E+B+W+S+T)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.250	173.64
Backfill Soil Covering on Footing	D	1.250	187.03
Buoyancy	B	1.250	0.00
Ground Reaction	-	-	-973.15
Total			-612.48
Per 1 meter			-114.91

Group-VI	γ(D+SD+L+CF+E+B+0.3W+WL+LF+S+T)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.250	173.64
Backfill Soil Covering on Footing	D	1.250	187.03
Buoyancy	B	1.250	0.00
Ground Reaction	-	-	-1030.03
Total			-669.36
Per 1 meter			-125.58

Group-VII	γ(D+SD+E+B+EQ)		
		γ x β	Vi(kN)
Self Weight of Footing	D	1.300	180.59
Backfill Soil Covering on Footing	D	1.300	194.51
Buoyancy	B	1.300	0.00
Ground Reaction	-	-	-2480.53
Total			-2105.43
Per 1 meter			-395.01

(5) Calculation of Stress for Service Load Design

Stress Equation

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As' \cdot \frac{(x-d') \cdot (h/2-d')}{x} + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

$$x^2 + \frac{2 \cdot n}{b} \left\{As' \cdot (x-d') + As \cdot (x-d)\right\} = 0.0$$

in which,

x : Distance from edge on compression side to neutral axis (mm)
h : Height of Member (mm)
b : Width in section (mm)
d : Effective height (mm)
d' : Concrete Cover (mm)
As : Sectional area of reinforcing bar arranged on tension side (mm^2)
As': Sectional area of reinforcing bar arranged on compression side (mm^2)
n : Elastic Modulus Ratio of Reinforce and Concrete , n = 15.00
σc: Compressive Stress of Concrete (N/mm^2)
σs: Tensile Stress of Reinforcing (N/mm^2)
M: Bending Moment (kN.m)

Bar Arrangement

		Longitudinal Direction	Transverse Direction
Dimension	b(mm)	1000	1000
	h(mm)	1800	1800
	d1(mm)	1590	1616
	d2(mm)	1690	1716
Bar Arrangement	As1(mm^2)	8-D32 6434	8-D20 2513
	As2(mm^2)	8-D32 6434	8-D20 2513

Calculation Result of Bending Stress

	Longitudinal Direction					
	M (kNm)	σc (N/mm^2)	σs (N/mm^2)	σca (N/mm^2)	σsa (N/mm^2)	Remarks
Group-I	920.5	2.11	54.88	9.60	168.00	OK
Group-II	844.2	1.94	50.43	12.00	210.00	OK
Group-III	937.6	2.15	55.90	12.00	210.00	OK
Group-IV	897.8	2.06	53.56	12.00	210.00	OK
Group-V	821.5	1.89	49.10	13.44	235.20	OK
Group-VI	914.9	2.10	54.57	13.44	235.20	OK
Group-VII	3429.2	7.99	207.54	12.77	223.44	OK

	Transverse Direction					
	M (kNm)	σc (N/mm^2)	σs (N/mm^2)	σca (N/mm^2)	σsa (N/mm^2)	Remarks
Group-I	229.9	0.67	31.59	9.60	168.00	OK
Group-II	210.9	0.62	29.03	12.00	210.00	OK
Group-III	229.9	0.67	31.59	12.00	210.00	OK
Group-IV	224.2	0.66	30.83	12.00	210.00	OK
Group-V	205.2	0.60	28.26	13.44	235.20	OK
Group-VI	224.2	0.66	30.83	13.44	235.20	OK
Group-VII	769.2	2.91	136.17	12.77	223.44	OK

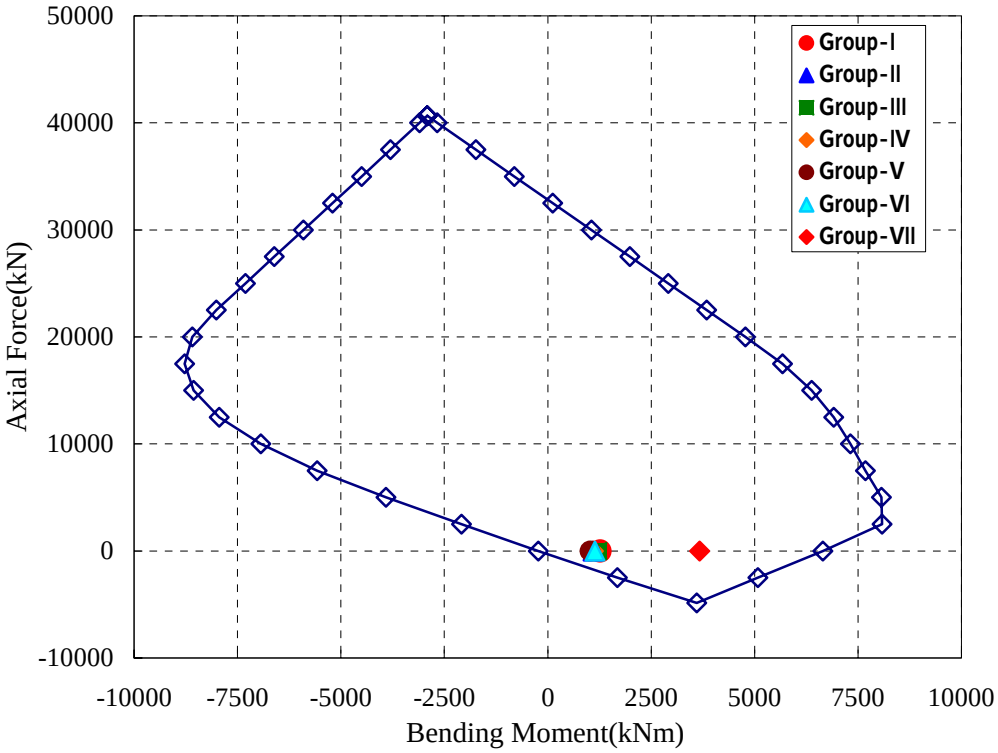
(6) Calculation of Strength for Load Factor Design

*) Flexural Strength

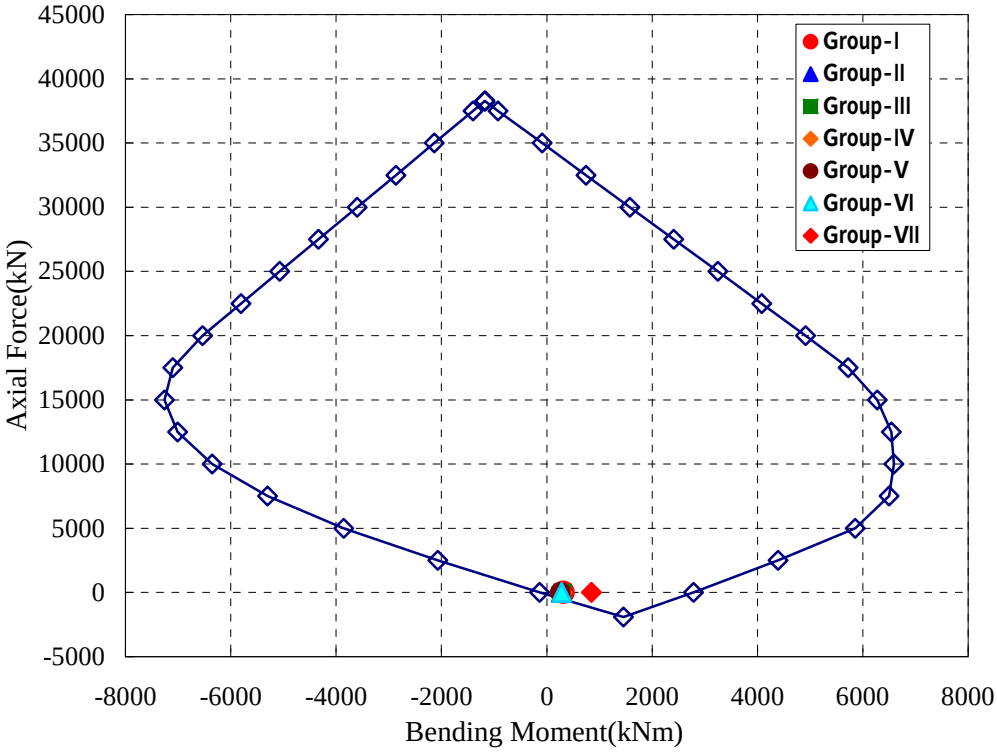
Factored Bending Moment for Load Factor Design

	Longitudinal Direction	Transverse Direction
Group-I	1263.1 kNm	315.52 kNm
Group-II	1097.5 kNm	274.15 kNm
Group-III	1218.9 kNm	298.91 kNm
Group-IV	1106.2 kNm	291.52 kNm
Group-V	1026.9 kNm	256.49 kNm
Group-VI	1143.6 kNm	280.32 kNm
Group-VII	3674.4 kNm	847.84 kNm

Interaction of Longitudinal Direction



Interaction of Transverse Direction



*) Shear Strength

Shear Strength "Vn" is Calculated as follows.

Vn= Vc + Vs

In Which

Vc : Normal Shear Strength provided by the Concrete

Vc = vc x bw x d (vc=1/6x $\sqrt{}$ f'c)

= 1/6x $\sqrt{}$ f'c x bw x d)

f'c : 28days Cylinder Strength

bw : Width of Section

d : Effective Height of Section

Vs : Normal Shear Strength provided by the Shear Reinforcement

Vs = Av x fy x d / s

Av : Area of Shear Reinforcement within a distancees.

fy : Yeild Strength of Shear Reinforcement

d : Effective Height of Section

s : Calculated Distance.

Factored Shear Force for Load Factor Design

	Longitudinal Direction	Transverse Direction
Group-I	562.1 kN	141.35 kN
Group-II	488.4 kN	122.82 kN
Group-III	542.1 kN	133.91 kN
Group-IV	492.2 kN	130.61 kN
Group-V	456.9 kN	114.91 kN
Group-VI	508.6 kN	125.58 kN
Group-VII	1598.5 kN	395.01 kN

Calculation of Shear Strength

vc = $1/6 \times \sqrt{f'c} = 1/6 \times \sqrt{(24)} = 0.816 N/mm^2 \rightarrow 816 kN/m^2$

fy = 420 N/mm^2 -> 420000 kN/m^2

s = 1.000 m

Longitudinal Direction

	Su(kN)	bw(m)	d(m)	Vc(kN)	Vsreq(kN)	Asreq(mm^2/m)
Group-I	562.1	1.000	1.690	1172.18	0.00	0.0
Group-II	488.4	1.000	1.690	1172.18	0.00	0.0
Group-III	542.1	1.000	1.690	1172.18	0.00	0.0
Group-IV	492.2	1.000	1.690	1172.18	0.00	0.0
Group-V	456.9	1.000	1.690	1172.18	0.00	0.0
Group-VI	508.6	1.000	1.690	1172.18	0.00	0.0
Group-VII	1598.5	1.000	1.690	1172.18	501.54	706.6

Arrangement of Stirrup D16 -ctc.500 804.25 mm^2/m > 706.6 mm^2/m

Transverse Direction

	Su(kN)	bw(m)	d(m)	Vc(kN)	Vsreq(kN)	Asreq(mm^2/m)
Group-I	141.3	1.000	1.716	1190.22	0.00	0.0
Group-II	122.8	1.000	1.716	1190.22	0.00	0.0
Group-III	133.9	1.000	1.716	1190.22	0.00	0.0
Group-IV	130.6	1.000	1.716	1190.22	0.00	0.0
Group-V	114.9	1.000	1.716	1190.22	0.00	0.0
Group-VI	125.6	1.000	1.716	1190.22	0.00	0.0
Group-VII	395.0	1.000	1.716	1190.22	0.00	0.0

Arrangement of Stirrup D16 -ctc.500 804.25 mm^2/m > 0 mm^2/m

3.6 Design of Beam

3.6.1 Reaction from Superstructure per Each Bearing

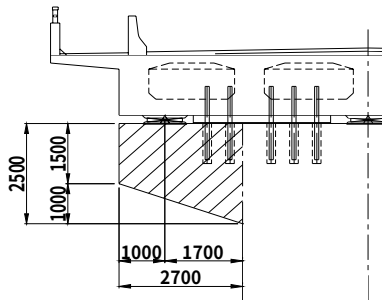
(1)Vertical Reaction

Loadings		G1	G2	G3	Total
Mark	Type of Loading	Ry(kN)	Ry(kN)	Ry(kN)	ΣRz(kN)
D	Self Weight of Girder	2493.3	2493.3	2493.3	7480.0
	Prestress	-110.0	-110.0	-110.0	-330.0
	Creep Effect	0.0	0.0	0.0	0.0
	Total	2383.3	2383.3	2383.3	7150.0
SD	Surfacing	776.7	776.7	776.7	2330.0
L	CLASS-A Loading Maximum	230.0	230.0	230.0	690.0
	Impuct Factor	10.0	10.0	10.0	30.0
	Footway Load	106.7	106.7	106.7	320.0
	Total	346.7	346.7	346.7	1040.0
S	Shrinkage	0.0	0.0	0.0	0.0
T	Temparature Change (Rise)	0.0	0.0	0.0	0.0
T	Temparature Difference	-103.3	-103.3	-103.3	-310.0

(2)Horizontal Force for Longitudinal Direction

Loadings		G1	G2	G3	Total
Mark	Type of Loading	Ry(kN)	Ry(kN)	Ry(kN)	ΣRz(kN)
S	Shrinkage	0.0	0.0	0.0	0.0
T	Temparature Change (Rise)	0.0	0.0	0.0	0.0
T	Temparature Difference	0.0	0.0	0.0	0.0
LF	Longitudanl Force	13.3	13.3	13.3	40.0
EQ	Seismic Force	1893.3	1893.3	1893.3	5680.0

3.6.2 Sectional Force at Base of Cantilever Beam



(1) Self Weight of Cantilever Beam

Equation		W (kN)	x (m)	M (kNm)
Self Weight	24.5 × 2.700 × 1.500 × 2.500	248.1	1.350	334.9
	24.5 × 2.700 × 1.000 / 2 × 2.500	82.7	0.900	74.4
	Total	330.8	1.238	409.3

(2) Seismic Force for Longitudinal Direction

Seismic Coefficient = 0.35 (Longitudinal)

Loadings	H (kN)	x (m)	M (kNm)
Self Weight of Cantilever Beam	115.8	1.238	143.3

(2) Summary of Sectional Force at Base of Cantilever Beam for Vertical Direction

1) Service Load Design

Group-I	D+SD+L		V	x	M
Loading			(kN)	(m)	(kNm)
Self Weight of Cantilever Beam		D	330.8	1.238	409.3
Reaction of Dead Load from Superstructure		D	2383.3	1.700	4051.7
Reaction of Surfacing from Superstructure		SD	776.7	1.700	1320.3
Reaction of Live Load from Superstructure		L	346.7	1.700	589.3
Total			3837.4		6370.6

Group-II	D+SD+W		V	x	M
Loading			(kN)	(m)	(kNm)
Self Weight of Cantilever Beam		D	330.8	1.238	409.3
Reaction of Dead Load from Superstructure		D	2383.3	1.700	4051.7
Reaction of Surfacing from Superstructure		SD	776.7	1.700	1320.3
Wind Load		W	0.0	1.700	0.0
Total			3490.8		5781.3

Group-III	D+SD+L+0.3W+WL		V	x	M
Loading			(kN)	(m)	(kNm)
Self Weight of Cantilever Beam		D	330.8	1.238	409.3
Reaction of Dead Load from Superstructure		D	2383.3	1.700	4051.7
Reaction of Surfacing from Superstructure		SD	776.7	1.700	1320.3
Reaction of Live Load from Superstructure		L	346.7	1.700	589.3
Wind Load on Live Load		WL	0.0	1.700	0.0
Wind Load		0.3W	0.0	1.700	0.0
Total			3837.4		6370.6

Group-IV	D+SD+L+T		V	x	M
Loading			(kN)	(m)	(kNm)
Self Weight of Cantilever Beam		D	330.8	1.238	409.3
Reaction of Dead Load from Superstructure		D	2383.3	1.700	4051.7
Reaction of Surfacing from Superstructure		SD	776.7	1.700	1320.3
Reaction of Live Load from Superstructure		L	346.7	1.700	589.3
Reaction of Temp. Diff. from Superstructure		T	-103.3	1.700	-175.7
Total			3734.1		6195.0

Group-V	D+SD+W+T		V	x	M
Loading			(kN)	(m)	(kNm)
Self Weight of Cantilever Beam		D	330.8	1.238	409.3
Reaction of Dead Load from Superstructure		D	2383.3	1.700	4051.7
Reaction of Surfacing from Superstructure		SD	776.7	1.700	1320.3
Reaction of Live Load from Superstructure		L	346.7	1.700	589.3
Wind Load		W	0.0	1.700	0.0
Reaction of Temp. Diff. from Superstructure		T	-103.3	1.700	-175.7
Total			3734.1		6195.0

Group-VI	D+SD+L+0.3W+WL+T		V	x	M
Loading			(kN)	(m)	(kNm)
Self Weight of Cantilever Beam		D	330.8	1.238	409.3
Reaction of Dead Load from Superstructure		D	2383.3	1.700	4051.7
Reaction of Surfacing from Superstructure		SD	776.7	1.700	1320.3
Reaction of Live Load from Superstructure		L	346.7	1.700	589.3
Wind Load on Live Load		WL	0.0	1.700	0.0
Wind Load		0.3W	0.0	1.700	0.0
Reaction of Temp. Diff. from Superstructure		T	-103.3	1.700	-175.7
Total			3734.1		6195.0

2) Load Factor Design

Group-I	γ(D+SD+L)		V	x	M
Loading		γ x β	(kN)	(m)	(kNm)
Self Weight of Cantilever Beam	D	1.300	430.0	1.238	532.1
Reaction of Dead Load from Superstructure	D	1.300	3098.3	1.700	5267.2
Reaction of Surfacing from Superstructure	SD	1.300	1009.7	1.700	1716.4
Reaction of Live Load from Superstructure	L	1.300	450.7	1.700	766.1
Total			4988.6		8281.8

Group-II	γ(D+SD+W)		V	x	M
Loading		γ x β	(kN)	(m)	(kNm)
Self Weight of Cantilever Beam	D	1.300	430.0	1.238	532.1
Reaction of Dead Load from Superstructure	D	1.300	3098.3	1.700	5267.2
Reaction of Surfacing from Superstructure	SD	1.300	1009.7	1.700	1716.4
Wind Load	W	1.300	0.0	1.700	0.0
Total			4538.0		7515.7

Group-III	γ(D+SD+L+0.3W+WL)		V	x	M
Loading		γ x β	(kN)	(m)	(kNm)
Self Weight of Cantilever Beam	D	1.300	430.0	1.238	532.1
Reaction of Dead Load from Superstructure	D	1.300	3098.3	1.700	5267.2
Reaction of Surfacing from Superstructure	SD	1.300	1009.7	1.700	1716.4
Reaction of Live Load from Superstructure	L	1.300	450.7	1.700	766.1
Wind Load	0.3W	1.300	0.0	1.700	0.0
Wind Load on Live Load	WL	1.300	0.0	1.700	0.0
Total			4988.6		8281.8

Group-IV	γ(D+SD+L+T)		V	x	M
Loading		γ x β	(kN)	(m)	(kNm)
Self Weight of Cantilever Beam	D	1.300	430.0	1.238	532.1
Reaction of Dead Load from Superstructure	D	1.300	3098.3	1.700	5267.2
Reaction of Surfacing from Superstructure	SD	1.300	1009.7	1.700	1716.4
Reaction of Live Load from Superstructure	L	1.300	450.7	1.700	766.1
Reaction of Temp. Diff. from Superstructure	T	1.300	-134.3	1.700	-228.4
Total			4854.3		8053.5

Group-V	γ(D+SD+W+T)			V	x	M
Loading			γ x β	(kN)	(m)	(kNm)
Self Weight of Cantilever Beam		D	1.250	413.4	1.238	511.6
Reaction of Dead Load from Superstructure		D	1.250	2979.2	1.700	5064.6
Reaction of Surfacing from Superstructure		SD	1.250	970.8	1.700	1650.4
Reaction of Live Load from Superstructure		L	1.250	433.3	1.700	736.7
Wind Load		W	1.250	0.0	1.700	0.0
Reaction of Temp. Diff. from Superstructure		T	1.250	-129.2	1.700	-219.6
Total				4667.6		7743.7

Group-VI	γ(D+SD+L+0.3W+WL+T)			V	x	M
Loading			γ x β	(kN)	(m)	(kNm)
Self Weight of Cantilever Beam		D	1.250	413.4	1.238	511.6
Reaction of Dead Load from Superstructure		D	1.250	2979.2	1.700	5064.6
Reaction of Surfacing from Superstructure		SD	1.250	970.8	1.700	1650.4
Reaction of Live Load from Superstructure		L	1.250	433.3	1.700	736.7
Wind Load		0.3W	1.250	0.0	1.700	0.0
Wind Load on Live Load		WL	1.250	0.0	1.700	0.0
Reaction of Temp. Diff. from Superstructure		T	1.250	-129.2	1.700	-219.6
Total				4667.6		7743.7

(3) Summary of Sectional Force at Base of Cantilever Beam for Longitudinal Direction

1) Service Load Design

Group-III	LF		H	x	M
Loading			(kN)	(m)	(kNm)
Reaction of Longitudinal Force from Superstructure		LF	13.3	1.700	22.7
Total			13.3		22.7

Group-VI	LF		H	x	M
Loading			(kN)	(m)	(kNm)
Reaction of Longitudinal Force from Superstructure		LF	13.3	1.700	22.7
Total			13.3		22.7

Group-VII	EQ		H	x	M
Loading			(kN)	(m)	(kNm)
Seismic Force from Superstructure		EQ	1893.3	1.700	3218.7
Seismic Force by Self Weight of Cantilever Beam		EQ	115.8	1.238	143.3
Total			2009.1		3361.9

2) Load Factor Design

Group-III	γ(LF)			H	x	M
Loading			γ x β	(kN)	(m)	(kNm)
Reaction of Longitudinal Force from Superstructure		LF	1.300	17.3	1.700	29.5
Total				17.3		29.5

Group-VI	γ(LF)			H	x	M
Loading			γ x β	(kN)	(m)	(kNm)
Reaction of Longitudinal Force from Superstructure		LF	1.250	16.7	1.700	28.3
Total				16.7		28.3

Group-VII	γ(EQ)		H	x	M
Loading		γ x β	(kN)	(m)	(kNm)
Seismic Force from Superstructure	EQ	1.300	2461.3	1.700	4184.3
Seismic Force by Self Weight of Cantilever Beam	EQ	1.300	150.5	1.238	186.2
Total			2611.8		4370.5

3.6.3 Summary of Sectional Force

Summary of Force at Bottom of Footing

		Vertical Direction		Longitudinal Direction	
		M(kNm)	S(kN)	M(kNm)	S(kN)
Service Load Design	Group-I	6370.6	3837.4	-	-
	Group-II	5781.3	3490.8	-	-
	Group-III	6370.6	3837.4	22.7	13.3
	Group-IV	6195.0	3734.1	-	-
	Group-V	6195.0	3734.1	-	-
	Group-VI	6195.0	3734.1	22.7	13.3
	Group-VII	-	-	3361.9	2009.1
Load Factor Design	Group-I	8281.8	4988.6	-	-
	Group-II	7515.7	4538.0	-	-
	Group-III	8281.8	4988.6	29.5	17.3
	Group-IV	8053.5	4854.3	-	-
	Group-V	7743.7	4667.6	-	-
	Group-VI	7743.7	4667.6	28.3	16.7
	Group-VII	-	-	4370.5	2611.8

3.6.4 Calculation of Stress for Service Load Design

Stress Equation

$$\sigma_c = \frac{M}{\frac{b \cdot x}{2} \cdot \left(\frac{h}{2} - \frac{x}{3}\right) + n \cdot As' \cdot \frac{(x-d') \cdot (h/2-d')}{x} + n \cdot As \cdot \frac{(x-d) \cdot (h/2-d)}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

$$x^2 + \frac{2 \cdot n}{b} \{As' \cdot (x-d') + As \cdot (x-d)\} = 0.0$$

in which,

x : Distance from edge on compression side to neutral axis (mm)
h : Height of Member (mm)
b : Width in section (mm)
d : Effective height (mm)
d' : Concrete Cover (mm)
As : Sectional area of reinforcing bar arranged on tension side (mm^2)
As': Sectional area of reinforcing bar arranged on compression side (mm^2)
n : Elastic Modulus Ratio of Reinforce and Concrete , n = 15.00
σc: Compressive Stress of Concrete (N/mm^2)
σs: Tensile Stress of Reinforcing (N/mm^2)
M: Bending Moment (kN.m)

Bar Arrangement

		Vertical Direction	Longitudinal Direction
Dimension	b(mm)	2500	2500
	h(mm)	2500	2500
	d1(mm)	2400	2400
	d2(mm)	2300	-
Bar Arrangement	As1(mm^2)	18-D32 14476	15-D22 5702
	As2(mm^2)	18-D32 14476	-

Calculation Result of Bending Stress

	Vertical Direction					
	M (kNm)	σc (N/mm^2)	σs (N/mm^2)	σca (N/mm^2)	σsa (N/mm^2)	Remarks
Group-I	6370.6	3.40	113.65	9.60	168.00	OK
Group-II	5781.3	2.96	99.08	12.00	210.00	OK
Group-III	6370.6	3.40	113.65	12.00	210.00	OK
Group-IV	6195.0	3.31	110.52	12.00	210.00	OK
Group-V	6195.0	3.31	110.52	13.44	235.20	OK
Group-VI	6195.0	3.31	110.52	13.44	235.20	OK

	Lonigitudinal Direction					
	M (kNm)	σc (N/mm^2)	σs (N/mm^2)	σca (N/mm^2)	σsa (N/mm^2)	Remarks
Group-III	22.7	0.01	1.17	12.00	210.00	OK
Group-VI	22.7	0.01	1.17	13.44	235.20	OK
Group-VII	3361.9	2.14	174.10	12.77	223.44	OK

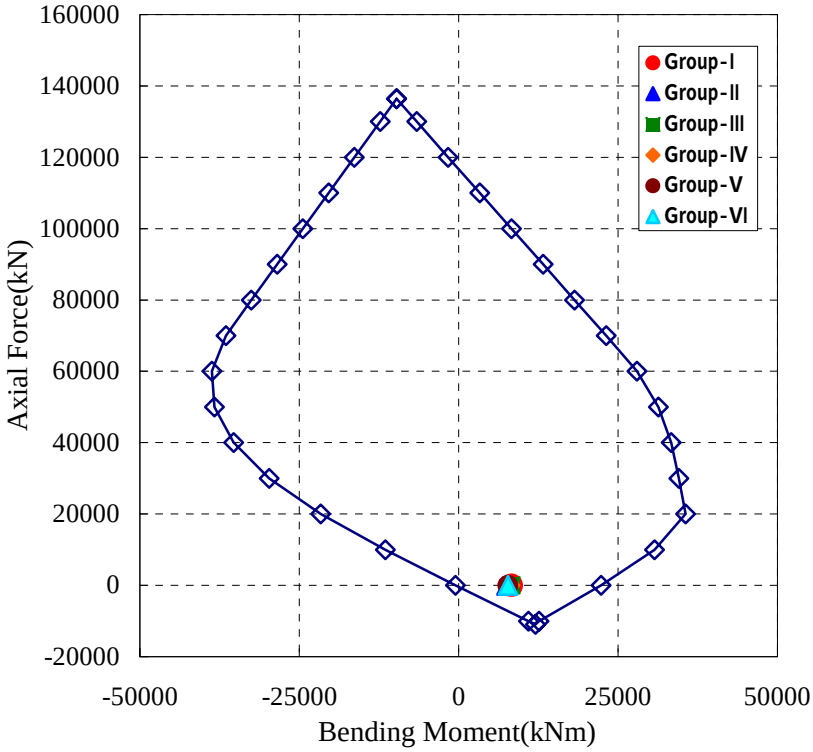
(6) Calculation of Strength for Load Factor Design

*) Flexural Strength

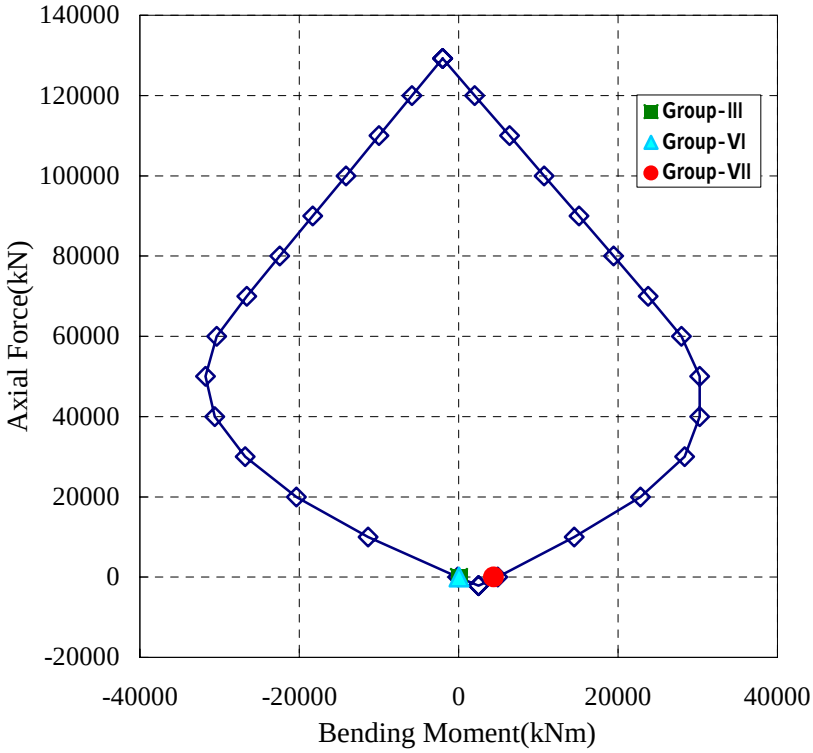
Factored Bending Moment for Load Factor Design

	Vertical Direction	Longitudinal Direction
Group-I	8281.8 kNm	- kNm
Group-II	7515.7 kNm	- kNm
Group-III	8281.8 kNm	29.5 kNm
Group-IV	8053.5 kNm	- kNm
Group-V	7743.7 kNm	- kNm
Group-VI	7743.7 kNm	28.3 kNm
Group-VII	- kNm	4370.5 kNm

Interaction of Vertical Direction



Interaction of Longitudinal Direction



*) Shear Strength

Shear Strength "Vn" is Calculated as follows.

Vn= Vc + Vs

In Which

Vc : Normal Shear Strength provided by the Concrete

Vc = vc x bw x d (vc=1/6x $\sqrt{}$ f'c)

= 1/6x $\sqrt{}$ f'c x bw x d)

f'c : 28days Cylinder Strength

bw : Width of Section

d : Effective Height of Section

Vs : Normal Shear Strength provided by the Shear Reinforcement

Vs = Av x fy x d / s

Av : Area of Shear Reinforcement within a distancees.

fy : Yeild Strength of Shear Reinforcement

d : Effective Height of Section

s : Calculated Distance.

Factored Shear Force for Load Factor Design

	Vertical Direction	Longitudinal Direction
Group-I	4988.6 kN	- kN
Group-II	4538.0 kN	- kN
Group-III	4988.6 kN	17.3 kN
Group-IV	4854.3 kN	- kN
Group-V	4667.6 kN	- kN
Group-VI	4667.6 kN	16.7 kN
Group-VI	- kN	2611.8 kN

Calculation of Shear Strength

vc = 1/6x $\sqrt{}$ f'c = 1/6 $\sqrt{}$ (24) = 0.816N/mm^2 -> 816kN/m^2

fy = 420 N/mm^2 -> 420000 kN/m^2

s = 1.000 m

Vertical Direction

	Su(kN)	bw(m)	d(m)	Vc(kN)	Vsreq(kN)	Asreq(mm^2/m)
Group-I	4988.6	2.500	2.400	4161.60	973.0	965.3
Group-II	4538.0	2.500	2.400	4161.60	442.8	439.3
Group-III	4988.6	2.500	2.400	4161.60	973.0	965.3
Group-IV	4854.3	2.500	2.400	4161.60	815.0	808.5
Group-V	4667.6	2.500	2.400	4161.60	595.3	590.6
Group-VI	4667.6	2.500	2.400	4161.60	595.3	590.6

Arrangement of Stirr D22 -ctc.125 12164 mm^2/m > 965.3 mm^2/m

Longitudinal Direction

	Su(kN)	bw(m)	d(m)	Vc(kN)	Vsreq(kN)	Asreq(mm^2/m)
Group-III	17.3	2.500	2.400	4161.60	0.0	0.0
Group-VI	16.7	2.500	2.400	4161.60	0.0	0.0
Group-VII	2611.8	2.500	2.400	4161.60	0.0	0.0

Arrangement of Stirr D25 -ctc.125 7854 mm^2/m > 0 mm^2/m

3.7 Design of Wall

3.7.1 Summary of Sectional Force at Base of Wall

		Longitudinal Direction			Transverse Direction		
		N(kN)	S(kN)	M(kNm)	N(kN)	S(kN)	M(kNm)
Service Load Design	Group-I	13202.8	0.0	0.0	13202.8	0.0	0.0
	Group-II	12162.8	0.0	0.0	12162.8	0.0	0.0
	Group-III	13202.8	40.0	388.4	13202.8	0.0	0.0
	Group-IV	12892.8	0.0	0.0	12892.8	0.0	0.0
	Group-V	11852.8	0.0	0.0	11852.8	0.0	0.0
	Group-VI	12892.8	40.0	388.4	12892.8	0.0	0.0
	Group-VII	12162.8	6619.0	37355.1	12162.8	5233.6	28503.7
Load Factor Design	Group-I	18069.4	0.0	0.0	18069.4	0.0	0.0
	Group-II	15811.6	0.0	0.0	15811.6	0.0	0.0
	Group-III	17163.6	52.0	504.9	17163.6	0.0	0.0
	Group-IV	16760.6	0.0	0.0	16760.6	0.0	0.0
	Group-V	14815.9	0.0	0.0	14815.9	0.0	0.0
	Group-VI	16115.9	50.0	485.5	16115.9	0.0	0.0
	Group-VII	15811.6	7384.0	44304.0	15811.6	5304.0	31824.0

3.7.2 Calculation of Stress for Service Load Design

Stress Equation

$$\sigma_c = \frac{N}{\frac{b \cdot x}{2} - n \cdot As \cdot \frac{d-x}{x} + n \cdot As' \cdot \frac{x-d'}{x}}$$

$$\sigma_s = n \cdot \sigma_c \cdot \frac{d-x}{x}$$

$$x^3 - 3 \cdot \left(\frac{h}{2}-e\right) \cdot x^2 - \frac{6n}{b}\left\{As' \cdot \left(\frac{h}{2}-d'-e\right) + As \cdot \left(\frac{h}{2}-d-e\right)\right\} \cdot x + \frac{6n}{b}\left\{As' \cdot d' \cdot \left(\frac{h}{2}-d'-e\right) + As \cdot d \cdot \left(\frac{h}{2}-d-e\right)\right\} = 0.0$$

in which,

x : Distance from edge on compression side to neutral axis (mm)
h : Height of Member (mm)
b : Width in section (mm)
d : Effective height (mm)
d' : Concrete Cover (mm)
As : Sectional area of reinforcing bar arranged on tension side (mm^2)
As': Sectional area of reinforcing bar arranged on compression side (mm^2)
n : Elastic Modulus Ratio of Reinforce and Concrete , n = 15.00
e : Axis force eccentric distance (mm)
σc: Compressive Stress of Concrete (N/mm^2)
σs: Tensile Stress of Reinforcing (N/mm^2)
N : Axial Force (kN)
M: Bending Moment (kN.m)

Bar Arrangement

		Longitudinal Direction	Transverse Direction
Dimension	b(mm)	5500	2500
	h(mm)	2500	5500
	d1(mm)	2400	5400
	d2(mm)	2300	-
Bar Arrangement	As1(mm^2)	43-D32 34583	9-D22 3421
	As2(mm^2)	43-D32 34583	

Calculation Result of Bending Stress

	Lonigitudinal Direction						
	M (kNm)	N (kN)	σc (N/mm^2)	σs (N/mm^2)	σca (N/mm^2)	σsa (N/mm^2)	Remarks
Group-I	0.0	13202.8	0.84	-12.54	9.60	168.00	OK
Group-II	0.0	12162.8	0.77	-11.55	12.00	210.00	OK
Group-III	388.4	13202.8	0.88	-11.89	12.00	210.00	OK
Group-IV	0.0	12892.8	0.82	-12.24	12.00	210.00	OK
Group-V	0.0	11852.8	0.75	-11.25	13.44	235.20	OK
Group-VI	388.4	12892.8	0.86	-11.60	13.44	235.20	OK
Group-VII	37355.1	12162.8	7.30	183.30	12.77	223.44	OK

	Transverse Direction						
	M (kNm)	N (kN)	σc (N/mm^2)	σs (N/mm^2)	σca (N/mm^2)	σsa (N/mm^2)	Remarks
Group-I	0.0	13202.8	0.95	-14.20	9.60	168.00	OK
Group-II	0.0	12162.8	0.87	-13.08	12.00	210.00	OK
Group-III	0.0	13202.8	0.95	-14.20	12.00	210.00	OK
Group-IV	0.0	12892.8	0.92	-13.86	12.00	210.00	OK
Group-V	0.0	11852.8	0.85	-12.75	13.44	235.20	OK
Group-VI	0.0	12892.8	0.92	-13.86	13.44	235.20	OK
Group-VII	28503.7	12162.8	5.83	180.86	12.77	223.44	OK

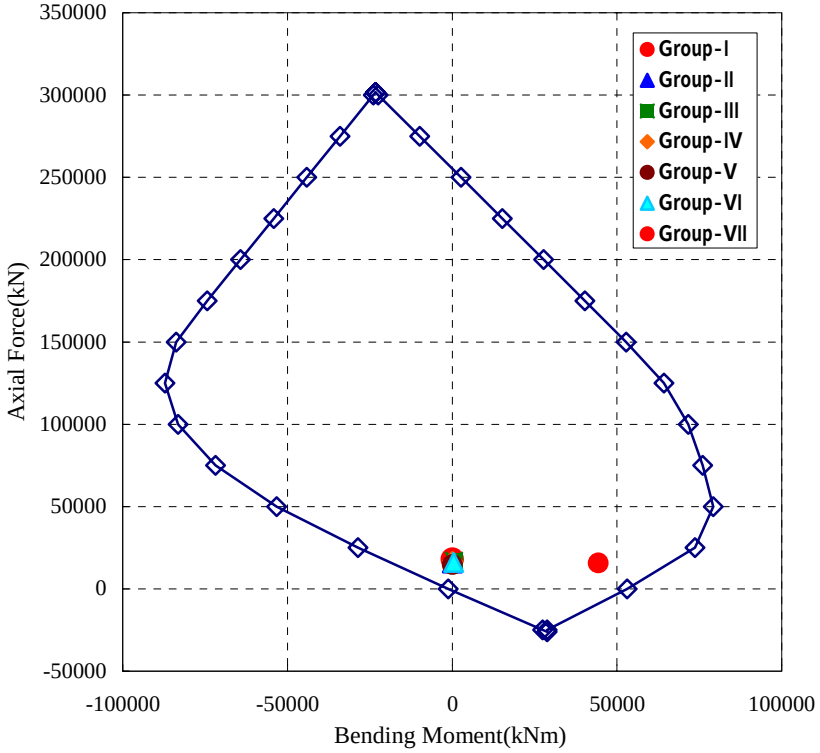
(6) Calculation of Strength for Load Factor Design

*) Flexural Strength

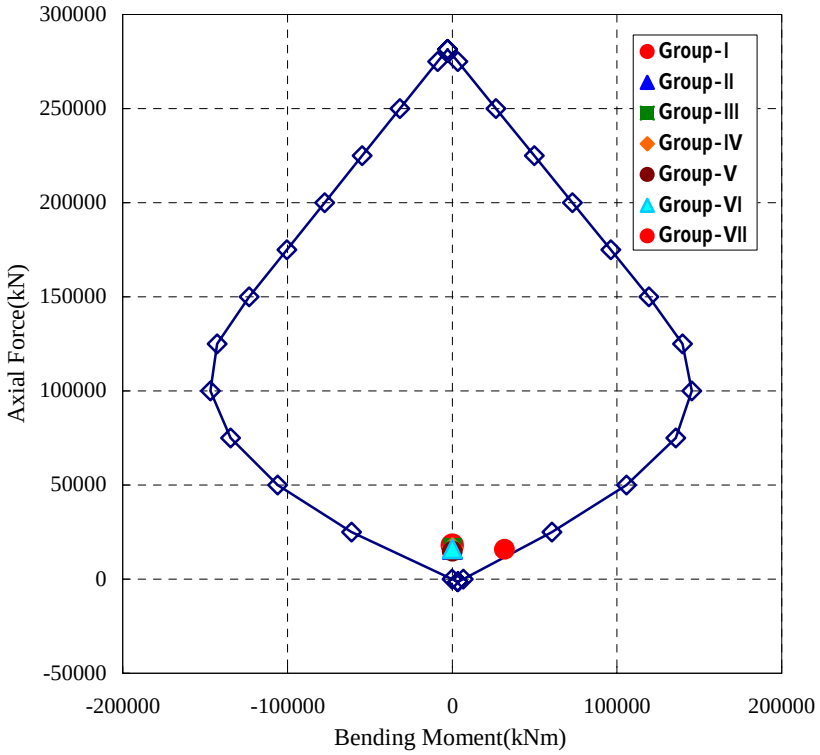
Factored Bending Moment for Load Factor Design

	Longitudinal Direction		Transverse Direction	
	M(kNm)	N(kN)	M(kNm)	N(kN)
Group-I	0.0	18069.4	0.0	18069.4
Group-II	0.0	15811.6	0.0	15811.6
Group-III	504.9	17163.6	0.0	17163.6
Group-IV	0.0	16760.6	0.0	16760.6
Group-V	0.0	14815.9	0.0	14815.9
Group-VI	485.5	16115.9	0.0	16115.9
Group-VII	44304.0	15811.6	31824.0	15811.6

Interaction of Longitudinal Direction



Interaction of Transverse Direction



*) Shear Strength

Shear Strength "Vn" is Calculated as follows.

Vn= Vc + Vs

In Which

Vc : Normal Shear Strength provided by the Concrete

Vc = vc x bw x d (vc=1/6x $\sqrt{}$ f'c)

= 1/6x $\sqrt{}$ f'c x bw x d)

f'c : 28days Cylinder Strength

bw : Width of Section

d : Effective Height of Section

Vs : Normal Shear Strength provided by the Shear Reinforcement

Vs = Av x fy x d / s

Av : Area of Shear Reinforcement within a distancees.

fy : Yeild Strength of Shear Reinforcement

d : Effective Height of Section

s : Calculated Distance.

Factored Shear Force for Load Factor Design

	Longitudinal Direction	Transverse Direction
Group-I	0.0 kN	0.00 kN
Group-II	0.0 kN	0.00 kN
Group-III	52.0 kN	0.00 kN
Group-IV	0.0 kN	0.00 kN
Group-V	0.0 kN	0.00 kN
Group-VI	50.0 kN	0.00 kN
Group-VII	7384.0 kN	5304.00 kN

Calculation of Shear Strength

vc = 1/6x $\sqrt{}$ f'c = 1/6x $\sqrt{}$ (24) = 0.816N/mm^2 -> 816kN/m^2

fy = 420 N/mm^2 -> 420000 kN/m^2

s = 1.000 m

Longitudinal Direction

	Su(kN)	bw(m)	d(m)	Vc(kN)	Vsreq(kN)	Asreq(mm^2/m)
Group-I	0.0	5.500	2.400	9155.5	0.0	0.0
Group-II	0.0	5.500	2.400	9155.5	0.0	0.0
Group-III	52.0	5.500	2.400	9155.5	0.0	0.0
Group-IV	0.0	5.500	2.400	9155.5	0.0	0.0
Group-V	0.0	5.500	2.400	9155.5	0.0	0.0
Group-VI	50.0	5.500	2.400	9155.5	0.0	0.0
Group-VII	7384.0	5.500	2.400	9155.5	0.0	0.0

Arrangement of Stirr D16 -ctc.150 9382.9 mm^2/m > 0 mm^2/m

Transverse Direction

	Su(kN)	bw(m)	d(m)	Vc(kN)	Vsreq(kN)	Asreq(mm^2/m)
Group-I	0.0	2.500	5.400	9363.6	0.0	0.0
Group-II	0.0	2.500	5.400	9363.6	0.0	0.0
Group-III	0.0	2.500	5.400	9363.6	0.0	0.0
Group-IV	0.0	2.500	5.400	9363.6	0.0	0.0
Group-V	0.0	2.500	5.400	9363.6	0.0	0.0
Group-VI	0.0	2.500	5.400	9363.6	0.0	0.0
Group-VII	5304.0	2.500	5.400	9363.6	0.0	0.0

Arrangement of Stirr D16 -ctc.150 4021.2 mm^2/m > 0 mm^2/m