REPUBLIC OF THE PHILIPPINES

DEPARTMENT OF
PUBLIC WORKS AND HIGHWAYS

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

FINAL REPORT

VOLUME-4B
STRUCTURAL CALCULATION FOR CONTRACT PACKAGE-2

AUGUST 2020

JAPAN INTERNATIONAL COOPERATION AGENCY

CTI ENGINEERING INTERNATIONAL CO., LTD.
JAPAN WATER AGENCY
NIPPON KOEI CO., LTD.
CTI ENGINEERING CO., LTD.

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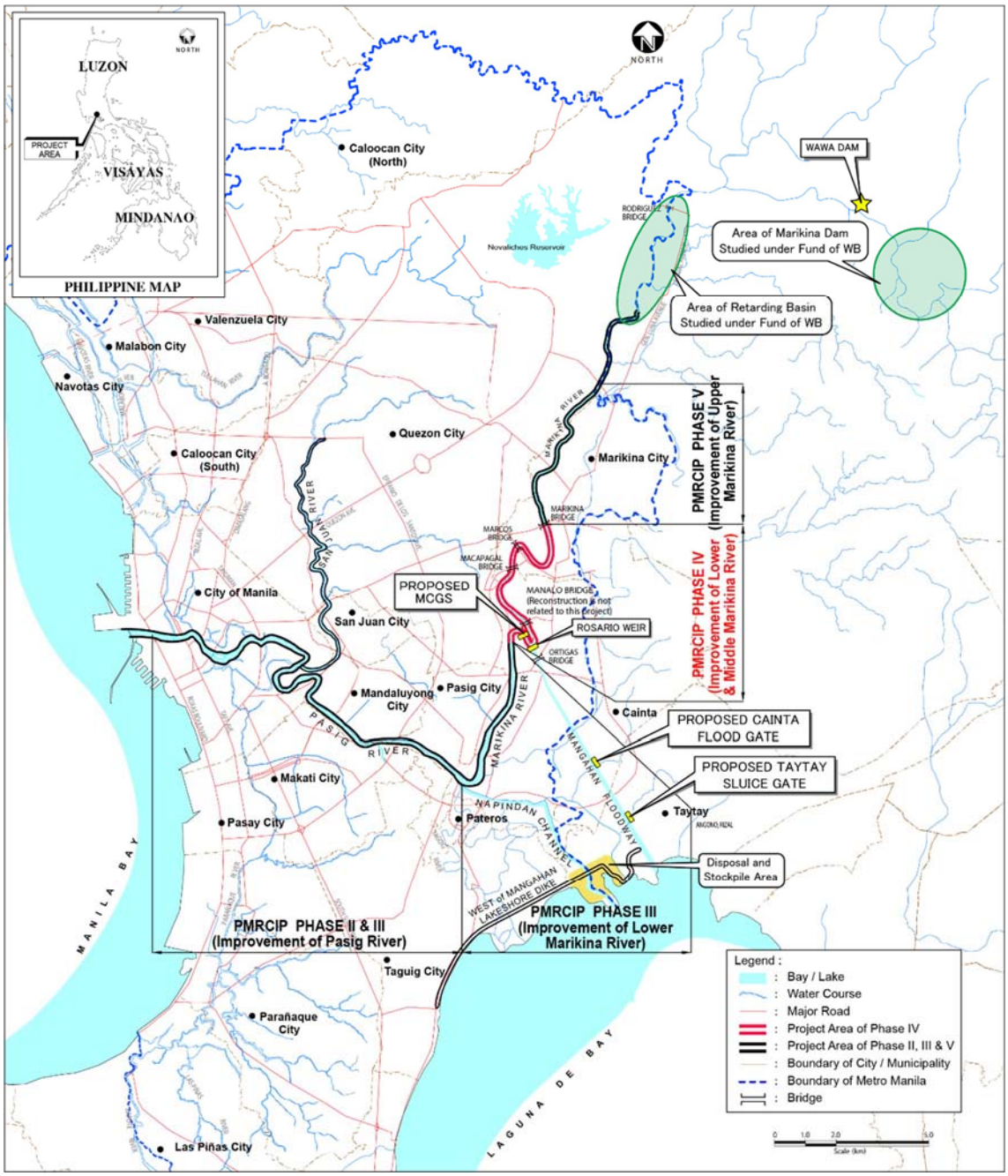
COMPOSITION OF FINAL REPORT

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

EXCHANGE RATES USED IN THE REPORT:
PHP 1.0 = JPY 2.15
US $1.0 = JPY 108.9 = PHP 50.7
(November 2019)



PROJECT LOCATION MAP

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

FINAL REPORT VOLUME-4B STRUCTURAL CALCULATION FOR CONTRACT PACKAGE-2

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CHAPTER 1 RIVER STRUCTURE

1.1 Low Water Channel Revetment

1.1.1 Liquefaction Analysis

The calculation sheets are shown in the following pages.

1.1 LOW WATER CHANNEL REVETMENT

1.1.1 LIQUEFACTION ANALYSIS

1.1.1.1 Left Bank

Name of the point BH-G-01

PL Value 1.488

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 3.18 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Dynamic shear strength ratio	Soil category	Soil type	Observed N value		Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.00	1.00	17.5	18.5	1.0	alluvial	sandy	5.00		17.5	17.5	31.00	0.000	1.00	0.262	0.262	0.197	**5		1
2.00	1.00	17.5	18.5	2.0	alluvial	sandy	3.00		35.0	35.0	59.00	0.000	1.00	0.238	0.238	0.194	**5		1
3.00	1.00	17.5	18.5	3.0	alluvial	sandy	3.00		52.5	52.5	42.00	0.160	1.00	0.198	0.198	0.191	**5		1
4.00	1.00	17.5	18.5	4.0	alluvial	sandy	4.00		62.6	62.6	19.00	0.410	1.00	0.173	0.173	0.213	0.814		2/3
5.00	1.00	17.5	18.5	5.0	alluvial	sandy	37.00		71.1	71.1	21.00	0.410	1.00	29.450	29.450	0.232	126.698		1
6.00	1.00	17.0	18.0	6.0	diluvial	cohesiv	50.00		79.1	79.1	20.00	0.000					**1		1
7.00	1.00	17.0	18.0	7.0	diluvial	cohesiv	50.00		87.1	87.1	0.00	0.000					**1		1
8.00	1.00	17.0	18.0	8.0	diluvial	cohesiv	50.00		95.1	95.1	0.00	0.000					**1		1
9.00	1.00	17.0	18.0	9.0	diluvial	cohesiv	50.00		103.1	103.1	0.00	0.000					**1		1
10.00	1.00	17.0	18.0	10.0	diluvial	cohesiv	50.00		111.1	111.1	0.00	0.000					**1		1
11.00	1.00	17.0	18.0	11.0	diluvial	cohesiv	50.00		119.1	119.1	0.00	0.000					**1		1
12.00	1.00	17.0	18.0	12.0	diluvial	cohesiv	50.00		127.1	127.1	0.00	0.000					**1		1
13.00	1.00	17.0	18.0	13.0	diluvial	cohesiv	50.00		135.1	135.1	0.00	0.000					**1		1
14.00	1.00	17.0	18.0	14.0	diluvial	cohesiv	50.00		143.1	143.1	0.00	0.000					**1		1
15.00	1.00	17.0	18.0	15.0	diluvial	cohesiv	50.00		151.1	151.1	0.00	0.000					**1		1
16.00	1.00	17.0	18.0	16.0	diluvial	cohesiv	50.00		159.1	159.1	0.00	0.000					**1		1
17.00	1.00	17.0	18.0	17.0	diluvial	cohesiv	50.00		167.1	167.1	0.00	0.000					**1		1
18.00	1.00	17.0	18.0	18.0	diluvial	cohesiv	50.00		175.1	175.1	0.00	0.000					**1		1
19.00	1.00	17.0	18.0	19.0	diluvial	cohesiv	50.00		183.1	183.1	0.00	0.000					**1		1
20.00	1.00	17.0	18.0	20.0	diluvial	cohesiv	50.00		191.1	191.1	0.00	0.000					**1		1

Name of the point BH-G-04

PL Value 5.398

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 0.77 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property														Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Judgement depth(m)	Soil category	Soil type	Observed N value		Effective Loading Pressure(kn/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)					Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.00	1.00	17.5	18.5	1.0	alluvial	sandy	7.00		15.4	15.4	36.00	0.000	1.00	0.348	0.348	0.227	1.535		1
2.00	1.00	17.5	18.5	2.0	alluvial	sandy	9.00		23.9	23.9	17.00	0.400	1.00	0.297	0.297	0.294	1.010		1
3.00	1.00	17.5	18.5	3.0	alluvial	sandy	9.00		32.4	32.4	24.00	0.250	1.00	0.306	0.306	0.322	0.950		1
4.00	1.00	17.5	18.5	4.0	alluvial	sandy	2.00		40.9	40.9	14.00	0.400	1.00	0.127	0.127	0.336	0.378		1/3
5.00	1.00	17.5	18.5	5.0	alluvial	sandy	20.00		49.4	49.4	14.00	0.500	1.00	0.923	0.923	0.343	2.688		1
6.00	1.00	17.5	18.5	6.0	alluvial	sandy	50.00		57.9	57.9	18.00	0.450	1.00	208.239	208.239	0.346	601.205		1
7.00	1.00	17.0	18.0	7.0	diluvial	cohesiv	50.00		65.9	65.9	0.00	0.000					**1		1
8.00	1.00	17.0	18.0	8.0	diluvial	cohesiv	50.00		73.9	73.9	0.00	0.000					**1		1
9.00	1.00	17.0	18.0	9.0	diluvial	cohesiv	50.00		81.9	81.9	0.00	0.000					**1		1
10.00	1.00	17.0	18.0	10.0	diluvial	cohesiv	50.00		89.9	89.9	0.00	0.000					**1		1
11.00	1.00	17.0	18.0	11.0	diluvial	cohesiv	50.00		97.9	97.9	0.00	0.000					**1		1
12.00	1.00	17.0	18.0	12.0	diluvial	cohesiv	50.00		105.9	105.9	0.00	0.000					**1		1
13.00	1.00	17.0	18.0	13.0	diluvial	cohesiv	50.00		113.9	113.9	0.00	0.000					**1		1
14.00	1.00	17.0	18.0	14.0	diluvial	cohesiv	50.00		121.9	121.9	0.00	0.000					**1		1
15.00	1.00	17.0	18.0	15.0	diluvial	cohesiv	50.00		129.9	129.9	0.00	0.000					**1		1
16.00	1.00	17.0	18.0	16.0	diluvial	cohesiv	50.00		137.9	137.9	0.00	0.000					**1		1
17.00	1.00	17.0	18.0	17.0	diluvial	cohesiv	50.00		145.9	145.9	0.00	0.000					**1		1
18.00	1.00	17.0	18.0	18.0	diluvial	cohesiv	50.00		153.9	153.9	0.00	0.000					**1		1
19.00	1.00	17.0	18.0	19.0	diluvial	cohesiv	50.00		161.9	161.9	0.00	0.000					**1		1
20.00	1.00	17.0	18.0	20.0	diluvial	cohesiv	50.00		169.9	169.9	0.00	0.000					**1		1

Name of the point BH-L-02

PL Value 0.000

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 5.49 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property													Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Judgement depth(m)	Soil categor	Soil type	Observed N value		Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kN/m2)	Fine fraction content (%)	Particle size (mm)				Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}		C_W	R_L	R	L	FL	0 1 2	D_E
1.00	1.00	17.5	18.5	1.0	alluvial	sandy	7.00		17.5	17.5	26.00	0.000		1.00	0.296	0.296	0.197	**5		1
2.00	1.00	17.5	18.5	2.0	alluvial	sandy	4.00		35.0	35.0	26.00	0.000		1.00	0.208	0.208	0.194	**5		1
3.00	1.00	17.5	18.5	3.0	alluvial	sandy	12.00		52.5	52.5	5.00	2.000		1.00	0.276	0.276	0.191	**5		1
4.00	1.00	17.5	18.5	4.0	alluvial	sandy	11.00		70.0	70.0	5.00	2.000		1.00	0.247	0.247	0.188	**5		1
5.00	1.00	17.5	18.5	5.0	alluvial	sandy	5.00		87.5	87.5	29.00	1.200		1.00	0.197	0.197	0.185	**5		1
6.00	1.00	17.5	18.5	6.0	alluvial	sandy	23.00		100.4	100.4	29.00	1.200		1.00	1.238	1.238	0.191	6.471		1
7.00	1.00	17.5	18.5	7.0	alluvial	sandy	34.00		108.9	108.9	10.00	1.500		1.00	1.154	1.154	0.204	5.662		1
8.00	1.00	17.5	18.5	8.0	alluvial	sandy	31.00		117.4	117.4	10.00	1.500		1.00	0.598	0.598	0.214	2.799		1
9.00	1.00	18.0	19.0	9.0	diluvial	cohesiv	3.00		126.4	126.4	55.00	0.100						**1		1
10.00	1.00	18.0	19.0	10.0	diluvial	cohesiv	19.00		135.4	135.4	55.00	0.100						**1		1
11.00	1.00	18.0	19.0	11.0	diluvial	cohesiv	13.00		144.4	144.4	47.00	0.160						**1		1
12.00	1.00	19.0	20.0	12.0	diluvial	sandy	6.00		154.4	154.4	47.00	0.160						**1		1
13.00	1.00	19.0	20.0	13.0	diluvial	sandy	12.00		164.4	164.4	68.00	0.000						**1		1
14.00	1.00	18.0	19.0	14.0	diluvial	cohesiv	12.00		173.4	173.4	68.00	0.000						**1		1
15.00	1.00	18.0	19.0	15.0	diluvial	cohesiv	18.00		182.4	182.4	78.00	0.000						**1		1
16.00	1.00	18.0	19.0	16.0	diluvial	cohesiv	19.00		191.4	191.4	78.00	0.000						**1		1
17.00	1.00	18.0	19.0	17.0	diluvial	cohesiv	16.00		200.4	200.4	70.00	0.000						**1		1
18.00	1.00	18.0	19.0	18.0	diluvial	cohesiv	19.00		209.4	209.4	70.00	0.000						**1		1
19.00	1.00	18.0	19.0	19.0	diluvial	cohesiv	40.00		218.4	218.4	43.00	0.000						**1		1
20.00	1.00	18.0	19.0	20.0	diluvial	cohesiv	50.00		227.4	227.4	43.00	0.000						**1		1

Name of the point BH-L-03

PL Value 0.000

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 1.99 (m)

Design horizontal seismic coefficient 0.20

Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Judgement depth(m)	Soil category	Soil type	Observed N value		Effective Loading Pressure(kn/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.00	1.00	17.5	18.5	1.0	alluvial	sandy	9.90		17.5	17.5	97.00	0.000	0.00	0.000	0.000	0.000	**2		1
2.00	1.00	17.5	18.5	2.0	alluvial	sandy	9.90		34.9	34.9	15.00	0.400	1.00	0.287	0.287	0.194	1.477		1
3.00	1.00	17.5	18.5	3.0	alluvial	sandy	9.90		43.4	43.4	15.00	0.400	1.00	0.276	0.276	0.235	1.172		1
4.00	1.00	17.5	18.5	4.0	alluvial	sandy	9.90		51.9	51.9	15.00	0.400	1.00	0.266	0.266	0.261	1.021		1
5.89	1.89	18.0	19.0	5.9	Hongzh	cohesiv	4.00		69.0	69.0	0.00	0.000					**1		1
6.89	1.00	19.0	20.0	6.9	Hongzh	sandy	3.00		79.0	79.0	77.00	0.000					**1		1
7.89	1.00	19.0	20.0	7.9	Hongzh	sandy	4.00		89.0	89.0	77.00	0.000					**1		1
8.89	1.00	19.0	20.0	8.9	Hongzh	sandy	5.50		99.0	99.0	97.00	0.000					**1		1
9.89	1.00	18.0	19.0	9.9	Hongzh	cohesiv	7.00		108.0	108.0	97.00	0.000					**1		1
10.89	1.00	18.0	19.0	10.9	Hongzh	cohesiv	7.00		117.0	117.0	87.00	0.000					**1		1
11.89	1.00	18.0	19.0	11.9	Hongzh	cohesiv	13.00		126.0	126.0	87.00	0.000					**1		1
12.89	1.00	18.0	19.0	12.9	Hongzh	cohesiv	12.00		135.0	135.0	94.00	0.000					**1		1
13.89	1.00	18.0	19.0	13.9	Hongzh	cohesiv	10.00		144.0	144.0	94.00	0.000					**1		1
14.89	1.00	18.0	19.0	14.9	Hongzh	cohesiv	9.00		153.0	153.0	88.00	0.000					**1		1
15.89	1.00	18.0	19.0	15.9	Hongzh	cohesiv	12.00		162.0	162.0	88.00	0.000					**1		1
16.89	1.00	18.0	19.0	16.9	Hongzh	cohesiv	12.00		171.0	171.0	88.00	0.000					**1		1
17.89	1.00	18.0	19.0	17.9	Hongzh	cohesiv	11.00		180.0	180.0	88.00	0.000					**1		1
18.89	1.00	18.0	19.0	18.9	Hongzh	cohesiv	13.00		189.0	189.0	31.00	0.200					**1		1
19.89	1.00	18.0	19.0	19.9	Hongzh	cohesiv	17.00		198.0	198.0	31.00	0.200					**1		1
20.89	1.00	18.0	19.0	20.9	Hongzh	sandy	17.00		207.0	207.0	29.00	0.200					**1		1
21.89	1.00	18.0	19.0	21.9	Hongzh i	cohesiv e soil	39.00		216.0	216.0	29.00	0.200					**1		1
22.89	1.00	18.0	19.0	22.9	Hongzh	cohesiv	38.00		225.0	225.0	0.00	0.000					**1		1
23.89	1.00	18.0	19.0	23.9	Hongzh	cohesiv	43.00		234.0	234.0	0.00	0.000					**1		1
24.89	1.00	18.0	19.0	24.9	Hongzh	cohesiv	48.00		243.0	243.0	0.00	0.000					**1		1

Name of the point BH-L-07

PL Value 0.654

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 2.55 (m)

Design horizontal seismic coefficient 0.20

Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Judgement depth(m)	Soil category	Soil type	Observed N value		Effective Loading Pressure (kn/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.59	1.59	17.5	18.5	1.6	alluvial	sandy	2.00		27.9	27.9	0.00	0.000	1.00	0.126	0.126	0.195	**5		1
2.59	1.00	17.5	18.5	2.6	alluvial	sandy	2.00		45.0	45.0	49.00	0.000	1.00	0.184	0.184	0.194	0.951		2/3
3.59	1.00	17.5	18.5	3.6	alluvial	sandy	13.00		53.5	53.5	6.00	5.000	1.00	0.287	0.287	0.226	1.270		1
4.59	1.00	17.5	18.5	4.6	alluvial	sandy	12.00		62.0	62.0	6.00	3.200	1.00	0.266	0.266	0.247	1.075		1
5.59	1.00	17.5	18.5	5.6	alluvial	sandy	11.00		70.5	70.5	6.00	3.200	1.00	0.247	0.247	0.262	0.941		2/3
6.59	1.00	18.0	19.0	6.6	diluvial	cohesiv	14.00		79.5	79.5	75.00	0.000					**1		1
7.59	1.00	18.0	19.0	7.6	diluvial	cohesiv	50.00		88.5	88.5	75.00	0.000					**1		1
8.59	1.00	18.0	19.0	8.6	diluvial	cohesiv	50.00		97.5	97.5	75.00	0.000					**1		1
9.59	1.00	18.0	19.0	9.6	diluvial	cohesiv	50.00		106.5	106.5	75.00	0.000					**1		1
10.5	1.00	18.0	19.0	10.6	diluvial	cohesiv	50.00		115.5	115.5	75.00	0.000					**1		1

Name of the point BH-L-09

PL Value 0.000

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 2.72 (m)

Design horizontal seismic coefficient 0.20

Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Judgement depth(m)	Soil category	Soil type	Observed N value		Effective Loading Pressure (kn/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.00	1.00	15.5	16.5	1.0	alluvial	cohesiv	3.00		15.5	15.5	0.00	0.000	1.00	0.165	0.165	0.197	**5		1
2.00	1.00	15.5	16.5	2.0	alluvial	cohesiv	3.00		31.0	31.0	82.00	0.000	1.00	0.304	0.304	0.194	**5		1
3.00	1.00	15.5	16.5	3.0	alluvial	cohesiv	4.00		44.0	44.0	82.00	0.000	1.00	0.345	0.345	0.203	1.698		1
4.00	1.00	15.5	16.5	4.0	alluvial	sandy	8.00		50.5	50.5	49.00	0.080	1.00	0.341	0.341	0.236	1.445		1
5.00	1.00	17.5	18.5	5.0	alluvial	sandy	11.00		59.0	59.0	49.00	0.080	1.00	0.586	0.586	0.257	2.284		1
6.00	1.00	15.5	16.5	6.0	alluvial	cohesiv	16.00		65.5	65.5	78.00	0.000	0.00	0.000	0.000	0.000	**2		1
7.00	1.00	15.5	16.5	7.0	alluvial	cohesiv	26.00		72.0	72.0	78.00	0.000	0.00	0.000	0.000	0.000	**2		1
8.00	1.00	15.5	16.5	8.0	alluvial	cohesiv	27.00		78.5	78.5	43.00	0.000	0.00	0.000	0.000	0.000	**2		1
9.00	1.00	18.0	19.0	9.0	diluvial	cohesiv	16.00		87.5	87.5	43.00	0.000					**1		1
10.00	1.00	18.0	19.0	10.0	diluvial	cohesiv	25.00		96.5	96.5	51.00	0.000					**1		1
11.00	1.00	18.0	19.0	11.0	diluvial	cohesiv	20.00		105.5	105.5	51.00	0.000					**1		1
12.00	1.00	18.0	19.0	12.0	diluvial	cohesiv	22.00		114.5	114.5	99.00	0.000					**1		1
13.00	1.00	18.0	19.0	13.0	diluvial	cohesiv	50.00		123.5	123.5	99.00	0.000					**1		1
14.00	1.00	18.0	19.0	14.0	diluvial	cohesiv	50.00		132.5	132.5	93.00	0.000					**1		1
15.00	1.00	18.0	19.0	15.0	diluvial	cohesiv	50.00		141.5	141.5	93.00	0.000					**1		1
16.00	1.00	18.0	19.0	16.0	diluvial	cohesiv	36.00		150.5	150.5	99.00	0.000					**1		1
17.00	1.00	18.0	19.0	17.0	diluvial	cohesiv	26.00		159.5	159.5	99.00	0.000					**1		1
18.00	1.00	18.0	19.0	18.0	diluvial	cohesiv	21.00		168.5	168.5	99.00	0.000					**1		1
19.00	1.00	18.0	19.0	19.0	diluvial	cohesiv	29.00		177.5	177.5	99.00	0.000					**1		1
20.00	1.00	18.0	19.0	20.0	diluvial	cohesiv	29.00		186.5	186.5	98.00	0.000					**1		1

Name of the point BH-L -10

PL Value 1.321

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 3.12 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property													Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Judgement depth(m)	Soil category	Soil type	Observed N value		Effective Loading Pressure (kn/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)				Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.17	1.17	15.5	16.5	1.2	alluvial	cohesiv	3.00		18.2	18.2	67.00	0.000	1.00	0.277	0.277	0.196	**5		1
2.17	1.00	15.5	16.5	2.2	alluvial	cohesiv	2.00		33.7	33.7	67.00	0.000	1.00	0.223	0.223	0.193	**5		1
3.17	1.00	17.5	18.5	3.2	alluvial	sandy	3.00		50.7	50.7	54.00	0.100	1.00	0.218	0.218	0.192	1.133		1
4.17	1.00	17.5	18.5	4.2	alluvial	sandy	2.00		59.2	59.2	54.00	0.100	1.00	0.184	0.184	0.221	0.833		2/3
5.17	1.00	15.5	16.5	5.2	alluvial	cohesiv	3.50		65.7	65.7	95.00	0.100	1.00	0.322	0.322	0.242	1.332		1
6.17	1.00	15.5	16.5	6.2	alluvial	cohesiv	5.00		72.2	72.2	95.00	0.100	1.00	0.525	0.525	0.258	2.034		1
7.17	1.00	15.5	16.5	7.2	alluvial	cohesiv	8.00		78.7	78.7	92.00	0.000	0.00	0.000	0.000	0.000	**2		1
8.17	1.00	15.5	16.5	8.2	alluvial	cohesiv	11.00		85.2	85.2	92.00	0.000	0.00	0.000	0.000	0.000	**2		1
9.17	1.00	15.5	16.5	9.2	alluvial	cohesiv	14.00		91.7	91.7	70.00	0.000	0.00	0.000	0.000	0.000	**2		1
10.17	1.00	15.5	16.5	10.2	alluvial	cohesiv	4.00		98.2	98.2	70.00	0.000	0.00	0.000	0.000	0.000	**2		1
11.17	1.00	15.5	16.5	11.2	alluvial	cohesiv	18.00		104.7	104.7	51.00	0.000	0.00	0.000	0.000	0.000	**2		1
12.17	1.00	15.5	16.5	12.2	alluvial	cohesiv	11.00		111.2	111.2	51.00	0.000	0.00	0.000	0.000	0.000	**2		1
13.17	1.00	18.0	19.0	13.2	diluvial	cohesiv	21.00		120.2	120.2	68.00	0.000					**1		1
14.17	1.00	18.0	19.0	14.2	diluvial	cohesiv	21.00		129.2	129.2	68.00	0.000					**1		1
15.17	1.00	18.0	19.0	15.2	diluvial	cohesiv	28.00		138.2	138.2	68.00	0.100					**1		1
16.17	1.00	18.0	19.0	16.2	diluvial	cohesiv	27.00		147.2	147.2	68.00	0.100					**1		1
17.17	1.00	18.0	19.0	17.2	diluvial	cohesiv	25.00		156.2	156.2	94.00	0.000					**1		1
18.17	1.00	18.0	19.0	18.2	diluvial	cohesiv	21.00		165.2	165.2	94.00	0.000					**1		1
19.17	1.00	18.0	19.0	19.2	diluvial	cohesiv	26.00		174.2	174.2	94.00	0.000					**1		1
20.17	1.00	18.0	19.0	20.2	diluvial	cohesiv	36.00		183.2	183.2	94.00	0.000					**1		1

Name of the point BH-L -11

PL Value 0.071

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 1.64 (m)

Design horizontal seismic coefficient 0.20

Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Judgement depth(m)	Soil category	Soil type	Observed N value		Effective Loading Pressure (kn/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.29	1.29	17.5	18.5	1.3	alluvial	sandy	2.00		22.5	22.5	55.00	0.000	1.00	0.208	0.208	0.196	**5		1
2.29	1.00	15.5	16.5	2.3	alluvial	cohesiv	4.00		32.2	32.2	36.00	0.000	1.00	0.230	0.230	0.232	0.992		2/3
3.29	1.00	17.5	18.5	3.3	alluvial	sandy	5.00		40.7	40.7	83.00	0.000	0.00	0.000	0.000	0.000	**2		1
4.29	1.00	15.5	16.5	4.3	alluvial	cohesiv	14.00		47.2	47.2	60.00	0.050	1.00	6.919	6.919	0.292	23.696		1
5.29	1.00	19.0	20.0	5.3	diluvial	sandy	26.00		57.2	57.2	28.00	0.350					**1		1
6.29	1.00	19.0	20.0	6.3	diluvial	sandy	24.00		67.2	67.2	30.00	0.250					**1		1
7.29	1.00	19.0	20.0	7.3	diluvial	sandy	46.00		77.2	77.2	23.00	1.300					**1		1
8.29	1.00	15.5	16.5	8.3	diluvial	cohesiv	26.00		83.7	83.7	87.00	0.000					**1		1
9.29	1.00	18.0	19.0	9.3	diluvial	cohesiv	18.00		92.7	92.7	83.00	0.000					**1		1
10.29	1.00	18.0	19.0	10.3	diluvial	cohesiv	14.00		101.7	101.7	31.00	0.000					**1		1
11.29	1.00	18.0	19.0	11.3	diluvial	cohesiv	50.00		110.7	110.7	40.00	0.000					**1		1
12.29	1.00	16.5	17.5	12.3	diluvial	cohesiv	50.00		118.2	118.2	0.00	0.000					**1		1
13.29	1.00	16.5	17.5	13.3	diluvial	cohesiv	50.00		125.7	125.7	0.00	0.000					**1		1
14.29	1.00	16.5	17.5	14.3	diluvial	cohesiv	50.00		133.2	133.2	0.00	0.000					**1		1
15.29	1.00	16.5	17.5	15.3	diluvial	cohesiv	50.00		140.7	140.7	0.00	0.000					**1		1
16.29	1.00	16.5	17.5	16.3	diluvial	cohesiv	50.00		148.2	148.2	0.00	0.000					**1		1
17.29	1.00	16.5	17.5	17.3	diluvial	cohesiv	50.00		155.7	155.7	0.00	0.000					**1		1
18.29	1.00	16.5	17.5	18.3	diluvial	cohesiv	50.00		163.2	163.2	0.00	0.000					**1		1
19.29	1.00	16.5	17.5	19.3	diluvial	cohesiv	50.00		170.7	170.7	0.00	0.000					**1		1
20.29	1.00	16.5	17.5	20.3	diluvial	cohesiv	50.00		178.2	178.2	0.00	0.000					**1		1

Name of the point BH-L -12

PL Value 0.000

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 5.49 (m)

Design horizontal seismic coefficient 0.20

Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Judgement depth(m)	Soil category	Soil type	Observed N value		Effective Loading Pressure (kn/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.00	1.00	17.5	18.5	1.0	alluvial	sandy	7.00		17.5	17.5	26.00	0.000	1.00	0.296	0.296	0.197	**5		1
2.00	1.00	17.5	18.5	2.0	alluvial	sandy	4.00		35.0	35.0	26.00	0.000	1.00	0.208	0.208	0.194	**5		1
3.00	1.00	17.5	18.5	3.0	alluvial	sandy	12.00		52.5	52.5	5.00	2.000	1.00	0.276	0.276	0.191	**5		1
4.00	1.00	17.5	18.5	4.0	alluvial	sandy	11.00		70.0	70.0	5.00	2.000	1.00	0.247	0.247	0.188	**5		1
5.00	1.00	17.5	18.5	5.0	alluvial	sandy	5.00		87.5	87.5	29.00	1.200	1.00	0.197	0.197	0.185	**5		1
6.00	1.00	17.5	18.5	6.0	alluvial	sandy	23.00		100.4	100.4	29.00	1.200	1.00	1.238	1.238	0.191	6.471		1
7.00	1.00	17.5	18.5	7.0	alluvial	sandy	34.00		108.9	108.9	10.00	1.500	1.00	1.154	1.154	0.204	5.662		1
8.00	1.00	17.5	18.5	8.0	alluvial	sandy	31.00		117.4	117.4	10.00	1.500	1.00	0.598	0.598	0.214	2.799		1
9.00	1.00	18.0	19.0	9.0	diluvial	cohesiv	3.00		126.4	126.4	55.00	0.100					**1		1
10.00	1.00	18.0	19.0	10.0	diluvial	cohesiv	19.00		135.4	135.4	55.00	0.100					**1		1
11.00	1.00	18.0	19.0	11.0	diluvial	cohesiv	13.00		144.4	144.4	47.00	0.160					**1		1
12.00	1.00	19.0	20.0	12.0	diluvial	sandy	6.00		154.4	154.4	47.00	0.160					**1		1
13.00	1.00	19.0	20.0	13.0	diluvial	sandy	12.00		164.4	164.4	68.00	0.000					**1		1
14.00	1.00	18.0	19.0	14.0	diluvial	cohesiv	12.00		173.4	173.4	68.00	0.000					**1		1
15.00	1.00	18.0	19.0	15.0	diluvial	cohesiv	18.00		182.4	182.4	78.00	0.000					**1		1
16.00	1.00	18.0	19.0	16.0	diluvial	cohesiv	19.00		191.4	191.4	78.00	0.000					**1		1
17.00	1.00	18.0	19.0	17.0	diluvial	cohesiv	16.00		200.4	200.4	70.00	0.000					**1		1
18.00	1.00	18.0	19.0	18.0	diluvial	cohesiv	19.00		209.4	209.4	70.00	0.000					**1		1
19.00	1.00	18.0	19.0	19.0	diluvial	cohesiv	40.00		218.4	218.4	43.00	0.000					**1		1
20.00	1.00	18.0	19.0	20.0	diluvial	cohesiv	50.00		227.4	227.4	43.00	0.000					**1		1
21.00	1.00	19.0	20.0	21.0	diluvial	sandy	21.00		237.4	237.4	74.00	0.000					**1		1
22.00	1.00	19.0	20.0	22.0	diluvial	sandy	26.00		247.4	247.4	74.00	0.000					**1		1
23.00	1.00	19.0	20.0	23.0	diluvial	sandy	30.00		257.4	257.4	57.00	0.000					**1		1
24.00	1.00	19.0	20.0	24.0	diluvial	sandy	25.00		267.4	267.4	57.00	0.000					**1		1
25.00	1.00	18.0	19.0	25.0	diluvial	cohesiv	25.00		276.4	276.4	58.00	0.000					**1		1
26.00	1.00	18.0	19.0	26.0	diluvial	cohesiv	16.00		285.4	285.4	58.00	0.000					**1		1
27.00	1.00	18.0	19.0	27.0	diluvial	cohesiv	24.00		294.4	294.4	56.00	0.000					**1		1
28.00	1.00	18.0	19.0	28.0	diluvial	cohesiv	31.00		303.4	303.4	0.00	0.000					**1		1
29.00	1.00	18.0	19.0	29.0	diluvial	cohesiv	50.00		312.4	312.4	0.00	0.000					**1		1

Name of the point BH-L -14

PL Value 0.000

Unit volume weight of water 10.0 (kN/m3)
Load 0.0 (kN/m2)
Groundwater level 2.67 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Judgement depth(m)	Soil category	Soil type	Observed N value		Effective Loading Pressure (kn/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.00	1.00	15.5	16.5	1.0	alluvial	cohesiv	2.00		15.5	15.5	82.00	0.000	1.00	0.273	0.273	0.197	**5		1
2.00	1.00	15.5	16.5	2.0	alluvial	cohesiv	2.00		31.0	31.0	82.00	0.000	1.00	0.257	0.257	0.194	**5		1
3.00	1.00	15.5	16.5	3.0	alluvial	cohesiv	10.00		43.5	43.5	46.00	0.300	1.00	0.569	0.569	0.206	2.769		1
4.00	1.00	15.5	16.5	4.0	alluvial	cohesiv	17.00		50.0	50.0	46.00	0.300	1.00	6.950	6.950	0.238	29.185		1
5.00	1.00	15.5	16.5	5.0	alluvial	cohesiv	15.00		56.5	56.5	46.00	0.300	1.00	2.422	2.422	0.261	9.267		1
6.00	1.00	18.0	19.0	6.0	diluvial	cohesiv	16.00		65.5	65.5	71.00	0.000					**1		1
7.00	1.00	18.0	19.0	7.0	diluvial	cohesiv	15.00		74.5	74.5	71.00	0.000					**1		1
8.00	1.00	18.0	19.0	8.0	diluvial	cohesiv	18.00		83.5	83.5	94.00	0.000					**1		1
9.00	1.00	18.0	19.0	9.0	diluvial	cohesiv	26.00		92.5	92.5	64.00	0.000					**1		1
10.00	1.00	18.0	19.0	10.0	diluvial	cohesiv	20.00		101.5	101.5	64.00	0.000					**1		1
11.00	1.00	18.0	19.0	11.0	diluvial	cohesiv	22.00		110.5	110.5	93.00	0.000					**1		1
12.00	1.00	18.0	19.0	12.0	diluvial	cohesiv	31.00		119.5	119.5	93.00	0.000					**1		1
13.00	1.00	18.0	19.0	13.0	diluvial	cohesiv	22.00		128.5	128.5	91.00	0.000					**1		1
14.00	1.00	18.0	19.0	14.0	diluvial	cohesiv	19.00		137.5	137.5	91.00	0.000					**1		1
15.00	1.00	19.0	20.0	15.0	diluvial	sandy	20.00		147.5	147.5	67.00	0.000					**1		1
16.00	1.00	19.0	20.0	16.0	diluvial	sandy	14.00		157.5	157.5	67.00	0.000					**1		1
17.00	1.00	18.0	19.0	17.0	diluvial	sandy	30.00		166.5	166.5	30.00	0.000					**1		1
18.00	1.00	18.0	19.0	18.0	diluvial	sandy	19.00		175.5	175.5	30.00	0.000					**1		1
19.00	1.00	16.5	17.5	19.0	diluvial	cohesiv	28.00		183.0	183.0	96.00	0.000					**1		1
20.00	1.00	16.5	17.5	20.0	diluvial	cohesiv	25.00		190.5	190.5	96.00	0.000					**1		1

1.1.1 LIQUEFACTION ANALYSIS
1.1.1.2 Right Bank

Name of the point BH-R-03

PL Value 5.394

Unit volume weight of water 10.0 (kn/m3)
Load 0.0 (kn/m2)
Groundwater level 1.82 (m)

Design horizontal seismic coefficient 0.20

Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Dynamic shear strength ratio	Soil category	Soil type	Observed N value		Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
2.01	2.01	17.5	18.5	2.0	alluvial	Sandy	4.00		33.4	33.4	3.00	5.000	1.00	0.173	0.173	0.205	0.846		2/3
3.01	1.00	17.5	18.5	3.0	alluvial	Sandy	4.00		41.9	41.9	3.00	5.000	1.00	0.167	0.167	0.245	0.680		2/3
4.01	1.00	17.5	18.5	4.0	alluvial	Sandy	12.00		50.4	50.4	3.00	5.000	1.00	0.279	0.279	0.270	1.033		1
5.01	1.00	17.5	18.5	5.0	alluvial	Sandy	8.00		58.9	58.9	3.00	5.000	1.00	0.220	0.220	0.285	0.771		2/3
6.01	1.00	18.0	19.0	6.0	diluvial	Cohesiv	2.00		67.9	67.9	44.00	0.000					**1		1
7.01	1.00	17.5	18.5	7.0	alluvial	Sandy	3.00		76.4	76.4	44.00	0.000	0.00	0.000	0.000	0.000	**2		1
8.01	1.00	18.0	19.0	8.0	diluvial	Cohesiv	3.00		85.4	85.4	96.00	0.100					**1		1
9.01	1.00	18.0	19.0	9.0	diluvial	Cohesiv	9.00		94.4	94.4	76.00	0.000					**1		1
10.01	1.00	18.0	19.0	10.0	diluvial	Cohesiv	10.00		103.4	103.4	76.00	0.000					**1		1
11.01	1.00	18.0	19.0	11.0	diluvial	Cohesiv	13.00		112.4	112.4	83.00	0.000					**1		1
12.01	1.00	18.0	19.0	12.0	diluvial	Cohesiv	11.00		121.4	121.4	83.00	0.000					**1		1
13.01	1.00	18.0	19.0	13.0	diluvial	Cohesiv	11.00		130.4	130.4	83.00	0.000					**1		1
14.01	1.00	18.0	19.0	14.0	diluvial	Cohesiv	20.00		139.4	139.4	83.00	0.000					**1		1
15.01	1.00	18.0	19.0	15.0	diluvial	Cohesiv	50.00		148.4	148.4	74.00	0.000					**1		1
16.01	1.00	18.0	19.0	16.0	diluvial	Cohesiv	43.00		157.4	157.4	74.00	0.000					**1		1
17.01	1.00	18.0	19.0	17.0	diluvial	Cohesiv	22.00		166.4	166.4	29.00	1.200					**1		1
18.01	1.00	18.0	19.0	18.0	diluvial	Cohesiv	37.00		175.4	175.4	29.00	1.200					**1		1
19.01	1.00	18.0	19.0	19.0	diluvial	Cohesiv	36.00		184.4	184.4	34.00	0.850					**1		1
20.01	1.00	18.0	19.0	20.0	diluvial	Cohesiv	50.00		193.4	193.4	34.00	0.850					**1		1
21.01	1.00	18.0	19.0	21.0	diluvial	Cohesiv	47.00		202.4	202.4	16.00	1.200					**1		1
22.01	1.00	18.0	19.0	22.0	diluvial	Cohesiv	50.00		211.4	211.4	16.00	1.200					**1		1
23.01	1.00	18.0	19.0	23.0	diluvial	Cohesiv	50.00		220.4	220.4	23.00	0.000					**1		1
24.01	1.00	16.5	17.5	24.0	diluvial	Cohesiv	50.00		227.9	227.9	23.00	0.000					**1		1
25.01	1.00	16.5	17.5	25.0	diluvial	Cohesiv	50.00		235.4	235.4	0.00	0.000					**1		1

Name of the point BH-R -11

PL Value 0.000

Unit volume weight of water 10.0 (kn/m3)
Load 0.0 (kn/m2)
Groundwater level 3.92 (m)

Design horizontal seismic coefficient 0.20

Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state			Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Dynamic shear strength ratio	Soil category	Soil type	Observed N value		Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance	
	h	γt	γ sat	x			N		$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	D_E
0.54								0 10 20 30 40 50 0									0 1 2	
1.54	0.54	15.5	16.5	0.5	alluvial	Cohesive soil	3.00		8.4	8.4	0.00	0.000	1.00	0.173	0.173	0.198	**5	1
2.54	1.00	17.5	18.5	1.5	alluvial	Sandy	14.00		25.9	25.9	0.00	0.000	1.00	0.409	0.409	0.195	**5	1
3.54	1.00	17.5	18.5	2.5	alluvial	Sandy	16.00		43.4	43.4	39.00	0.000	1.00	3.853	3.853	0.192	**5	1
4.54	1.00	17.5	18.5	3.5	alluvial	Sandy	16.00		60.9	60.9	39.00	0.000	1.00	1.662	1.662	0.189	**5	1
5.54	1.00	17.5	18.5	4.5	alluvial	Sandy	20.00		72.8	72.8	9.00	0.550	1.00	0.377	0.377	0.202	1.862	1
6.54	1.00	18.0	19.0	5.5	diluvial	Cohesiv	12.00		81.8	81.8	77.00	0.550					**1	1
7.54	1.00	18.0	19.0	6.5	diluvial	Cohesiv	11.00		90.8	90.8	77.00	0.000					**1	1
8.54	1.00	18.0	19.0	7.5	diluvial	Cohesiv	11.00		99.8	99.8	77.00	0.000					**1	1
9.54	1.00	18.0	19.0	8.5	diluvial	Cohesiv	9.00		108.8	108.8	72.00	0.000					**1	1
10.54	1.00	18.0	19.0	9.5	diluvial	Cohesiv	10.00		117.8	117.8	72.00	0.000					**1	1
11.54	1.00	18.0	19.0	10.5	diluvial	Cohesiv	12.00		126.8	126.8	88.00	0.000					**1	1
12.54	1.00	18.0	19.0	11.5	diluvial	Cohesiv	11.00		135.8	135.8	88.00	0.000					**1	1
13.54	1.00	18.0	19.0	12.5	diluvial	Cohesiv	18.00		144.8	144.8	96.00	0.000					**1	1
14.54	1.00	18.0	19.0	13.5	diluvial	Cohesiv	24.00		153.8	153.8	96.00	0.000					**1	1
15.54	1.00	18.0	19.0	14.5	diluvial	Cohesiv	41.00		162.8	162.8	90.00	0.000					**1	1
16.54	1.00	18.0	19.0	15.5	diluvial	Cohesiv	34.00		171.8	171.8	90.00	0.000					**1	1
17.54	1.00	18.0	19.0	16.5	diluvial	Cohesiv	18.00		180.8	180.8	80.00	0.000					**1	1
18.54	1.00	16.5	17.5	17.5	diluvial	Cohesiv	22.00		188.3	188.3	80.00	0.000					**1	1
19.54	1.00	17.0	18.0	18.5	diluvial	Cohesiv	23.00		196.3	196.3	48.00	0.100					**1	1
20.54	1.00	17.0	18.0	19.5	diluvial	Cohesiv	22.00		204.3	204.3	48.00	0.100					**1	1
	1.00	17.0	18.0	20.5	diluvial	Cohesiv	32.00		212.3	212.3	22.00	0.000					**1	1

Name of the point BH-R -12

PL Value 0.000

Unit volume weight of water 10.0 (kn/m3)
Load 0.0 (kn/m2)
Groundwater level 1.98 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property											Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state			Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Dynamic shear strength ratio	Soil category	Soil type	Observed N value	Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance	
	h	γt	γ sat	x			N	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	D_E
1.00	1.00	17.5	18.5	1.0	alluvial	Sandy	9.90	17.5	17.5	0.00	0.000	1.00	0.299	0.299	0.197	**5	1
2.00	1.00	15.5	16.5	2.0	alluvial	Cohesiv	7.80	32.8	32.8	0.00	0.000	1.00	0.243	0.243	0.195	1.243	1
2.95	0.95	15.5	16.5	3.0	alluvial	Cohesiv	7.80	39.0	39.0	51.00	0.080	1.00	0.395	0.395	0.239	1.653	1
3.95	1.00	15.5	16.5	4.0	alluvial	Cohesiv	13.00	45.5	45.5	51.00	0.080	1.00	2.606	2.606	0.270	9.651	1
4.95	1.00	15.5	16.5	5.0	alluvial	Cohesiv	50.00	52.0	52.0	51.00	0.080	1.00			0.291		1
5.95	1.00	17.5	18.5	6.0	alluvial	Sandy	50.00	60.5	60.5	81.00	0.000	1.00			0.302		1
6.95	1.00	17.5	18.5	7.0	alluvial	Sandy	50.00	69.0	69.0	81.00	0.000	1.00			0.308		1
7.95	1.00	18.0	19.0	8.0	diluvial	Cohesiv	50.00	78.0	78.0	83.00	0.000					**1	1
8.95	1.00	18.0	19.0	9.0	diluvial	Cohesiv	50.00	87.0	87.0	83.00	0.000					**1	1
9.95	1.00	17.0	18.0	10.0	diluvial	Cohesiv	50.00	95.0	95.0	68.00	0.000					**1	1
10.95	1.00	17.0	18.0	11.0	diluvial	Cohesiv	50.00	103.0	103.0	68.00	0.000					**1	1
11.95	1.00	17.0	18.0	12.0	diluvial	Cohesiv	50.00	111.0	111.0	43.00	0.000					**1	1
12.95	1.00	17.0	18.0	13.0	diluvial	Cohesiv	50.00	119.0	119.0	43.00	0.000					**1	1
13.95	1.00	17.0	18.0	14.0	diluvial	Cohesiv	50.00	127.0	127.0	16.00	0.000					**1	1
14.95	1.00	17.0	18.0	15.0	diluvial	Cohesiv	50.00	135.0	135.0	16.00	0.000					**1	1
15.95	1.00	17.0	18.0	16.0	diluvial	Cohesiv	50.00	143.0	143.0	27.00	0.000					**1	1
16.95	1.00	17.0	18.0	17.0	diluvial	Cohesiv	50.00	151.0	151.0	27.00	0.000					**1	1
17.95	1.00	17.0	18.0	18.0	diluvial	Cohesiv	50.00	159.0	159.0	21.00	0.000					**1	1
18.95	1.00	17.0	18.0	19.0	diluvial	Cohesiv	50.00	167.0	167.0	21.00	0.000					**1	1

Name of the point BH-R -14

PL Value 0.000

Unit volume weight of water 10.0 (kn/m3)
Load 0.0 (kn/m2)
Groundwater level 4.48 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Dynamic shear strength ratio	Soil category	Soil type	Observed N value		Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.00	1.00	15.5	16.5	1.0	alluvial	Cohesiv	8.00		15.5	15.5	67.00	0.000	1.00	4.525	4.525	0.197	**5		1
2.00	1.00	15.5	16.5	2.0	alluvial	Cohesiv	8.00		31.0	31.0	67.00	0.000	1.00	1.768	1.768	0.194	**5		1
3.00	1.00	17.5	18.5	3.0	alluvial	Sandy	9.00		48.5	48.5	38.00	0.000	1.00	0.331	0.331	0.191	**5		1
4.00	1.00	17.5	18.5	4.0	alluvial	Sandy	35.00		66.0	66.0	38.00	0.000	1.00	116.488	116.488	0.188	**5		1
5.00	1.00	17.5	18.5	5.0	alluvial	Sandy	16.00		78.8	78.8	10.00	3.500	1.00	0.290	0.290	0.197	1.472		1
6.00	1.00	17.5	18.5	6.0	alluvial	Sandy	14.00		87.3	87.3	10.00	3.500	1.00	0.263	0.263	0.214	1.231		1
7.00	1.00	18.0	19.0	7.0	diluvial	Cohesiv	14.00		96.3	96.3	93.00	0.000					**1		1
8.00	1.00	18.0	19.0	8.0	diluvial	Cohesiv	6.00		105.3	105.3	93.00	0.000					**1		1
9.00	1.00	18.0	19.0	9.0	diluvial	Cohesiv	7.00		114.3	114.3	96.00	0.000					**1		1
10.00	1.00	18.0	19.0	10.0	diluvial	Cohesiv	12.00		123.3	123.3	96.00	0.000					**1		1
11.00	1.00	18.0	19.0	11.0	diluvial	Cohesiv	22.00		132.3	132.3	86.00	0.000					**1		1
12.00	1.00	18.0	19.0	12.0	diluvial	Cohesiv	18.00		141.3	141.3	86.00	0.000					**1		1
13.00	1.00	18.0	19.0	13.0	diluvial	Cohesiv	25.00		150.3	150.3	98.00	0.000					**1		1
14.00	1.00	18.0	19.0	14.0	diluvial	Cohesiv	27.00		159.3	159.3	98.00	0.000					**1		1
15.00	1.00	18.0	19.0	15.0	diluvial	Cohesiv	22.00		168.3	168.3	80.00	0.000					**1		1
16.00	1.00	18.0	19.0	16.0	diluvial	Cohesiv	17.00		177.3	177.3	80.00	0.000					**1		1
17.00	1.00	16.5	17.5	17.0	diluvial	Cohesiv	21.00		184.8	184.8	6.00	0.000					**1		1
18.00	1.00	16.5	17.5	18.0	diluvial	Cohesiv	25.00		192.3	192.3	6.00	0.000					**1		1
19.00	1.00	16.5	17.5	19.0	diluvial	Cohesiv	26.00		199.8	199.8	38.00	0.000					**1		1
20.00	1.00	16.5	17.5	20.0	diluvial	Cohesiv	39.00		207.3	207.3	38.00	0.000					**1		1

Name of the point BH-R -15

PL Value 1.578

Unit volume weight of water 10.0 (kn/m3)
Load 0.0 (kn/m2)
Groundwater level 4.58 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Dynamic shear strength ratio	Soil category	Soil type	Observed N value		Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
0.67	0.67	17.5	18.5	0.7	alluvial	Sandy soil	9.00		11.8	11.8	0.00	0.000	1.00	0.294	0.294	0.198	**5		1
1.67	1.00	17.5	18.5	1.7	alluvial	Sandy	4.00		29.3	29.3	0.00	0.000	1.00	0.177	0.177	0.195	**5		1
2.67	1.00	17.5	18.5	2.7	alluvial	Sandy	2.00		46.8	46.8	36.00	0.000	1.00	0.164	0.164	0.192	**5		1
3.67	1.00	17.5	18.5	3.7	alluvial	Sandy	15.00		64.3	64.3	36.00	0.000	1.00	0.829	0.829	0.189	**5		1
4.67	1.00	17.5	18.5	4.7	alluvial	Sandy	10.00		81.0	81.0	13.00	1.500	1.00	0.235	0.235	0.188	1.251		1
5.67	1.00	17.5	18.5	5.7	alluvial	Sandy	14.00		89.5	89.5	13.00	1.500	1.00	0.271	0.271	0.205	1.317		1
6.67	1.00	17.5	18.5	6.7	alluvial	Sandy	6.00		98.0	98.0	6.00	3.000	1.00	0.167	0.167	0.218	0.763		2/3
7.67	1.00	18.0	19.0	7.7	diluvial	Cohesiv	12.00		107.0	107.0	91.00	0.000					**1		1
8.67	1.00	18.0	19.0	8.7	diluvial	Cohesiv	18.00		116.0	116.0	91.00	0.000					**1		1
9.67	1.00	18.0	19.0	9.7	diluvial	Cohesiv	11.00		125.0	125.0	91.00	0.000					**1		1
10.67	1.00	18.0	19.0	10.7	diluvial	Cohesiv	21.00		134.0	134.0	92.00	0.000					**1		1
11.67	1.00	18.0	19.0	11.7	diluvial	Cohesiv	21.00		143.0	143.0	92.00	0.000					**1		1
12.67	1.00	18.0	19.0	12.7	diluvial	Cohesiv	18.00		152.0	152.0	76.00	0.000					**1		1
13.67	1.00	18.0	19.0	13.7	diluvial	Cohesiv	20.00		161.0	161.0	76.00	0.000					**1		1
14.67	1.00	18.0	19.0	14.7	diluvial	Cohesiv	13.00		170.0	170.0	99.00	0.000					**1		1
15.67	1.00	18.0	19.0	15.7	diluvial	Cohesiv	13.00		179.0	179.0	99.00	0.000					**1		1
16.67	1.00	18.0	19.0	16.7	diluvial	Cohesiv	12.00		188.0	188.0	96.00	0.000					**1		1
17.67	1.00	18.0	19.0	17.7	diluvial	Cohesiv	23.00		197.0	197.0	96.00	0.000					**1		1
18.67	1.00	16.5	17.5	18.7	diluvial	Cohesiv	37.00		204.5	204.5	16.00	0.000					**1		1
19.67	1.00	16.5	17.5	19.7	diluvial	Cohesiv	39.00		212.0	212.0	16.00	0.000					**1		1

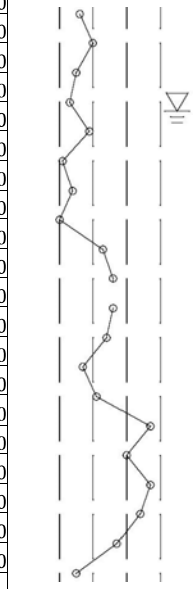
Name of the point BH-R -16

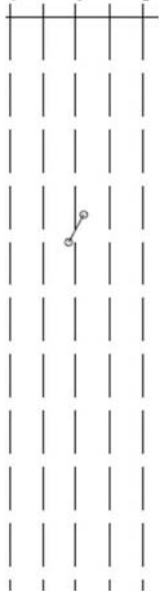
PL Value 0.687

Unit volume weight of water 10.0 (kn/m3)
Load 0.0 (kn/m2)
Groundwater level 4.30 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state			Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Dynamic shear strength ratio	Soil category	Soil type	Observed N value		Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance	
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	D_E
1.00	1.00	17.5	18.5	1.0	alluvial	Sandy	16.00		17.5	17.5	8.00	1.500	1.00	0.941	0.941	0.197	**5	1
2.00	1.00	17.5	18.5	2.0	alluvial	Sandy	20.00		35.0	35.0	8.00	1.500	1.00	1.168	1.168	0.194	**5	1
3.00	1.00	17.5	18.5	3.0	alluvial	Sandy	15.00		52.5	52.5	8.00	2.000	1.00	0.318	0.318	0.191	**5	1
4.00	1.00	17.5	18.5	4.0	alluvial	Sandy	13.00		70.0	70.0	8.00	2.000	1.00	0.269	0.269	0.188	**5	1
5.00	1.00	17.5	18.5	5.0	alluvial	Sandy	19.00		81.2	81.2	4.00	3.400	0.00	0.000	0.000	0.000	**4	1
6.00	1.00	17.5	18.5	6.0	alluvial	Sandy	11.00		89.7	89.7	4.00	3.400	0.00	0.000	0.000	0.000	**4	1
7.00	1.00	17.5	18.5	7.0	alluvial	Sandy	14.00		98.2	98.2	0.00	1.200	1.00	0.254	0.254	0.228	1.115	1
8.00	1.00	17.5	18.5	8.0	alluvial	Sandy	10.00		106.7	106.7	0.00	1.200	1.00	0.210	0.210	0.237	0.885	2/3
9.00	1.00	17.5	18.5	9.0	diluvial	Cohesiv	23.00		115.2	115.2	83.00	0.000					**1	1
10.00	1.00	18.0	19.0	10.0	diluvial	Cohesiv	26.00		124.2	124.2	83.00	0.000					**1	1
11.00	1.00	18.0	19.0	11.0	diluvial	Cohesiv	26.00		133.2	133.2	97.00	0.000					**1	1
12.00	1.00	18.0	19.0	12.0	diluvial	Cohesiv	24.00		142.2	142.2	97.00	0.000					**1	1
13.00	1.00	18.0	19.0	13.0	diluvial	Cohesiv	17.00		151.2	151.2	90.00	0.100					**1	1
14.00	1.00	18.0	19.0	14.0	diluvial	Cohesiv	21.00		160.2	160.2	90.00	0.100					**1	1
15.00	1.00	18.0	19.0	15.0	diluvial	Cohesiv	37.00		169.2	169.2	78.00	0.000					**1	1
16.00	1.00	18.0	19.0	16.0	diluvial	Cohesiv	30.00		178.2	178.2	78.00	0.000					**1	1
17.00	1.00	18.0	19.0	17.0	diluvial	Cohesiv	37.00		187.2	187.2	93.00	0.000					**1	1
18.00	1.00	18.0	19.0	18.0	diluvial	Cohesiv	34.00		196.2	196.2	93.00	0.000					**1	1
19.00	1.00	18.0	19.0	19.0	diluvial	Cohesiv	27.00		205.2	205.2	91.00	0.000					**1	1
20.00	1.00	18.0	19.0	20.0	diluvial	Sandy	15.00		214.2	214.2	91.00	0.000					**1	1





Name of the point BH-R -17

PL Value 0.000

Unit volume weight of water 10.0 (kn/m3)
Load 0.0 (kn/m2)
Groundwater level 4.79 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property												Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state				Reduction coefficient of soil constant
	Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Dynamic shear strength ratio	Soil category	Soil type	Observed N value		Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)			Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.00	1.00	17.5	18.5	1.0	alluvial	Sandy	8.00		17.5	17.5	0.00	0.000	1.00	0.267	0.267	0.197	**5		1
2.00	1.00	17.5	18.5	2.0	alluvial	Sandy	8.00		35.0	35.0	97.00	0.000	1.00	28.509	28.509	0.194	**5		1
3.00	1.00	17.5	18.5	3.0	alluvial	Sandy	2.00		52.5	52.5	97.00	0.100	1.00	0.266	0.266	0.191	**5		1
4.00	1.00	17.5	18.5	4.0	alluvial	Sandy	6.00		70.0	70.0	32.00	0.200	1.00	0.232	0.232	0.188	**5		1
5.00	1.00	17.5	18.5	5.0	alluvial	Sandy	14.00		85.6	85.6	32.00	0.200	1.00	0.362	0.362	0.189	1.909		1
6.00	1.00	17.5	18.5	6.0	alluvial	Sandy	21.00		94.1	94.1	17.00	0.700	1.00	0.423	0.423	0.205	2.061		1
7.00	1.00	17.5	18.5	7.0	alluvial	Sandy	50.00		102.6	102.6	17.00	0.700	1.00	34.594	34.594	0.217	159.07		1
8.00	1.00	17.5	18.5	8.0	alluvial	Sandy	50.00		111.1	111.1	0.00	2.500	0.00	0.000	0.000	0.000	**4		1
9.00	1.00	17.5	18.5	9.0	alluvial	Sandy	23.00		119.6	119.6	0.00	2.500	0.00	0.000	0.000	0.000	**4		1
10.00	1.00	18.0	19.0	10.0	diluvial	Cohesiv	25.00		128.6	128.6	99.00	0.000					**1		1
11.00	1.00	18.0	19.0	11.0	diluvial	Cohesiv	30.00		137.6	137.6	99.00	0.000					**1		1
12.00	1.00	18.0	19.0	12.0	diluvial	Cohesiv	17.00		146.6	146.6	94.00	0.000					**1		1
13.00	1.00	18.0	19.0	13.0	diluvial	Cohesiv	16.00		155.6	155.6	94.00	0.000					**1		1
14.00	1.00	18.0	19.0	14.0	diluvial	Cohesiv	18.00		164.6	164.6	84.00	0.000					**1		1
15.00	1.00	18.0	19.0	15.0	diluvial	Cohesiv	19.00		173.6	173.6	84.00	0.000					**1		1
16.00	1.00	18.0	19.0	16.0	diluvial	Cohesiv	23.00		182.6	182.6	100.00	0.000					**1		1
17.00	1.00	18.0	19.0	17.0	diluvial	Cohesiv	11.00		191.6	191.6	100.00	0.000					**1		1
18.00	1.00	18.0	19.0	18.0	diluvial	Cohesiv	20.00		200.6	200.6	93.00	0.000					**1		1
19.00	1.00	18.0	19.0	19.0	diluvial	Cohesiv	17.00		209.6	209.6	93.00	0.000					**1		1
20.00	1.00	18.0	19.0	20.0	diluvial	Cohesiv	21.00		218.6	218.6	96.00	0.000					**1		1

Name of the point BH-R -18

PL Value 2.984

Unit volume weight of water 10.0 (kn/m3)
Load 0.0 (kn/m2)
Groundwater level 3.29 (m)

Design horizontal seismic coefficient 0.20
Note: :** 1 to * * Z Out of Scope of Liquefaction Analysis

Soil Depth (m)	Soil Property: Layer Thickness(m)	Wet weight (kn/m3)	Saturated weight (kn/m3)	Dynamic shear strength ratio	Soil category	Soil type	Observed N value		Effective Loading Pressure(kN/m2)	Effective load at standard penetration test (kn/m2)	Fine fraction content (%)	Particle size (mm)	Earthquake Dynamic coefficient	Repeated triaxial strength ratio	Determination of the liquid state: Dynamic shear strength ratio	Seismic response ratio	Liquefaction resistance		Reduction coefficient of soil constant
	h	γt	γ sat	x			N	0 10 20 30 40 50	$\sigma_{v'}$	$\sigma_{vb'}$	F C	D_{50}	C_W	R_L	R	L	FL	0 1 2	D_E
1.01	1.01	17.5	18.5	1.0	alluvial	Sandy	5.00		17.7	17.7	16.00	0.000	1.00	0.226	0.226	0.197	**5		1
2.01	1.00	17.5	18.5	2.0	alluvial	Sandy	6.00		35.2	35.2	16.00	0.000	1.00	0.226	0.226	0.194	**5		1
3.01	1.00	15.5	16.5	3.0	alluvial	Cohesiv	2.00		50.7	50.7	0.00	0.000	1.00	0.114	0.114	0.191	**5		1
4.01	1.00	15.5	16.5	4.0	alluvial	Cohesiv	2.00		59.7	59.7	21.00	0.700	1.00	0.132	0.132	0.211	0.627		1/3
5.01	1.00	15.5	16.5	5.0	alluvial	Cohesiv	8.00		66.2	66.2	21.00	0.700	1.00	0.242	0.242	0.233	1.038		1
6.01	1.00	17.5	18.5	6.0	alluvial	Sandy	10.00		74.7	74.7	21.00	0.700	1.00	0.262	0.262	0.248	1.053		1
7.01	1.00	17.5	18.5	7.0	alluvial	Sandy	19.00		83.2	83.2	97.00	0.000	0.00	0.000	0.000	0.000	**2		1
8.01	1.00	17.5	18.5	8.0	alluvial	Sandy	20.00		91.7	91.7	97.00	0.000	0.00	0.000	0.000	0.000	**2		1
9.01	1.00	18.0	19.0	9.0	diluvial	Cohesiv	28.00		100.7	100.7	97.00	0.000					**1		1
10.01	1.00	18.0	19.0	10.0	diluvial	Cohesiv	23.00		109.7	109.7	97.00	0.000					**1		1
11.01	1.00	18.0	19.0	11.0	diluvial	Cohesiv	26.00		118.7	118.7	94.00	0.000					**1		1
12.01	1.00	18.0	19.0	12.0	diluvial	Cohesiv	24.00		127.7	127.7	94.00	0.000					**1		1
13.01	1.00	18.0	19.0	13.0	diluvial	Cohesiv	20.00		136.7	136.7	28.00	0.000					**1		1
14.01	1.00	18.0	19.0	14.0	diluvial	Cohesiv	41.00		145.7	145.7	28.00	0.000					**1		1
15.01	1.00	18.0	19.0	15.0	diluvial	Cohesiv	50.00		154.7	154.7	9.00	0.000					**1		1
16.01	1.00	18.0	19.0	16.0	diluvial	Cohesiv	50.00		163.7	163.7	9.00	0.000					**1		1
17.01	1.00	16.5	17.5	17.0	diluvial	Cohesiv	50.00		171.2	171.2	13.00	0.000					**1		1

1.1.2 Steel Sheet Pile

The summary of the structure calculation of the steel sheet pile for low water revetment is shown in the following table.

Table Summary of Steel Sheet Pile Calculation

Bank	Block No.	Sta. From - To	Length in Longidinal direction	Specification					Length			RIPRAP (SIDE SLOPE: 1.5 :1)		
				Combined					Total	SSP	H-beam	FINISHED HEIGHT FROM DRB	FINISHED TOP WIDTH	CLASS
				No.	Name	Unit Mass	Section Modulus	Moment of Inertia						
			(m)			(kg/m2)	(cm3/m)	(cm4/m)	(m)	(m)	(m)	(m)	(m)	
Left Bank	L-3	6+753 - 6+800	61.44	7	10H-550x200x12x16	207	3,900	177,600	15.0	13.0	14.5	1.5	3.5	D
	L-4	6+800 - 7+180	409.61	22	10H-850x250x14x22	293	8,840	532,300	20.5	18.5	20.0	3.5	3.5	D
	L-5	7+180 - 7+480	302.83	27	10H-1000x250x16x25	340	11,980	806,700	20.5	18.5	20.0	3.5	3.5	UP TO 7+300 : D, FROM 7+300: B
	L-6	7+480 - 7+820	359.77	27	10H-1000x250x16x25	340	11,980	806,700	22.5	20.5	22.0	3.5	3.5	B
	L-7	7+820 - 7+940	120.00	28	10H-1000x250x16x28	352	12,670	845,700	22.0	20.0	21.5	2.5	2.5	B
	L-8	7+940 - 8+120	180.00	29	25H-1000x250x16x22	358	12,240	892,400	22.0	20.0	21.5	2.5	2.5	B
	L-9	8+120 - 8+300	180.11	24	10H-900x250x14x25	311	10,120	631,400	19.0	17.0	18.5	1.5	3.5	B
	L-10	8+300 - 8+600	293.86	21	10H-800x250x14x22	287	8,240	471,700	16.5	14.5	16.0	1.5	3.5	B
	L-11	8+600 - 8+835	211.24	28	10H-1000x250x16x28	352	12,670	845,700	20.0	18.0	19.5	1.5	3.5	UP TO 8+700 : B, FROM 8+700: C
Right Bank	R-8	6+420 - 6+920	437.46	32	25H-1000x300x16x22	377	13,420	962,300	23.5	21.5	23	2.5	2.5	UP TO 6+650 : A, FROM 6+650: B
	R-9	6+920 - 7+220	295.15	30	10H-1000x250x16x32	369	13,590	896,800	23.0	21	22.5	2.5	UP TO 7+160 : 2.5, FROM 7+160 : 3.0	B
	R-10	7+220 - 7+620	387.86	38	25H-1000x300x16x32	426	16,330	1,129,800	23.5	21.5	23	3.5	3.5	B
	R-11	7+620 - 7+900	272.03	10	10H-700x200x12x16	224	5,130	281,600	17.5	15.5	17	3.5	3.5	B
	R-12	7+900 - 8+240	340.06	30	10H-1000x250x16x32	369	13,590	896,800	22.0	20	21.5	2.5	2.5	B
	R-13	8+240 - 8+500	260.19	25	10H-950x250x16x22	321	10,570	688,700	19.5	17.5	19	2.5	2.5	B
	R-14	8+500 - 8+620	124.41	25	10H-950x250x16x22	321	10,570	688,700	17.5	15.5	17	1.5	3.5	B
	R-15	8+620 - 8+940	340.55	29	25H-1000x250x16x22	358	12,240	892,400	20.0	18	19.5	3.5	3.5	B
	R-16	8+940 - 9+000	65.45	8	10H-600x200x12x16	212	4,270	208,200	15.0	13	14.5	1.5	3.5	B
	R-17	9+000 - 9+200	217.04	1	10H-400x200x9x12	169	2,320	87,800	12.0	10	11.5	1.5	3.5	B

Table Design Cross-section and Calculation Result

Bank	Block No.	Cross Section for Calculation		Calculation Result													
		Sta	Boring Name	Stress Intensity						Laterial Displacement							
				Normal Conditon				Seismic Conditon				Normal Conditon				Seismic Conditon			
				(N/mm2)				(N/mm2)				(mm)				(mm)			
Left Bank	L-3	6+780	BMLL-23	116	<	180	OK	168	<	270	OK	47.44	<	50.00	OK	36.03	<	75.00	OK
	L-4	7+100	DD-BH-L01	66	<	180	OK	168	<	270	OK	35.45	<	50.00	OK	70.23	<	75.00	OK
	L-5	7+400	DD-BH-L02	76	<	180	OK	179	<	270	OK	36.36	<	50.00	OK	72.62	<	75.00	OK
	L-6	7+520	DD-BH-L03	80	<	180	OK	122	<	270	OK	47.63	<	50.00	OK	52.55	<	75.00	OK
	L-7	7+860	DD-BH-L04	84	<	180	OK	125	<	270	OK	49.69	<	50.00	OK	55.87	<	75.00	OK
	L-8	7+940	BL-13	92	<	180	OK	134	<	270	OK	48.86	<	50.00	OK	54.88	<	75.00	OK
	L-9	8+120	DD-BH-L05	104	<	180	OK	160	<	270	OK	49.25	<	50.00	OK	11.50	<	75.00	OK
	L-10	8+400	DD-BH-L07	127	<	180	OK	207	<	270	OK	48.01	<	50.00	OK	61.59	<	75.00	OK
	L-11	8+780	DD-BH-L08	99	<	180	OK	150	<	270	OK	49.30	<	50.00	OK	56.04	<	75.00	OK
Right Bank	R-8	6+820	BMRL-23	80	<	180	OK	119	<	270	OK	49.66	<	50.00	OK	60.34	<	0.00	OK
	R-9	7+000	DD-BH-R03	74	<	180	OK	107	<	270	OK	49.60	<	50.00	OK	54.89	<	0.00	OK
	R-10	7+420	DD-BH-R04	77	<	180	OK	94	<	270	OK	48.90	<	50.00	OK	46.39	<	0.00	OK
	R-11	7+780	DD-BH-R06	97	<	180	OK	221	<	270	OK	41.14	<	50.00	OK	70.95	<	0.00	OK
	R-12	8+020	BDM-10	83	<	180	OK	119	<	270	OK	49.80	<	50.00	OK	54.45	<	0.00	OK
	R-13	8+320	DD-BH-R08	103	<	180	OK	153	<	270	OK	49.52	<	50.00	OK	55.51	<	0.00	OK
	R-14	8+500	DD-BH-R09	132	<	180	OK	189	<	270	OK	48.79	<	50.00	OK	54.95	<	0.00	OK
	R-15	8+820	DD-BH-R10	118	<	180	OK	188	<	270	OK	49.12	<	50.00	OK	57.47	<	0.00	OK
	R-16	8+940	BDM-11	125	<	180	OK	151	<	270	OK	48.78	<	50.00	OK	47.43	<	0.00	OK
	R-17	9+000	BMRL-25	127	<	180	OK	137	<	270	OK	47.39	<	50.00	OK	42.53	<	0.00	OK

The calculation sheets are shown in the following pages.

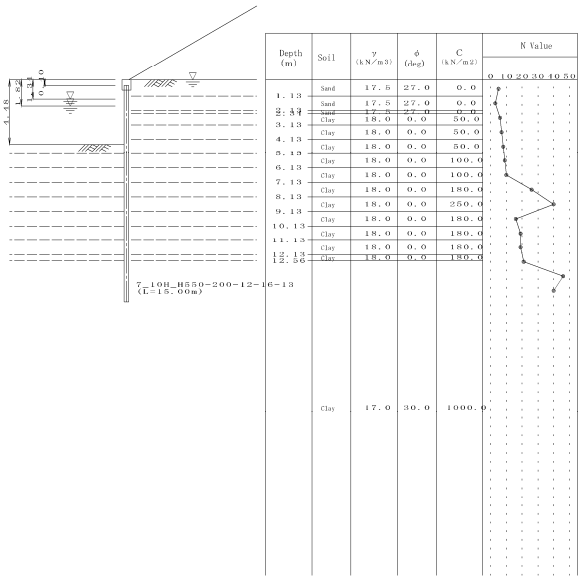
Block No. : L-3
Sta. : 6+753~6+800

Design Cross Section : Sta 6+780
Boring Name : BMLL-23

Specification : SSP SP-10H
（Combined） : H 550-200-12-16-13

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	4.48 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_R	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	1.82 m (Normal Condition)
	L_{wp}'	=	1.34 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress : Chang's formula

Penetration depths : $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water : γ_w = 9.8 kN/m³

Type of water pressure : trapezoidal water pressure

Lateral pressure : calculated in consideration of site conditions

Study case : - Normal Condition
- Seismic Condition

Design earthquake intensity : k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitary load : not considered

Wind load, Impact load : not considered

Minimum angle of rupture : ζ_0 = 10 degrees

Rear side angle of slope : not considered

Angle of rupture (clayey soil) : $\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C} \cdot \tan\theta}$

Equilibrium factor of compression : K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m
E_0 = 2800N

Average N-value : calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value
1	0.63	5
2	1.63	3
3	2.63	6
4	3.63	7
5	4.63	8
6	5.63	9
7	6.63	10
8	7.63	26
9	8.63	40
10	9.63	16
11	10.63	19
12	11.63	19
13	12.63	21
14	13.63	46
15	14.63	40

1.6 Vertical Load

Vertical load on landside : calculated in consideration of embankment shape on landside

Vertical load on riverside : not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	1.13	1.13
2	2.13	1.00
3	2.34	0.21
4	3.13	0.79
5	4.13	1.00
6	5.13	1.00
7	6.13	1.00
8	7.13	1.00
9	8.13	1.00
10	9.13	1.00
11	10.13	1.00
12	11.13	1.00
13	12.13	1.00
14	12.56	0.43
15	33.00	20.44

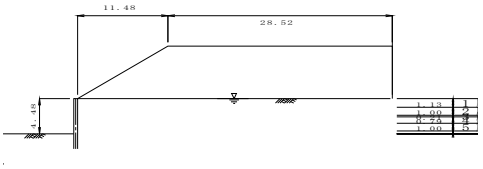
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition	Kh (kN/m3) Normal Condition	Kh (kN/m3) Seismic Condition
1	1.13	S	5.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto	——	——
2	2.13	S	3.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto	——	——
3	2.34	S	6.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto	——	——
4	3.13	C	6.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto	——	——
5	4.13	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto	——	——
6	5.13	C	8.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto	——	——
7	6.13	C	9.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto	——	——
8	7.13	C	10.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto	——	——
9	8.13	C	26.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	——	——
10	9.13	C	40.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto	——	——
11	10.13	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	——	——
12	11.13	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	——	——
13	12.13	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	——	——
14	12.56	C	21.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	——	——
15	33.00	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto	——	——

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate				Thickness	soil single weight γ		internal friction angle	stickiness	decay angle ζ	
		Bottom Left m	Top Left m	Top Right m	Bottom Right m	h m	Normal Condition kN/m3	Seismic Condition kN/m3	φ degree	C kN/m2	Normal Condition degree	Seismic Condition degree
1	Sand	0.00	11.48	40.00	40.00	6.66	19.0	19.0	30.0	0.0	Auto	Auto

Angle of rapture in embankment calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name 7 _ 10 H _ H 550 -200 - 12-16-13
Young's modulus $E = 200000$ N/mm²
Inertia sectional moment $I_0 = 177600$ cm⁴
Sectional factor $Z_0 = 3900$ cm³

Corrosion margin $t_1 = 1.00$ mm (riverside) $t_2 = 1.00$ mm (landside)

Corrosion rate (to I_0) $\eta = 0.83$
Corrosion rate (to Z_0) $\eta = 0.85$
Section efficiency (to I_0) $\mu = 1.00$
Section efficiency (to Z_0) $\mu = 1.00$

Round unit of SSP length 0.50 m

Allowable stress $\sigma_a = 180$ N/mm (Normal)
$\sigma_a' = 270$ N/mm (Seismic)

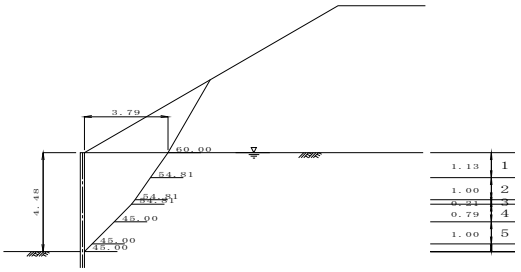
Allowable displacement $\delta_a = 50.0$ mm (Normal)
$\delta_a' = 75.0$ mm (Seismic)

Bending of cantilever beam calculated as distributed load of each layer

Reduction of material modulus
Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	4.48 ~ 4.13	Clay	0.0	15.0	50.0	35.57	31.41	43.90	45.00
2	4.13 ~ 3.13	Clay	0.0	15.0	50.0	32.70	31.41	40.47	45.00
3	3.13 ~ 2.34	Clay	0.0	15.0	50.0	24.50	31.41	30.67	45.00
4	2.34 ~ 2.13	Sand	27.0	15.0	0.0	18.02	31.41	22.93	54.81
5	2.13 ~ 1.13	Sand	27.0	15.0	0.0	16.40	31.41	20.87	54.81
6	1.13 ~ 0.00	Sand	27.0	15.0	0.0	8.70	31.41	11.07	54.81
7		embankment	30.0	—	0.0	126.54	0.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of the major collapse line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.00	0.35	0.00	0.00	0.35	0.35
2	45.00	1.00	0.35	0.35	1.35	1.35
3	45.00	0.79	1.35	1.35	2.14	2.14
4	54.81	0.21	2.14	2.14	2.29	2.35
5	54.81	1.00	2.29	2.35	2.99	3.35
6	54.81	1.13	2.99	3.35	3.79	4.48
7	60.00	3.31	3.79	4.48	5.70	7.79

From the above table, the loading width (L) on the ground surface is 3.79 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	6.27	119.04
Σ			119.04

γ: unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

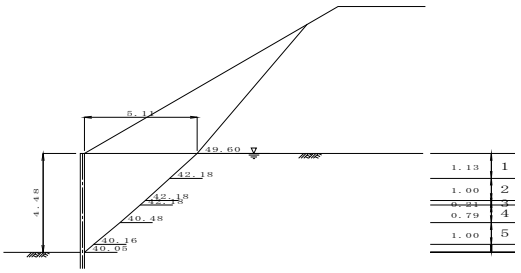
2.1.4 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{119.04 + 0.00 + 0.00}{3.79}$$

$$= 31.41 \text{ kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	4.48 ~ 4.13	Clay	0.0	15.0	50.0	35.57	55.62	43.90	0.200	11.31	40.05
2	4.13 ~ 3.13	Clay	0.0	15.0	50.0	32.70	55.62	40.47	0.200	11.31	40.16
3	3.13 ~ 2.34	Clay	0.0	15.0	50.0	24.50	55.62	30.67	0.200	11.31	40.48
4	2.34 ~ 2.13	Sand	27.0	15.0	0.0	18.02	55.62	22.93	0.200	11.31	42.18
5	2.13 ~ 1.13	Sand	27.0	15.0	0.0	16.40	55.62	20.87	0.200	11.31	42.18
6	1.13 ~ 0.00	Sand	27.0	15.0	0.0	8.70	55.62	11.07	0.200	11.31	42.18
7		embankment	30.0	—	0.0	126.54	0.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)

Q : surcharge load (kN/m^2)
C cohesive force of soil (kN/m^2)

2.2.2 Coordinates of the major collapse line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	40.05	0.35	0.00	0.00	0.42	0.35
2	40.16	1.00	0.42	0.35	1.60	1.35
3	40.48	0.79	1.60	1.35	2.53	2.14
4	42.18	0.21	2.53	2.14	2.76	2.35
5	42.18	1.00	2.76	2.35	3.86	3.35
6	42.18	1.13	3.86	3.35	5.11	4.48
7	49.60	5.85	5.11	4.48	10.09	10.33

From the above table, the loading width (L) on the ground surface is 5.11 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	14.96	284.16
Σ			284.16

γ: unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Calculated Load

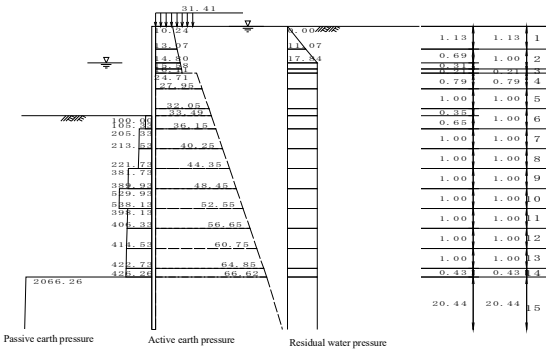
$$Q = \frac{\Sigma(\gamma \times A) + \Sigma(Q \times l) + \Sigma P}{L}$$

$$= \frac{284.16 + 0.00 + 0.00}{5.11}$$

$$= 55.62 \text{ kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh + Qa kN/m2	Ka	Ka × cosδ
1	0.00~ 1.13	Sand	7.7	27.0	—— ——	31.409 40.110	0.33738 0.33738	0.32589 0.32589
2	1.13~ 1.82	Sand	7.7	27.0	—— ——	40.110 45.423	0.33738 0.33738	0.32589 0.32589
3	1.82~ 2.13	Sand	7.7	27.0	—— ——	45.423 47.810	0.33738 0.33738	0.32589 0.32589
4	2.13~ 2.34	Sand	7.7	27.0	—— ——	47.810 49.427	0.33738 0.33738	0.32589 0.32589
5	2.34~ 3.13	Clay	8.2	—	50.0 50.0	49.427 55.905	—— ——	—— ——
6	3.13~ 4.13	Clay	8.2	—	50.0 50.0	55.905 64.105	—— ——	—— ——
7	4.13~ 4.48	Clay	8.2	—	50.0 50.0	64.105 66.975	—— ——	—— ——
8	4.48~ 5.13	Clay	8.2	—	50.0 50.0	66.975 72.305	—— ——	—— ——
9	5.13~ 6.13	Clay	8.2	—	100.0 100.0	72.305 80.505	—— ——	—— ——
10	6.13~ 7.13	Clay	8.2	—	100.0 100.0	80.505 88.705	—— ——	—— ——
11	7.13~ 8.13	Clay	8.2	—	180.0 180.0	88.705 96.905	—— ——	—— ——
12	8.13~ 9.13	Clay	8.2	—	250.0 250.0	96.905 105.105	—— ——	—— ——
13	9.13~ 10.13	Clay	8.2	—	180.0 180.0	105.105 113.305	—— ——	—— ——
14	10.13~ 11.13	Clay	8.2	—	180.0 180.0	113.305 121.505	—— ——	—— ——
15	11.13~ 12.13	Clay	8.2	—	180.0 180.0	121.505 129.705	—— ——	—— ——
16	12.13~ 12.56	Clay	8.2	—	180.0 180.0	129.705 133.231	—— ——	—— ——
17	12.56~ 33.00	Clay	7.2	—	1000.0 1000.0	133.231 280.399	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh + Qp kN/m2	Kp	Kp × cosδ
8	4.48~ 5.13	Clay	8.2	0.0	50.0 50.0	0.000 5.330	—— ——	—— ——
9	5.13~ 6.13	Clay	8.2	0.0	100.0 100.0	5.330 13.530	—— ——	—— ——
10	6.13~ 7.13	Clay	8.2	0.0	100.0 100.0	13.530 21.730	—— ——	—— ——
11	7.13~ 8.13	Clay	8.2	0.0	180.0 180.0	21.730 29.930	—— ——	—— ——
12	8.13~ 9.13	Clay	8.2	0.0	250.0 250.0	29.930 38.130	—— ——	—— ——
13	9.13~ 10.13	Clay	8.2	0.0	180.0 180.0	38.130 46.330	—— ——	—— ——
14	10.13~ 11.13	Clay	8.2	0.0	180.0 180.0	46.330 54.530	—— ——	—— ——
15	11.13~ 12.13	Clay	8.2	0.0	180.0 180.0	54.530 62.730	—— ——	—— ——
16	12.13~ 12.56	Clay	8.2	0.0	180.0 180.0	62.730 66.256	—— ——	—— ——
17	12.56~ 33.00	Clay	7.2	30.0	1000.0 1000.0	66.256 213.424	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.13	10.24 13.07	—— ——	10.24 13.07	0.00 11.07	—— ——
2	1.13~ 1.82	13.07 14.80	—— ——	13.07 14.80	11.07 17.84	—— ——
3	1.82~ 2.13	14.80 15.58	—— ——	14.80 15.58	17.84 17.84	—— ——
4	2.13~ 2.34	15.58 16.11	—— ——	15.58 16.11	17.84 17.84	—— ——
5	2.34~ 3.13	-50.57 -44.10	24.71 27.95	24.71 27.95	17.84 17.84	—— ——
6	3.13~ 4.13	-44.10 -35.90	27.95 32.05	27.95 32.05	17.84 17.84	—— ——
7	4.13~ 4.48	-35.90 -33.03	32.05 33.49	32.05 33.49	17.84 17.84	—— ——
8	4.48~ 5.13	-33.03 -27.70	33.49 36.15	33.49 36.15	17.84 17.84	100.00 105.33
9	5.13~ 6.13	-127.70 -119.50	36.15 40.25	36.15 40.25	17.84 17.84	205.33 213.53
10	6.13~ 7.13	-119.50 -111.30	40.25 44.35	40.25 44.35	17.84 17.84	213.53 221.73
11	7.13~ 8.13	-271.30 -263.10	44.35 48.45	44.35 48.45	17.84 17.84	381.73 389.93
12	8.13~ 9.13	-403.10 -394.90	48.45 52.55	48.45 52.55	17.84 17.84	529.93 538.13
13	9.13~ 10.13	-254.90 -246.70	52.55 56.65	52.55 56.65	17.84 17.84	398.13 406.33
14	10.13~ 11.13	-246.70 -238.50	56.65 60.75	56.65 60.75	17.84 17.84	406.33 414.53
15	11.13~ 12.13	-238.50 -230.30	60.75 64.85	60.75 64.85	17.84 17.84	414.53 422.73
16	12.13~ 12.56	-230.30 -226.77	64.85 66.62	64.85 66.62	17.84 17.84	422.73 426.26
17	12.56~ 33.00	-1866.77 -1719.60	66.62 140.20	66.62 140.20	17.84 17.84	2066.26 2213.42

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

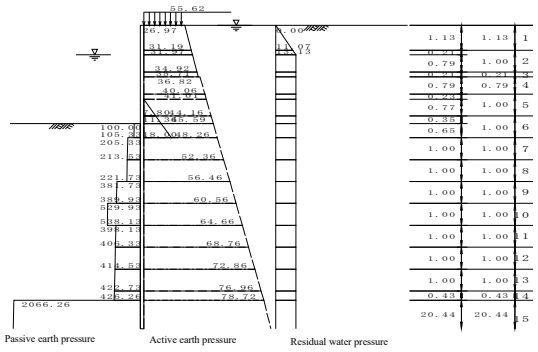
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



The dotted line in the figure shows the main earth pressure strength Pa2 using the consolidation equilibrium coefficient.

3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 1.13	Sand	7.7	27.0	—— ——	55.62 64.32	0.00 11.07	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
2	1.13~ 1.34	Sand	7.7	27.0	—— ——	64.32 65.93	11.07 13.13	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
3	1.34~ 2.13	Sand	7.7	27.0	—— ——	65.93 72.02	13.13 20.87	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
4	2.13~ 2.34	Sand	7.7	27.0	—— ——	72.02 73.63	20.87 22.93	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
5	2.34~ 3.13	Clay	8.2	——	50.0 50.0	73.63 80.11	22.93 30.67	0.200 0.200	11.31 11.31	—— ——	—— ——	40.73 40.48
6	3.13~ 3.36	Clay	8.2	——	50.0 50.0	80.11 82.03	30.67 ——	0.200 ——	11.31 ——	—— ——	—— ——	40.48 ——
7	3.36~ 4.13	Clay	8.2	——	50.0 50.0	82.03 88.31	—— 40.47	—— 0.200	—— 11.31	—— ——	—— ——	—— 40.16
8	4.13~ 4.48	Clay	8.2	——	50.0 50.0	88.31 91.18	40.47 43.90	0.200 0.200	11.31 11.31	—— ——	—— ——	40.16 40.05
9	4.48~ 5.13	Clay	8.2	——	50.0 50.0	91.18 96.51	43.90 50.27	0.200 0.200	11.31 11.31	—— ——	—— ——	40.05 39.83
10	5.13~ 6.13	Clay	8.2	——	100.0 100.0	96.51 104.71	50.27 60.07	0.200 0.200	11.31 11.31	—— ——	—— ——	42.64 42.50
11	6.13~ 7.13	Clay	8.2	——	100.0 100.0	104.71 112.91	60.07 69.87	0.200 0.200	11.31 11.31	—— ——	—— ——	42.50 42.36
12	7.13~ 8.13	Clay	8.2	——	180.0 180.0	112.91 121.11	69.87 79.67	0.200 0.200	11.31 11.31	—— ——	—— ——	43.59 43.52
13	8.13~ 9.13	Clay	8.2	——	250.0 250.0	121.11 129.31	79.67 89.47	0.200 0.200	11.31 11.31	—— ——	—— ——	43.95 43.90
14	9.13~ 10.13	Clay	8.2	——	180.0 180.0	129.31 137.51	89.47 99.27	0.200 0.200	11.31 11.31	—— ——	—— ——	43.45 43.38
15	10.13~ 11.13	Clay	8.2	——	180.0 180.0	137.51 145.71	99.27 109.07	0.200 0.200	11.31 11.31	—— ——	—— ——	43.38 43.30
16	11.13~ 12.13	Clay	8.2	——	180.0 180.0	145.71 153.91	109.07 118.87	0.200 0.200	11.31 11.31	—— ——	—— ——	43.30 43.23
17	12.13~ 12.56	Clay	8.2	——	180.0 180.0	153.91 157.44	118.87 123.09	0.200 0.200	11.31 11.31	—— ——	—— ——	43.23 43.20
18	12.56~ 33.00	Clay	7.2	——	1000.0 1000.0	157.44 304.61	123.09 323.40	0.200 0.200	11.31 11.31	—— ——	—— ——	44.69 44.47

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma \gamma h + 2Q}{2C}} \cdot \tan\theta$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh + Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
9	4.48~ 5.13	Clay	8.20	0.0	50.0 50.0	0.000 5.330	0.00 6.37	0.200 0.200	11.31 11.31	—— ——	—— ——
10	5.13~ 6.13	Clay	8.20	0.0	100.0 100.0	5.330 13.530	6.37 16.17	0.200 0.200	11.31 11.31	—— ——	—— ——
11	6.13~ 7.13	Clay	8.20	0.0	100.0 100.0	13.530 21.730	16.17 25.97	0.200 0.200	11.31 11.31	—— ——	—— ——
12	7.13~ 8.13	Clay	8.20	0.0	180.0 180.0	21.730 29.930	25.97 35.77	0.200 0.200	11.31 11.31	—— ——	—— ——
13	8.13~ 9.13	Clay	8.20	0.0	250.0 250.0	29.930 38.130	35.77 45.57	0.200 0.200	11.31 11.31	—— ——	—— ——
14	9.13~ 10.13	Clay	8.20	0.0	180.0 180.0	38.130 46.330	45.57 55.37	0.200 0.200	11.31 11.31	—— ——	—— ——
15	10.13~ 11.13	Clay	8.20	0.0	180.0 180.0	46.330 54.530	55.37 65.17	0.200 0.200	11.31 11.31	—— ——	—— ——
16	11.13~ 12.13	Clay	8.20	0.0	180.0 180.0	54.530 62.730	65.17 74.97	0.200 0.200	11.31 11.31	—— ——	—— ——
17	12.13~ 12.56	Clay	8.20	0.0	180.0 180.0	62.730 66.256	74.97 79.18	0.200 0.200	11.31 11.31	—— ——	—— ——
18	12.56~ 33.00	Clay	7.20	30.0	1000.0 1000.0	66.256 213.424	79.18 279.50	0.200 0.200	11.31 11.31	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma \gamma h + 2Q}{2C}} \cdot \tan\theta$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.13	26.97 31.19	—— ——	26.97 31.19	0.00 11.07	—— ——
2	1.13~ 1.34	31.19 31.97	—— ——	31.19 31.97	11.07 13.13	—— ——
3	1.34~ 2.13	31.97 34.92	—— ——	31.97 34.92	13.13 13.13	—— ——
4	2.13~ 2.34	34.92 35.71	—— ——	34.92 35.71	13.13 13.13	—— ——
5	2.34~ 3.13	-10.39 -2.37	36.82 40.06	36.82 40.06	13.13 13.13	—— ——
6	3.13~ 3.36	-2.37 0.00	40.06 41.01	40.06 41.01	13.13 13.13	—— ——
7	3.36~ 4.13	0.00 7.80	41.01 44.16	41.01 44.16	13.13 13.13	—— ——
8	4.13~ 4.48	7.80 11.36	44.16 45.59	44.16 45.59	13.13 13.13	—— ——
9	4.48~ 5.13	11.36 18.00	45.59 48.26	45.59 48.26	13.13 13.13	100.00 105.33
10	5.13~ 6.13	-83.21 -73.20	48.26 52.36	48.26 52.36	13.13 13.13	205.33 213.53
11	6.13~ 7.13	-73.20 -63.18	52.36 56.46	52.36 56.46	13.13 13.13	213.53 221.73
12	7.13~ 8.13	-223.80 -213.86	56.46 60.56	56.46 60.56	13.13 13.13	381.73 389.93
13	8.13~ 9.13	-354.10 -344.18	60.56 64.66	60.56 64.66	13.13 13.13	529.93 538.13
14	9.13~ 10.13	-203.92 -193.96	64.66 68.76	64.66 68.76	13.13 13.13	398.13 406.33
15	10.13~ 11.13	-193.96 -184.00	68.76 72.86	68.76 72.86	13.13 13.13	406.33 414.53
16	11.13~ 12.13	-184.00 -174.03	72.86 76.96	72.86 76.96	13.13 13.13	414.53 422.73
17	12.13~ 12.56	-174.03 -169.74	76.96 78.72	76.96 78.72	13.13 13.13	422.73 426.26
18	12.56~ 33.00	-1810.85 -1633.68	78.72 152.30	78.72 152.30	13.13 13.13	2066.26 2213.42

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$

$P_{a2} = K_e \cdot (\Sigma \gamma h + Q)$

K_e : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.34	0.00	0.00
2	2.34	1.00	3.04
3	3.34	2.00	4.30
4	4.34	3.00	5.26
5	4.48	3.14	5.39

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

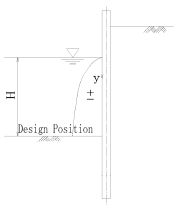
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

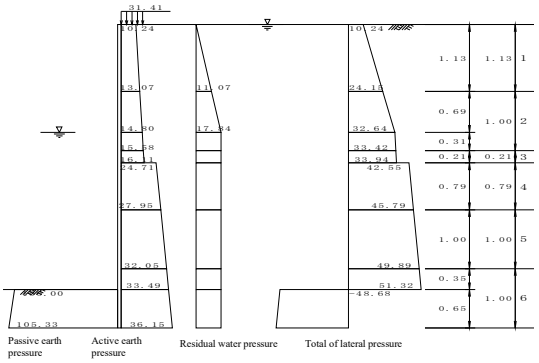
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition

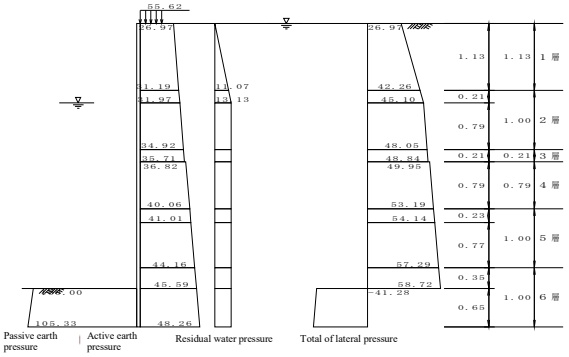


No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.13	10.24 13.07	0.00 11.07	—— ——	10.24 24.15
2	1.13~ 1.82	13.07 14.80	11.07 17.84	—— ——	24.15 32.64
3	1.82~ 2.13	14.80 15.58	17.84 17.84	—— ——	32.64 33.42
4	2.13~ 2.34	15.58 16.11	17.84 17.84	—— ——	33.42 33.94
5	2.34~ 3.13	24.71 27.95	17.84 17.84	—— ——	42.55 45.79
6	3.13~ 4.13	27.95 32.05	17.84 17.84	—— ——	45.79 49.89
7	4.13~ 4.48	32.05 33.49	17.84 17.84	—— ——	49.89 51.32
8	4.48~ 5.13	33.49 36.15	17.84 17.84	100.00 105.33	-48.68 -51.34

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -4.48 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.13	26.97 31.19	0.00 11.07	—— ——	26.97 42.26
2	1.13~ 1.34	31.19 31.97	11.07 13.13	—— ——	42.26 45.10
3	1.34~ 2.13	31.97 34.92	13.13 13.13	—— ——	45.10 48.05
4	2.13~ 2.34	34.92 35.71	13.13 13.13	—— ——	48.05 48.84
5	2.34~ 3.13	36.82 40.06	13.13 13.13	—— ——	49.95 53.19
6	3.13~ 3.36	40.06 41.01	13.13 13.13	—— ——	53.19 54.14
7	3.36~ 4.13	41.01 44.16	13.13 13.13	—— ——	54.14 57.29
8	4.13~ 4.48	44.16 45.59	13.13 13.13	—— ——	57.29 58.72
9	4.48~ 5.13	45.59 48.26	13.13 13.13	100.00 105.33	-41.28 -43.94

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -4.48 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of 1/β from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material name		10 H _ H 550 -200 - 12-16-13	
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.83
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	177600 cm⁴(original condition)
	I	=	147408 cm⁴(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 147408 \times 10^{-8} = 2.948 \times 10^5$

No	Depth m	N Value
1	0.63	5
2	1.63	3
3	2.63	6
4	3.63	7
5	4.63	8
6	5.63	9
7	6.63	10
8	7.63	26
9	8.63	40
10	9.63	16

No	Depth m	N Value
11	10.63	19
12	11.63	19
13	12.63	21
14	13.63	46
15	14.63	40

5.2 Normal Condition

Assuming Kh = 8754 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.294 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 3.41 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -4.48 m) to 3.41 m depth (GL -7.89 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	4.48	0.15	7.8	8.0	1.19
2	4.63	1.00	8.0	9.0	8.50
3	5.63	1.00	9.0	10.0	9.50
4	6.63	1.00	10.0	26.0	18.00
5	7.63	0.26	26.0	29.6	7.14
	L = Σh = 3.41		ΣA =	44.33	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{44.33}{3.41} = 13.01$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 13.01 = 36432 \text{ kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 36432 = 121440 \text{ kN/m}^3 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 121440(10.00/0.3)^{-3/4} = 8754 \text{ kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 8754 kN/m3.

5.3 Seismic Condition

Assuming Kh = 14912 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.335 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 2.98 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -4.48 m) and 2.98 m depth (GL -7.46 m).

No	Depth Z	Thickness h	N Value	Area A

	m	m	upper	lower	
1	4.48	0.15	7.8	8.0	1.19
2	4.63	1.00	8.0	9.0	8.50
3	5.63	1.00	9.0	10.0	9.50
4	6.63	0.83	10.0	23.3	13.86
	L = Σh = 2.98		ΣA =	33.05	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L}$

$= \frac{33.05}{2.98}$

$= 11.08$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 11.08 = 31031\ kN/m^2$

$K_{s0} = \frac{1}{0.3} \times \alpha \times 31031 = 206873\ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_s = K_{s0}(B_0/0.3)^{-3/4} = 206873(10.00/0.3)^{-3/4} = 14912\ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 14912 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.13	1.13	10.24 24.15	5.78 13.64	4.10 3.73	23.73 50.84
2	1.13~ 1.82	0.69	24.15 32.64	8.33 11.26	3.12 2.89	25.99 32.54
3	1.82~ 2.13	0.31	32.64 33.42	5.06 5.18	2.56 2.45	12.93 12.71
4	2.13~ 2.34	0.21	33.42 33.94	3.51 3.56	2.28 2.21	8.00 7.88
5	2.34~ 3.13	0.79	42.55 45.79	16.81 18.09	1.88 1.61	31.54 29.18
6	3.13~ 4.13	1.00	45.79 49.89	22.89 24.94	1.02 0.68	23.28 17.05
7	4.13~ 4.48	0.35	49.89 51.32	8.73 8.98	0.23 0.12	2.04 1.05
				ΣP = 156.77	ΣM = 278.75	

P_s : active earth pressure + residual water pressure - passive earth pressure

P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	0.0 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	4.48 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 0.0$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	1.34~ 2.34	1.00	0.0 3.0	0.00 1.52	2.81 2.47	0.00 3.76
2	2.34~ 3.34	1.00	3.0 4.3	1.52 2.15	1.81 1.47	2.75 3.17
3	3.34~ 4.34	1.00	4.3 5.3	2.15 2.63	0.81 0.47	1.73 1.25
4	4.34~ 4.48	0.14	5.3 5.4	0.37 0.38	0.09 0.05	0.03 0.02
				ΣPdw = 10.71	Σ Mdw = 12.70	

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}}$

$= \frac{438.72}{222.25} = 1.97$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 222.25}{4.48} = 99.22\ kN/m$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name	10 H _ H 550 -200 - 12-16-13		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.83
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	177600 cm^4 (original condition)
	I	=	147408 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 147408 × 10^{-8}		=	2.948 × 10^5

P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	0.0 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	4.48 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 0.00$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t}$

$= \frac{278.75}{156.77} = 1.78$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 156.77}{4.48} = 69.99\ kN/m$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.13	1.13	26.97 42.26	15.24 23.88	4.10 3.73	62.52 88.98
2	1.13~ 1.34	0.21	42.26 45.10	4.44 4.74	3.28 3.21	14.55 15.20
3	1.34~ 2.13	0.79	45.10 48.05	17.82 18.98	2.88 2.61	51.25 49.60
4	2.13~ 2.34	0.21	48.05 48.84	5.05 5.13	2.28 2.21	11.50 11.33
5	2.34~ 3.13	0.79	49.95 53.19	19.73 21.01	1.88 1.61	37.03 33.89
6	3.13~ 3.36	0.23	53.19 54.14	6.21 6.32	1.27 1.19	7.90 7.55
7	3.36~ 4.13	0.77	54.14 57.29	20.75 21.96	0.86 0.61	17.87 13.30
8	4.13~ 4.48	0.35	57.29 58.72	10.03 10.28	0.23 0.12	2.34 1.20
				ΣP = 211.54	ΣM = 426.02	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	0.0 kN/m

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$

$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp(-\tan^{-1}\frac{1}{1+2\beta h_0})$

$M_{max} = M_0 \cdot \phi_m$

$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$

$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$

$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	8754 kN/m^3
calculated value	β	=	0.29353 m^{-1}
resultant earth force (lateral)	P_0	=	156.77 kN/m
height of acting position of load	h_0	=	1.78 m
moment	M_0	=	278.75 kN・m/m
in consideration of ψ_m = 1.383, maximum moment	M_{max}	=	385.49 kN・m/m
depth of generated position of M_{max}	l_m	=	1.550 m
depth of 1st fixed point	l_i	=	4.226 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	14912 kN/m^3
calculated value	β	=	0.33534 m^{-1}
resultant earth force (lateral)	P_0	=	222.25 kN/m
height of acting position of load	h_0	=	1.97 m
moment	M_0	=	438.72 kN・m/m
in consideration of ψ_m = 1.273, maximum moment	M_{max}	=	558.42 kN・m/m
depth of generated position of M_{max}	l_m	=	1.212 m
depth of 1st fixed point	l_i	=	3.554 m

6.3 Stress Intensity

Material Name	10 H _ H 550 -200 - 12-16-13		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.85
Section efficiency	μ	=	1.00
Module of section	Z_0	=	3900 cm^3 (original condition)
	Z	=	3315 cm^3 (after reduction by corrosion and section)

6.3.1 Normal Condition

$\sigma = \frac{M_{max}}{Z} = \frac{385.49 \times 10^6}{3315 \times 10^3} = 116\ N/mm^2 \leqq \sigma_a = 180\ N/mm^2$

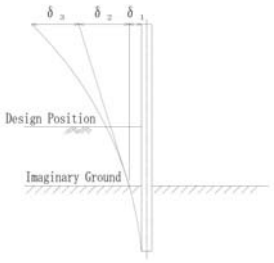
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{558.42\times10^{6}}{3315\times10^{3}} = 168\ N/mm^{2} \leqq \sigma_a = 270\ N/mm^{2}$$

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation

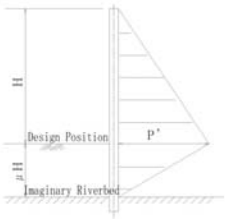


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2935\times1.78)\times156.77}{2\times2.00\times10^{8}\times147408\times10^{-8}\times0.2935^{3}} = 0.01600\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times0.2935\times1.78)\times156.77}{2\times2.00\times10^{8}\times147408\times10^{-8}\times0.2935^{2}}\times(4.48+0.00) = 0.02826\ m$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{4.48} = 0.000$$

$$\delta_3 = \frac{P'H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{69.99\times4.48^{4}}{120\times2.00\times10^{8}\times147408\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4)$$

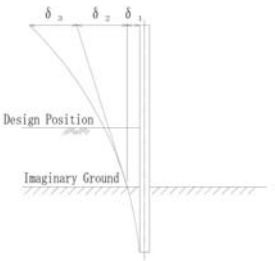
$$= 0.00319\ m$$

$\delta = \delta1 + \delta2 + \delta3$
$= 0.01600 + 0.02826 + 0.00319$
$= 0.04744$ m
Size = 47.44 ≦ δa = 50.00 mm

Where,
- δ_1 : Displacement at imaginary ground
- δ_2 : Displacement by angle of inclination slope at imaginary ground
- δ_3 : Displacement at higher part of imaginary ground as cantilever
- δ : Displacement at top of SSP
- δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

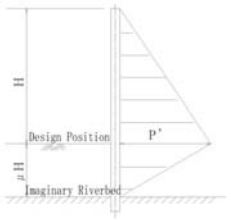


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.3353\times1.97)\times222.25}{2\times2.00\times10^{8}\times147408\times10^{-8}\times0.3353^{3}} = 0.01661\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times0.3353\times1.97)\times222.25}{2\times2.00\times10^{8}\times147408\times10^{-8}\times0.3353^{2}}\times(4.48+0.00) = 0.03490\ m$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{4.48} = 0.000$$

$$\delta_3 = \frac{P'H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{99.22\times4.48^{4}}{120\times2.00\times10^{8}\times147408\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4)$$

$$= 0.00452\ m$$

$\delta = \delta1 + \delta2 + \delta3$
$= 0.01661 + 0.03490 + 0.00452$
$= 0.05603$ m
Size = 56.03 ≦ δa = 75.00 mm

Where,
- δ_1 : Displacement at imaginary ground
- δ_2 : Displacement by angle of inclination slope at imaginary ground
- δ_3 : Displacement at higher part of imaginary ground as cantilever
- δ : Displacement at top of SSP
- δ_a : Allowable displacement

7 Penetration Depth

Material Name		7 _ 10 H _ H 550 -200 - 12-16-13	
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	177600 cm⁴ (original condition)
	I	=	177600 cm⁴ (after reduction by corrosion and section)
$EI = 200000\times10^{3}\times177600\times10^{-8}$		=	3.552×10^{5}

7.1 Penetration Depth and Whole Length of SSP (Chang)

When the depth of the virtual ground surface is Lk, the grouting length (D) below the design surface and the total length (L) of the sheet pile are as follows.

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h\cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction: $K_h = 8754\ kN/m^3$
Calculated value: $\beta = 0.28017\ m^{-1}$

Penetration length of SSP: $D = 0.00 + \frac{3}{0.280} = 10.71\ m$
Whole length of SSP: $L = 4.48 - 0.40 + 10.71 = 14.79\ m$

7.1.2 Seismic Condition

Modules of lateral subgrade reaction: $K_h = 14912\ kN/m^3$
Calculated value: $\beta = 0.32008\ m^{-1}$

Penetration length of SSP: $D = 0.00 + \frac{3}{0.320} = 9.37\ m$
Whole length of SSP: $L = 4.48 - 0.40 + 9.37 = 13.45\ m$

Therefore, the total length of the sheet pile is 15.00 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile 10 H _ H 550 -200 - 12-16-13

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	177600		
Sectional Modulus	Z (cm3)	3900		
Maximum bending moment	Mmax (kN・m・m)		385.49	558.42
Stress intensity	σ (N/mm2)		116 (180)	168 (270)
Lateral displacement	δ (mm)		47.44 (50.0)	56.03 (75.0)
Penetration depths	D (m)		10.71	9.37
Whole length of SSP	L (m)	15.00		

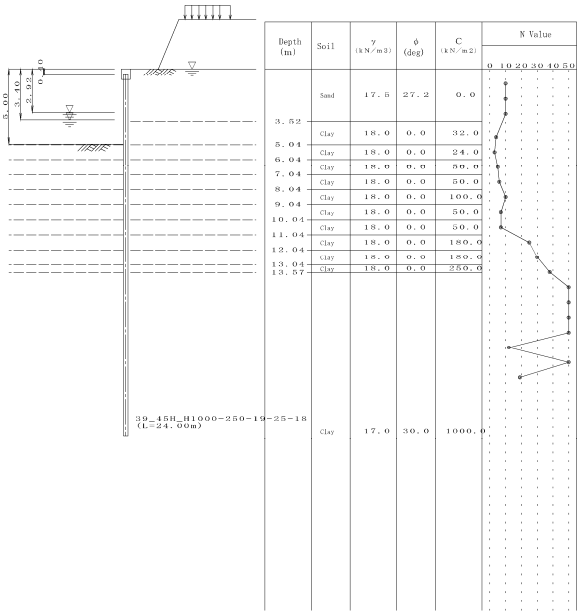
Block No. : L-4
Sta. : 6+800~7+180

Design Cross Section : Sta 7+100
Boring Name : DD-BH-L01

Specification : SSP SP-10H
（Combined） : H 850-250-14-22-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



Depth (m)	Soil	γ (kN/m3)	ϕ (deg)	C (kN/m2)
	Sand	17.5	27.2	0.0
3.52	Clay	18.0	0.0	32.0
5.04	Clay	18.0	0.0	24.0
6.04	Clay	18.0	0.0	50.0
7.04	Clay	18.0	0.0	50.0
8.04	Clay	18.0	0.0	100.0
9.04	Clay	18.0	0.0	50.0
10.04	Clay	18.0	0.0	50.0
11.04	Clay	18.0	0.0	180.0
12.04	Clay	18.0	0.0	180.0
13.04	Clay	18.0	0.0	250.0
13.57	Clay	17.0	30.0	1000.0

N Value: 0 10 20 30 40 50

1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	3.50 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_R	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	1.90 m (Normal Condition)
	L_{wp}'	=	1.42 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress : Chang's formula
Penetration depths : $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water : γ_w = 9.8 kN/m³

Type of water pressure : trapezoidal water pressure

Lateral pressure : calculated in consideration of site conditions

Study case : - Normal Condition
- Seismic Condition

Design earthquake intensity : k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	37.2 kN/m	(Normal Condition)
		Pt'	=	90.4 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	Mm	=	1.2 kN･m/m	(Normal Condition)
		Mm'	=	87.9 kN･m/m	(Seismic Condition)
	Depth of acting point	Hm'	=	0.00 m	(Seismic Condition)
		Hm	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load : not considered

Minimum angle of rupture : ζ_0 = 10 degrees

Rear side angle of slope : not considered

Angle of rupture (clayey soil) : $\zeta = \tan^{-1}\sqrt{1-\frac{\sum \gamma h + 2Q}{2C}\cdot\tan\theta}$

Equilibrium factor of compression : K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula : $K_h = K_{h0}\left(\frac{B_u}{0.3}\right)^{-3/4}$

$K_{h0} = \frac{1}{0.3}\alpha E_0$ (α :Normal Condition =1, Seismi Condition =2)

B_u = 10.00 m
E_0 = 2800N

Average N-value : calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value
1	1.00	10	11	10.04	25	21	20.04	50
2	2.00	10	12	11.04	30	22	21.04	50
3	3.00	10	13	12.04	38	23	22.04	50
4	3.04	4	14	13.04	50			
5	4.04	3	15	14.04	50			
6	5.04	5	16	15.04	50			
7	6.04	6	17	16.04	50			
8	7.04	10	18	17.04	12			
9	8.04	7	19	18.04	50			
10	9.04	7	20	19.04	19			

1.6 Vertical Load

Vertical load on landside : calculated in consideration of embankment shape on landside

Vertical load on riverside : not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	2.02	2.02
2	3.54	1.52
3	4.54	1.00
4	5.54	1.00
5	6.54	1.00
6	7.54	1.00
7	8.54	1.00
8	9.54	1.00
9	10.54	1.00
10	11.54	1.00
11	12.07	0.53
12	33.10	21.03

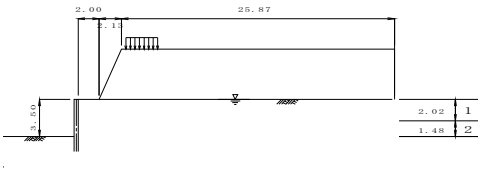
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	ϕ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	2.02	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
2	3.54	C	4.0	18.00	8.20	0.0	32.0	0.0	0.200	Auto	Auto
3	4.54	C	3.0	18.00	8.20	0.0	24.0	0.0	0.200	Auto	Auto
4	5.54	C	4.5	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
5	6.54	C	6.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
6	7.54	C	10.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
7	8.54	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
8	9.54	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
9	10.54	C	25.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
10	11.54	C	30.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
11	12.07	C	38.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
12	33.10	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
ϕ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate				Thickness	soil single weight γ		internal friction angle	stickiness	decay angle ζ	
		Bottom Left m	Top Left m	Top Right m	Bottom Right m	h m	Normal Condition kN/m3	Seismic Condition kN/m3	φ degree	C kN/m2	Normal Condition degree	Seismic Condition degree
1	Sand	2.00	4.13	30.00	30.00	4.78	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area		load strength	
	From m	End point m	Normal Condition kN/m2	Seismic Condition kN/m2
1	4.53	7.53	10.0	5.0

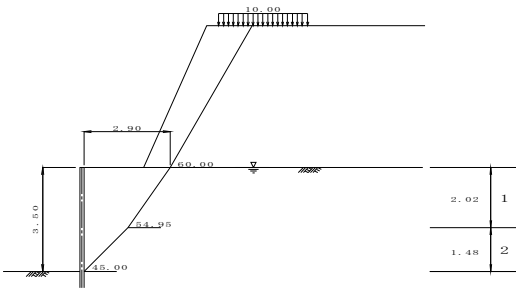
Angle of rapture in embankment calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name	10 H _ H 850 -250 -14 -22 -18				
Young's modulus	E	=	200000 N/mm^2		
Inertia sectional moment	I_0	=	532300 cm^4		
Sectional factor	Z_0	=	8840 cm^3		
Corrosion margin	t_1	=	1.00 mm (riverside)	t_2 =	1.00 mm (landside)
Corrosion rate (to I_0)	η	=	0.86		
Corrosion rate (to Z_0)	η	=	0.88		
Section efficiency (to I_0)	μ	=	1.00		
Section efficiency (to Z_0)	μ	=	1.00		
Round unit of SSP length			0.50 m		
Allowable stress	σ_a	=	180 N/mm (Normal)		
	σ_a'	=	270 N/mm (Seismic)		
Allowable displacement	δ_a	=	50.0 mm (Normal)		
	δ_a'	=	75.0 mm (Seismic)		
Bending of cantilever beam			calculated as distributed load of each layer		
Reduction of material modulus			Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction Not reduced: I_0 applied to calculation of penetration depth Reduced: I_0 applied to calculation of section forces and displacement Reduced: Z_0 applied to calculation of stresses		

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σ γ h kN/m2	Q kN/m2	γ whw kN/m2	Angle of Rupture ζ degree
1	3.50 ~ 2.02	Clay	0.0	15.0	32.0	27.69	41.88	34.30	45.00
2	2.02 ~ 0.00	Sand	27.2	15.0	0.0	15.55	41.88	19.80	54.95
3		embankment	30.0	——	0.0	90.82	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,

ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan^{-1}k or θ = tan^{-1}k'
γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m^2)
C cohesive force of soil (kN/m^2)

2.1.2 Coordinates of the major collapse line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.00	1.48	0.00	0.00	1.48	1.48
2	54.95	2.02	1.48	1.48	2.90	3.50
3	60.00	4.78	2.90	3.50	5.66	8.28

From the above table, the loading width (L) on the ground surface is 2.90 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	5.79	110.07
Σ			110.07

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	1.13	11.27
Σ			11.27

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

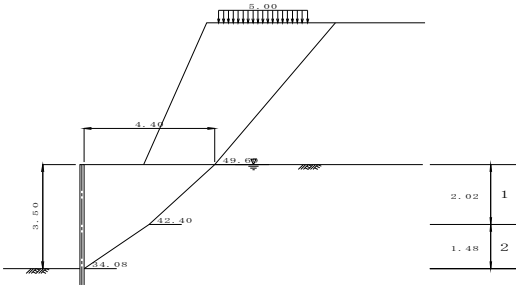
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times l)+\Sigma P}{L}$$

$$= \frac{110.07 + 11.27 + 0.00}{2.90}$$

$$= 41.88 \text{ kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σ γ h kN/m2	Q kN/m2	γ whw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	3.50 ~ 2.02	Clay	0.0	15.0	32.0	27.69	72.94	34.30	0.200	11.31	34.08
2	2.02 ~ 0.00	Sand	27.2	15.0	0.0	15.55	72.94	19.80	0.200	11.31	42.40
3		embankment	30.0	——	0.0	90.82	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma\gamma h + 2Q}{2C}} \cdot \tan\theta$$

Where,

- ζ : angle of active rupture (degree, $\zeta \geq 10.00^{o}$)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  $\theta = \tan^{-1}k$ or $\theta = \tan^{-1}k'$
- γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m^2)
- C : cohesive force of soil (kN/m^2)

2.2.2 Coordinates of the major collapse line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	34.08	1.48	0.00	0.00	2.19	1.48
2	42.40	2.02	2.19	1.48	4.40	3.50
3	49.60	4.78	4.40	3.50	8.47	8.28

From the above table, the loading width (L) on the ground surface is 4.40 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	16.10	305.95
Σ			305.95

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.00	15.00
Σ			15.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

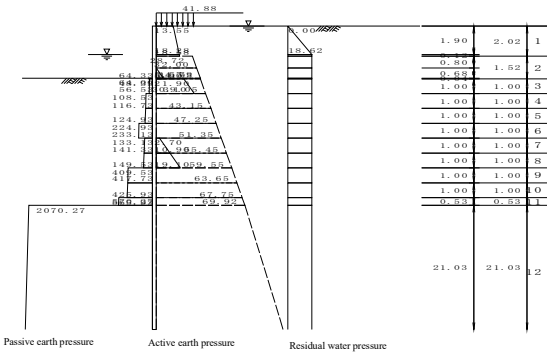
$$Q = \frac{\Sigma(\gamma \times A) + \Sigma(Q \times l) + \Sigma P}{L}$$

$$= \frac{305.95 + 15.00 + 0.00}{4.40}$$

$$= 72.94 \text{ kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 1.90	Sand	7.7	27.2	———	41.882	0.33489	0.32348
					———	56.512	0.33489	0.32348
2	1.90~ 2.02	Sand	7.7	27.2	———	56.512	0.33489	0.32348
					———	57.436	0.33489	0.32348
3	2.02~ 2.82	Clay	8.2	———	32.0	57.436	———	———
					32.0	64.000	———	———
4	2.82~ 3.50	Clay	8.2	———	32.0	64.000	———	———
					32.0	69.572	———	———
5	3.50~ 3.54	Clay	8.2	———	32.0	69.572	———	———
					32.0	69.900	———	———
6	3.54~ 4.54	Clay	8.2	———	24.0	69.900	———	———
					24.0	78.100	———	———
7	4.54~ 5.54	Clay	8.2	———	50.0	78.100	———	———
					50.0	86.300	———	———
8	5.54~ 6.54	Clay	8.2	———	50.0	86.300	———	———
					50.0	94.500	———	———
9	6.54~ 7.54	Clay	8.2	———	100.0	94.500	———	———
					100.0	102.700	———	———
10	7.54~ 8.54	Clay	8.2	———	50.0	102.700	———	———
					50.0	110.900	———	———
11	8.54~ 9.54	Clay	8.2	———	50.0	110.900	———	———
					50.0	119.100	———	———
12	9.54~ 10.54	Clay	8.2	———	180.0	119.100	———	———
					180.0	127.300	———	———
13	10.54~ 11.54	Clay	8.2	———	180.0	127.300	———	———
					180.0	135.500	———	———
14	11.54~ 12.07	Clay	8.2	———	250.0	135.500	———	———
					250.0	139.846	———	———
15	12.07~ 33.10	Clay	7.2	———	1000.0	139.846	———	———
					1000.0	291.262	———	———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
$\delta = 15.00$、$\beta = 0.00$、$\theta = 0.00$

$$K_a = \frac{\cos^2(\phi - \theta)}{\cos\theta \cdot \cos(\delta + \theta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \beta - \theta)}{\cos(\delta + \theta) \cdot \cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
5	3.50~ 3.54	Clay	8.2	0.0	32.0	0.000	———	———
					32.0	0.328	———	———
6	3.54~ 4.54	Clay	8.2	0.0	24.0	0.328	———	———
					24.0	8.528	———	———
7	4.54~ 5.54	Clay	8.2	0.0	50.0	8.528	———	———
					50.0	16.728	———	———
8	5.54~ 6.54	Clay	8.2	0.0	50.0	16.728	———	———
					50.0	24.928	———	———
9	6.54~ 7.54	Clay	8.2	0.0	100.0	24.928	———	———
					100.0	33.128	———	———
10	7.54~ 8.54	Clay	8.2	0.0	50.0	33.128	———	———
					50.0	41.328	———	———
11	8.54~ 9.54	Clay	8.2	0.0	50.0	41.328	———	———
					50.0	49.528	———	———
12	9.54~ 10.54	Clay	8.2	0.0	180.0	49.528	———	———
					180.0	57.728	———	———
13	10.54~ 11.54	Clay	8.2	0.0	180.0	57.728	———	———
					180.0	65.928	———	———
14	11.54~ 12.07	Clay	8.2	0.0	250.0	65.928	———	———
					250.0	70.274	———	———
15	12.07~ 33.10	Clay	7.2	30.0	1000.0	70.274	———	———
					1000.0	221.690	———	———

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
$\delta = -15.00$、$\beta = 0.00$、$\theta = 0.00$

$$K_p = \frac{\cos^2(\phi - \theta)}{\cos\theta \cdot \cos(\delta - \theta) \cdot \left[1 - \sqrt{\frac{\sin(\phi - \delta) \cdot \sin(\phi + \beta - \theta)}{\cos(\delta - \theta) \cdot \cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 1.90	13.55	———	13.55	0.00	———
		18.28	———	18.28	18.62	———
2	1.90~ 2.02	18.28	———	18.28	18.62	———
		18.58	———	18.58	18.62	———
3	2.02~ 2.82	-6.56	28.72	28.72	18.62	———
		0.00	32.00	32.00	18.62	———
4	2.82~ 3.50	0.00	32.00	32.00	18.62	———
		5.57	34.79	34.79	18.62	———
5	3.50~ 3.54	5.57	34.79	34.79	18.62	64.00
		5.90	34.95	34.95	18.62	64.33
6	3.54~ 4.54	21.90	34.95	34.95	18.62	48.33
		30.10	39.05	39.05	18.62	56.53
7	4.54~ 5.54	-21.90	39.05	39.05	18.62	108.53
		-13.70	43.15	43.15	18.62	116.73
8	5.54~ 6.54	-13.70	43.15	43.15	18.62	116.73
		-5.50	47.25	47.25	18.62	124.93
9	6.54~ 7.54	-105.50	47.25	47.25	18.62	224.93
		-97.30	51.35	51.35	18.62	233.13
10	7.54~ 8.54	2.70	51.35	51.35	18.62	133.13
		10.90	55.45	55.45	18.62	141.33
11	8.54~ 9.54	10.90	55.45	55.45	18.62	141.33
		19.10	59.55	59.55	18.62	149.53
12	9.54~ 10.54	-240.90	59.55	59.55	18.62	409.53
		-232.70	63.65	63.65	18.62	417.73
13	10.54~ 11.54	-232.70	63.65	63.65	18.62	417.73
		-224.50	67.75	67.75	18.62	425.93
14	11.54~ 12.07	-364.50	67.75	67.75	18.62	565.93
		-360.15	69.92	69.92	18.62	570.27
15	12.07~ 33.10	-1860.15	69.92	69.92	18.62	2070.27
		-1708.74	145.63	145.63	18.62	2221.69

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

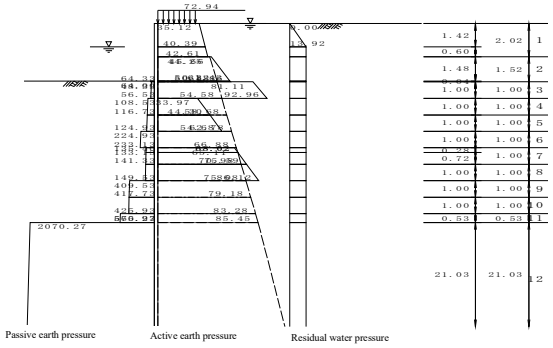
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 1.42	Sand	7.7	27.2	——— ———	72.94 83.88	0.00 13.92	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
2	1.42~ 2.02	Sand	7.7	27.2	——— ———	83.88 88.50	13.92 19.80	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
3	2.02~ 3.50	Clay	8.2	———	32.0 32.0	88.50 100.63	19.80 34.30	0.200 0.200	11.31 11.31	——— ———	——— ———	35.14 34.08
4	3.50~ 3.54	Clay	8.2	———	32.0 32.0	100.63 100.96	34.30 34.69	0.200 0.200	11.31 11.31	——— ———	——— ———	34.08 34.05
5	3.54~ 4.54	Clay	8.2	———	24.0 24.0	100.96 109.16	34.69 44.49	0.200 0.200	11.31 11.31	——— ———	——— ———	27.69 26.16
6	4.54~ 5.54	Clay	8.2	———	50.0 50.0	109.16 117.36	44.49 54.29	0.200 0.200	11.31 11.31	——— ———	——— ———	38.57 38.20
7	5.54~ 6.54	Clay	8.2	———	50.0 50.0	117.36 125.56	54.29 64.09	0.200 0.200	11.31 11.31	——— ———	——— ———	38.20 37.83
8	6.54~ 7.54	Clay	8.2	———	100.0 100.0	125.56 133.76	64.09 73.89	0.200 0.200	11.31 11.31	——— ———	——— ———	41.84 41.69
9	7.54~ 7.82	Clay	8.2	———	50.0 50.0	133.76 136.03	73.89 ———	0.200 ———	11.31 ———	——— ———	——— ———	37.45 ———
10	7.82~ 8.54	Clay	8.2	———	50.0 50.0	136.03 141.96	——— 83.69	——— 0.200	——— 11.31	——— ———	——— ———	——— 37.06
11	8.54~ 9.54	Clay	8.2	———	50.0 50.0	141.96 150.16	83.69 93.49	0.200 0.200	11.31 11.31	——— ———	——— ———	37.06 36.66
12	9.54~ 10.54	Clay	8.2	———	180.0 180.0	150.16 158.36	93.49 103.29	0.200 0.200	11.31 11.31	——— ———	——— ———	43.11 43.03
13	10.54~ 11.54	Clay	8.2	———	180.0 180.0	158.36 166.56	103.29 113.09	0.200 0.200	11.31 11.31	——— ———	——— ———	43.03 42.96
14	11.54~ 12.07	Clay	8.2	———	250.0 250.0	166.56 170.91	113.09 118.29	0.200 0.200	11.31 11.31	——— ———	——— ———	43.56 43.53
15	12.07~ 33.10	Clay	7.2	———	1000.0 1000.0	170.91 322.32	118.29 324.38	0.200 0.200	11.31 11.31	——— ———	——— ———	44.65 44.42

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
4	3.50~ 3.54	Clay	8.20	0.0	32.0 32.0	0.000 0.328	0.00 0.39	0.200 0.200	11.31 11.31	——— ———	——— ———
5	3.54~ 4.54	Clay	8.20	0.0	24.0 24.0	0.328 8.528	0.39 10.19	0.200 0.200	11.31 11.31	——— ———	——— ———
6	4.54~ 5.54	Clay	8.20	0.0	50.0 50.0	8.528 16.728	10.19 19.99	0.200 0.200	11.31 11.31	——— ———	——— ———
7	5.54~ 6.54	Clay	8.20	0.0	50.0 50.0	16.728 24.928	19.99 29.79	0.200 0.200	11.31 11.31	——— ———	——— ———
8	6.54~ 7.54	Clay	8.20	0.0	100.0 100.0	24.928 33.128	29.79 39.59	0.200 0.200	11.31 11.31	——— ———	——— ———
9	7.54~ 7.82	Clay	8.20	0.0	50.0 50.0	33.128 35.401	39.59 ———	0.200 ———	11.31 ———	——— ———	——— ———
10	7.82~ 8.54	Clay	8.20	0.0	50.0 50.0	35.401 41.328	——— 49.39	——— 0.200	——— 11.31	——— ———	——— ———
11	8.54~ 9.54	Clay	8.20	0.0	50.0 50.0	41.328 49.528	49.39 59.19	0.200 0.200	11.31 11.31	——— ———	——— ———
12	9.54~ 10.54	Clay	8.20	0.0	180.0 180.0	49.528 57.728	59.19 68.99	0.200 0.200	11.31 11.31	——— ———	——— ———
13	10.54~ 11.54	Clay	8.20	0.0	180.0 180.0	57.728 65.928	68.99 78.79	0.200 0.200	11.31 11.31	——— ———	——— ———
14	11.54~ 12.07	Clay	8.20	0.0	250.0 250.0	65.928 70.274	78.79 83.99	0.200 0.200	11.31 11.31	——— ———	——— ———
15	12.07~ 33.10	Clay	7.20	30.0	1000.0 1000.0	70.274 221.690	83.99 290.08	0.200 0.200	11.31 11.31	——— ———	——— ———

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 1.42	35.12 40.39	——— ———	35.12 40.39	0.00 13.92	——— ———
2	1.42~ 2.02	40.39 42.61	——— ———	40.39 42.61	13.92 13.92	——— ———
3	2.02~ 3.50	45.66 61.43	44.25 50.32	45.66 61.43	13.92 13.92	——— ———
4	3.50~ 3.54	61.43 61.86	50.32 50.48	61.43 61.86	13.92 13.92	64.00 64.33
5	3.54~ 4.54	81.11 92.96	50.48 54.58	81.11 92.96	13.92 13.92	48.33 56.53
6	4.54~ 5.54	33.97 44.30	54.58 58.68	54.58 58.68	13.92 13.92	108.53 116.73
7	5.54~ 6.54	44.30 54.68	58.68 62.78	58.68 62.78	13.92 13.92	116.73 124.93
8	6.54~ 7.54	-47.61 -37.54	62.78 66.88	62.78 66.88	13.92 13.92	224.93 233.13
9	7.54~ 7.82	65.11 68.02	66.88 68.02	66.88 68.02	13.92 13.92	133.13 135.40
10	7.82~ 8.54	68.02 75.59	68.02 70.98	68.02 75.59	13.92 13.92	135.40 141.33
11	8.54~ 9.54	75.59 86.12	70.98 75.08	75.59 86.12	13.92 13.92	141.33 149.53
12	9.54~ 10.54	-178.54 -168.56	75.08 79.18	75.08 79.18	13.92 13.92	409.53 417.73
13	10.54~ 11.54	-168.56 -158.58	79.18 83.28	79.18 83.28	13.92 13.92	417.73 425.93
14	11.54~ 12.07	-299.04 -293.77	83.28 85.45	83.28 85.45	13.92 13.92	565.93 570.27
15	12.07~ 33.10	-1794.64 -1612.31	85.45 161.16	85.45 161.16	13.92 13.92	2070.27 2221.69

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.42	0.00	0.00
2	2.42	1.00	2.47
3	3.42	2.00	3.50
4	3.50	2.08	3.57

$$p_{dw} = \pm\frac{7}{8} k_{hs}\cdot\gamma_w\cdot\sqrt{H\cdot y}$$

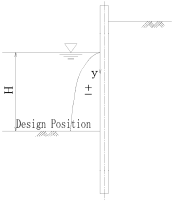
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

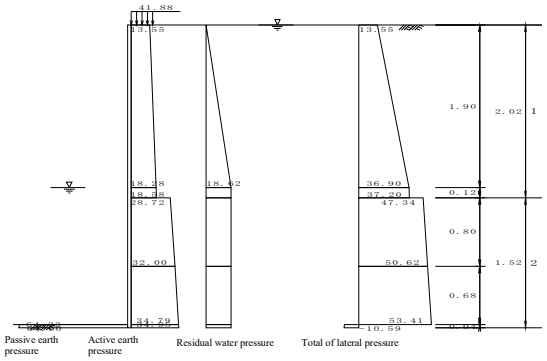
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition

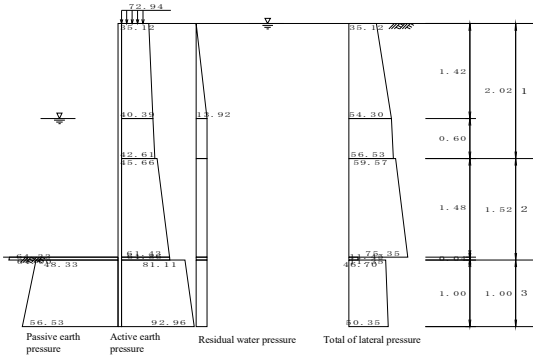


No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.90	13.55 18.28	0.00 18.62	——— ———	13.55 36.90
2	1.90~ 2.02	18.28 18.58	18.62 18.62	——— ———	36.90 37.20
3	2.02~ 2.82	28.72 32.00	18.62 18.62	——— ———	47.34 50.62
4	2.82~ 3.50	32.00 34.79	18.62 18.62	——— ———	50.62 53.41
5	3.50~ 3.54	34.79 34.95	18.62 18.62	64.00 64.33	-10.59 -10.76

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -3.50 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.42	35.12 40.39	0.00 13.92	——— ———	35.12 54.30
2	1.42~ 2.02	40.39 42.61	13.92 13.92	——— ———	54.30 56.53
3	2.02~ 3.50	45.66 61.43	13.92 13.92	——— ———	59.57 75.35
4	3.50~ 3.54	61.43 61.86	13.92 13.92	64.00 64.33	11.35 11.45
5	3.54~ 4.54	81.11 92.96	13.92 13.92	48.33 56.53	46.70 50.35
6	4.54~ 5.54	54.58 58.68	13.92 13.92	108.53 116.73	-40.03 -44.13

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 1.04 m (GL -4.54 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_{II}}{0.3}\right)^{-3/4} \qquad (B_{II} = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material name		10 H _ H 850 -250 -14 -22 -18	
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.86
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	532300 cm⁴(original condition)
	I	=	457778 cm⁴(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 457778 \times 10^{-8} = 9.156 \times 10^5$

No	Depth m	N Value
1	1.00	10
2	2.00	10
3	3.00	10
4	3.04	4
5	4.04	3
6	5.04	5
7	6.04	6
8	7.04	10
9	8.04	7
10	9.04	7
11	10.04	25
12	11.04	30
13	12.04	38
14	13.04	50
15	14.04	50
16	15.04	50
17	16.04	50
18	17.04	12
19	18.04	50
20	19.04	19
21	20.04	50
22	21.04	50
23	22.04	50

5.2 Normal Condition

Assuming Kh = 4212 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.184\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 5.43\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -3.50 m) to 5.43 m depth (GL -8.93 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	3.50	0.54	3.5	3.0	1.77
2	4.04	1.00	3.0	5.0	4.00
3	5.04	1.00	5.0	6.0	5.50
4	6.04	1.00	6.0	10.0	8.00
5	7.04	1.00	10.0	7.0	8.50
6	8.04	0.89	7.0	7.0	6.23
		L = Σh = 5.43		Σ A =	34.00

A: (Top N + Bottom N) x h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{34.00}{5.43} = 6.26$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 6.26 = 17530\ \text{kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 17530 = 58432\ \text{kN/m}^3 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_{II}/0.3)^{-3/4} = 58432(10.00/0.3)^{-3/4} = 4212\ \text{kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 4212 kN/m3.

5.3 Seismic Condition

Assuming Kh = 9343 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.225\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 4.45\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -4.54 m) and 4.45 m depth (GL -9.99 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	4.54	0.50	4.0	5.0	2.25
2	5.04	1.00	5.0	6.0	5.50
3	6.04	1.00	6.0	10.0	8.00
4	7.04	1.00	10.0	7.0	8.50
5	8.04	0.95	7.0	7.0	6.65
		L = Σh = 4.45		Σ A =	30.90

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L}$

$$= \frac{30.90}{4.45}$$

$$= 6.94$$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 6.94 = 19443 \ kN/m^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 19443 = 129618 \ kN/m^3 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_{II}/0.3)^{-3/4} = 129618(10.00/0.3)^{-3/4} = 9343 \ kN/m^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 9343 kN/m3.

6 Sectional Forces and Displacement

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.90	1.90	13.55 36.90	12.87 35.06	2.87 2.23	36.90 78.29
2	1.90~ 2.02	0.12	36.90 37.20	2.21 2.23	1.56 1.52	3.45 3.39
3	2.02~ 2.82	0.80	47.34 50.62	18.95 20.26	1.21 0.95	22.98 19.17
4	2.82~ 3.50	0.68	50.62 53.41	17.20 18.15	0.45 0.23	7.79 4.11
				ΣP = 126.92	ΣM = 176.09	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	37.2 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	1.2 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	3.50 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 131.40$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{307.49}{164.12} = 1.87 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 340.47}{4.54} = 149.99 \ kN/m$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name	10 H _ H 850 -250 -14 -22 -18		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.86
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	542300 cm⁴ (original condition)
	I	=	457778 cm⁴ (after reduction by corrosion and section)

$EI = 200000 \times 10^3 \times 457778 \times 10^{-8} = 9.156 \times 10^5$

$$\beta = 4\sqrt{\frac{K_h \cdot B}{4EI}}$$

$$\phi_{II} = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_{II}$$

$$l_{II} = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_{\perp} = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x}(\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	4212 kN/m³
calculated value	β	=	0.18416 m⁻¹
resultant earth force (lateral)	P_0	=	164.12 kN/m
height of acting position of load	h_0	=	1.87 m
moment	M_0	=	307.49 kN・m/m
in consideration of ψ_m = 1.668, maximum moment	M_{max}	=	512.86 kN・m/m
depth of generated position of M_{max}	l_m	=	2.901 m
depth of 1st fixed point	l_i	=	7.166 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	9434 kN/m³
calculated value	β	=	0.22475 m⁻¹
resultant earth force (lateral)	P_0	=	340.47 kN/m
height of acting position of load	h_0	=	3.05 m
moment	M_0	=	1039.33 kN・m/m
in consideration of ψ_m = 1.273, maximum moment	M_{max}	=	1308.43 kN・m/m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 164.12}{3.50} = 93.78 \ kN/m$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.42	1.42	35.12 54.30	24.94 38.56	4.07 3.59	101.41 138.54
2	1.42~ 2.02	0.60	54.30 56.53	16.29 16.96	2.92 2.72	47.57 46.13
3	2.02~ 3.50	1.48	59.57 75.35	44.08 55.76	2.03 1.53	89.34 85.50
4	3.50~ 3.54	0.04	11.35 11.45	0.23 0.23	1.03 1.01	0.23 0.23
5	3.54~ 4.54	1.00	46.70 50.35	23.35 25.17	0.67 0.33	15.57 8.39
				ΣP = 245.57	ΣM = 532.92	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	90.4 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	87.9 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	3.50 m
Depth of Imaginary riverbed from riverbed	L_k	=	1.04 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 498.32$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	1.42~ 2.42	1.00	0.0 2.5	0.00 1.24	2.79 2.45	0.00 3.03
2	2.42~ 3.42	1.00	2.5 3.5	1.24 1.75	1.79 1.45	2.21 2.54
3	3.42~ 3.50	0.08	3.5 3.6	0.14 0.14	1.09 1.07	0.15 0.15
				ΣPdw = 4.51	Σ Mdw = 8.09	

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1039.33}{340.47} = 3.05 \ m$$

depth of generated position of M_{max} l_m = 1.775 m
depth of 1st fixed point l_i = 5.270 m

6.3 Stress Intensity

Material Name	10 H _ H 850 -250 -14 -22 -18		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.88
Section efficiency	μ	=	1.00
Module of section	Z_0	=	8840 cm³ (original condition)
	Z	=	7779 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{512.86 \times 10^6}{7779 \times 10^3} = 66 \ N/mm^2 \leqq \sigma_a = 180 \ N/mm^2$$

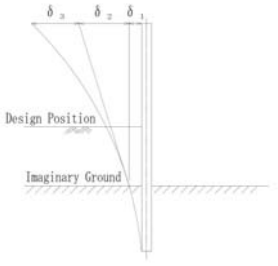
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1308.43 \times 10^6}{7779 \times 10^3} = 168 \ N/mm^2 \leqq \sigma_a = 270 \ N/mm^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

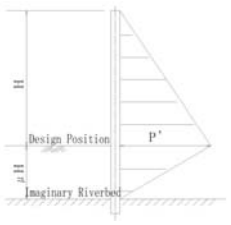
Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0) \times P_0}{2EI\beta^3} = \frac{(1+0.1842 \times 1.87) \times 164.12}{2 \times 2.00 \times 10^8 \times 457778 \times 10^{-8} \times 0.1842^3} = 0.01930 \ m$$

$$\delta_2 = \frac{(1+2\beta h_0) \times P_0}{2EI\beta^2} \times (H + L_k)$$

$$= \frac{(1+2\times0.1842\times1.87)\times164.12}{2\times2.00\times10^{8}\times457778\times10^{-8}\times0.1842^{2}} \times(3.50+0.00) = 0.01563 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{3.50} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120 E I}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{93.78\times3.50^4}{120\times2.00\times10^8\times457778\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4)$$

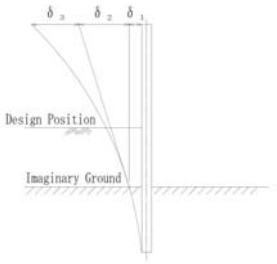
$$= 0.00051 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.01930 + 0.01563 + 0.00051
= 0.03545 m
Size = 35.45 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

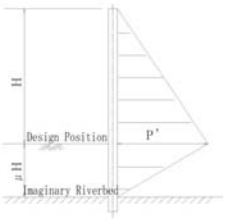


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2 E I \beta^3}$$

$$= \frac{(1+0.2248\times3.05)\times340.47}{2\times2.00\times10^8\times457778\times10^{-8}\times0.2248^3} = 0.02762 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2 E I \beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times0.2248\times3.05)\times340.47}{2\times2.00\times10^8\times457778\times10^{-8}\times0.2248^2}\times(3.50+1.04) = 0.03964 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{1.04}{3.50} = 0.297$$

$$\delta_3 = \frac{P' H^4}{120 E I}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{149.99\times3.50^4}{120\times2.00\times10^8\times457778\times10^{-8}}(4+20\times0.297+40\times0.297^2+35\times0.297^3+11\times0.297^4)$$

$$= 0.00297 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.02762 + 0.03964 + 0.00297
= 0.07023 m
Size = 70.23 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Material Name			10 H _ H 850 -250 -14 -22 -18
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	532300 cm^4 (original condition)
	I	=	532300 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 532300 × 10^{-8}		=	1.065 × 10^6

7.1 Penetration Depth and Whole Length of SSP (Chang)

When the depth of the virtual ground surface is Lk, the grouting length (D) below the design surface and the total length (L) of the sheet pile are as follows.

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 4212 kN/m^3
Calculated value β = 0.17734 m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.177} = 16.92$ m
Whole length of SSP $L = 3.50 - 0.40 + 16.92 = 20.02$ m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction K_h = 9343 kN/m^3
Calculated value β = 0.21643 m^{-1}

Penetration length of SSP $D = 1.04 + \frac{3}{0.216} = 14.90$ m
Whole length of SSP $L = 3.50 - 0.40 + 14.90 = 18.00$ m

Therefore, the total length of the sheet pile is 20.50 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile 10 H _ H 850 -250 -14 -22 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	532300		
Sectional Modulus	Z (cm3)	8840		
Maximum bending moment	Mmax (kN・m・m)		512.86	1308.43
Stress intensity	σ (N/mm2)		66 (180)	168 (270)
Lateral displacement	δ (mm)		35.45 (50.0)	70.23 (75.0)
Penetration depths	D (m)		16.92	14.90
Whole length of SSP	L (m)	20.50		

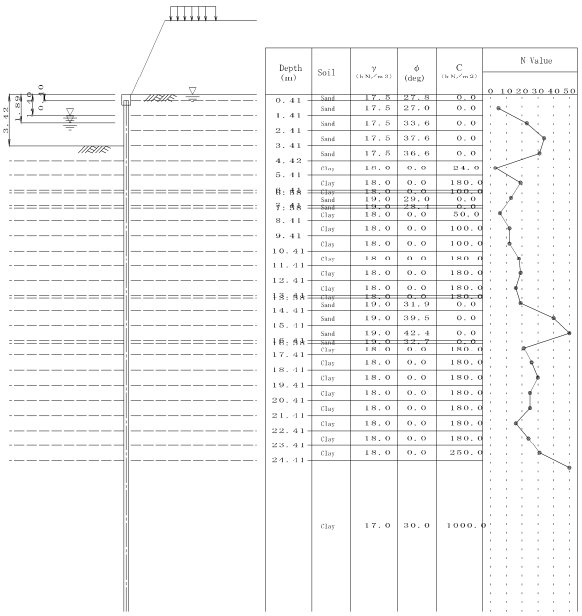
Block No. : L-5
Sta. : 7+180~7+480

Design Cross Section : Sta 7+400
Boring Name : DD-BH-L02

Specification : SSP SP-10H
(Combined) : H 1000-250-16-25-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



Depth (m)	Soil	γ (kN/m3)	φ (deg)	C (kN/m2)
0.41	Sand	17.5	27.8	0.0
1.41	Sand	17.5	27.0	0.0
2.41	Sand	17.5	33.6	0.0
3.41	Sand	17.5	37.6	0.0
4.42	Sand	17.5	36.6	0.0
5.41	Clay	18.0	0.0	24.0
6.41	Clay	18.0	0.0	180.0
7.41	Clay	18.0	0.0	100.0
8.41	Sand	19.0	29.0	0.0
9.41	Sand	19.0	28.1	0.0
10.41	Clay	18.0	0.0	50.0
11.41	Clay	18.0	0.0	100.0
12.41	Clay	18.0	0.0	100.0
13.41	Clay	18.0	0.0	180.0
14.41	Clay	18.0	0.0	180.0
15.41	Clay	18.0	0.0	180.0
16.41	Clay	18.0	0.0	180.0
17.41	Sand	19.0	31.9	0.0
18.41	Sand	19.0	39.5	0.0
19.41	Sand	19.0	42.4	0.0
20.41	Sand	19.0	32.7	0.0
21.41	Clay	18.0	0.0	180.0
22.41	Clay	18.0	0.0	180.0
23.41	Clay	18.0	0.0	180.0
24.41	Clay	18.0	0.0	180.0
25.41	Clay	18.0	0.0	180.0
26.41	Clay	18.0	0.0	180.0
27.41	Clay	18.0	0.0	180.0
28.41	Clay	18.0	0.0	180.0
29.41	Clay	18.0	0.0	180.0
30.41	Clay	18.0	0.0	250.0
	Clay	17.0	30.0	1000.0

N Value: 0 10 20 30 40 50

1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	3.42 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_t	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	1.89 m (Normal Condition)
	L_{wp}'	=	1.40 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress: Chang's formula

Penetration depths: $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water: γ_w = 9.8 kN/m³

Type of water pressure: trapezoidal water pressure

Lateral pressure: calculated in consideration of site conditions

Study case:
- Normal Condition
- Seismic Condition

Design earthquake intensity: k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	P_t	= 37.2 kN/m	(Normal Condition)
		P_t'	= 90.4 kN/m	(Seismic Condition)
	Depth of acting point	H_t	= 0.0 m	(Normal Condition)
		H_t'	= 0.0 m	(Seismic Condition)
	Moment	M_m	= 1.2 kN･m/m	(Normal Condition)
		M_m'	= 87.9 kN･m/m	(Seismic Condition)
	Depth of acting point	H_m'	= 0.00 m	(Seismic Condition)
		H_m	= 0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load: not considered

Minimum angle of rupture: ζ_0 = 10 degrees

Rear side angle of slope: not considered

Angle of rupture (clayey soil): $\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C} \cdot \tan\theta}$

Equilibrium factor of compression: K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula:

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m

E_0 = 2800N

Average N-value: calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value
1	0.91	5	11	10.91	18	21	20.91	25
2	1.91	23	12	11.91	19	22	21.91	16
3	2.91	34	13	12.91	16	23	22.91	24
4	3.91	31	14	13.91	19	24	23.91	31
5	4.91	3	15	14.91	40	25	24.91	50
6	5.91	19	16	15.91	50			
7	6.91	13	17	16.91	21			
8	7.91	6	18	17.91	26			
9	8.91	12	19	18.91	30			
10	9.91	12	20	19.91	25			

1.6 Vertical Load

Vertical load on landside: calculated in consideration of embankment shape on landside

Vertical load on riverside: not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	0.41	0.41
2	1.41	1.00
3	2.41	1.00
4	3.41	1.00
5	4.42	1.01
6	5.41	0.99
7	6.41	1.00
8	6.58	0.17
9	7.41	0.83
10	7.58	0.17
11	8.41	0.83
12	9.41	1.00
13	10.41	1.00
14	11.41	1.00
15	12.41	1.00
16	13.41	1.00
17	13.58	0.17
18	14.41	0.83
19	15.41	1.00
20	16.41	1.00
21	16.58	0.17
22	17.41	0.83
23	18.41	1.00
24	19.41	1.00
25	20.41	1.00
26	21.41	1.00
27	22.41	1.00
28	23.41	1.00
29	24.41	1.00
30	33.10	8.69

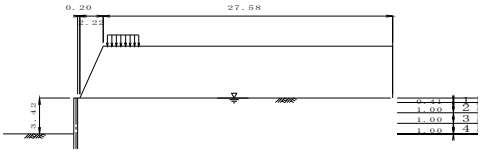
No	Depth m	earth Soil	N Value	γ kN/m3	γ ' kN/m3	φ degree	C kN/m2	a	k'
1	0.41	S	11.0	17.50	7.70	27.8	0.0	0.0	0.200
2	1.41	S	5.0	17.50	7.70	27.0	0.0	0.0	0.200
3	2.41	S	23.0	17.50	7.70	33.6	0.0	0.0	0.200
4	3.41	S	34.0	17.50	7.70	37.6	0.0	0.0	0.200
5	4.42	S	31.0	17.50	7.70	36.6	0.0	0.0	0.200
6	5.41	C	3.0	18.00	8.20	0.0	24.0	0.0	0.200
7	6.41	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200
8	6.58	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200
9	7.41	S	13.0	19.00	9.20	29.0	0.0	0.0	0.200
10	7.58	S	12.0	19.00	9.20	28.4	0.0	0.0	0.200
11	8.41	C	6.0	18.00	8.20	0.0	50.0	0.0	0.200
12	9.41	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200
13	10.41	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200
14	11.41	C	18.0	18.00	8.20	0.0	180.0	0.0	0.200
15	12.41	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200
16	13.41	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200
17	13.58	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200
18	14.41	S	19.0	19.00	9.20	31.9	0.0	0.0	0.200
19	15.41	S	40.0	19.00	9.20	39.5	0.0	0.0	0.200
20	16.41	S	50.0	19.00	9.20	42.4	0.0	0.0	0.200
21	16.58	S	21.0	19.00	9.20	32.7	0.0	0.0	0.200
22	17.41	C	21.0	18.00	8.20	0.0	180.0	0.0	0.200
23	18.41	C	26.0	18.00	8.20	0.0	180.0	0.0	0.200
24	19.41	C	30.0	18.00	8.20	0.0	180.0	0.0	0.200
25	20.41	C	25.0	18.00	8.20	0.0	180.0	0.0	0.200
26	21.41	C	25.0	18.00	8.20	0.0	180.0	0.0	0.200
27	22.41	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200
28	23.41	C	24.0	18.00	8.20	0.0	180.0	0.0	0.200
29	24.41	C	31.0	18.00	8.20	0.0	250.0	0.0	0.200
30	33.10	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate				Thickness	soil single weight γ		internal friction angle	stickiness	decay angle ζ	
		Bottom Left m	Top Left m	Top Right m	Bottom Right m	h m	Normal Condition kN/m3	Seismic Condition kN/m3	φ degree	C kN/m2	Normal Condition degree	Seismic Condition degree
1	Sand	0.20	2.42	30.00	30.00	4.93	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area		load strength	
	From m	End point m	Normal Condition kN/m2	Seismic Condition kN/m2
1	2.82	5.82	10.0	5.0

Angle of rapture in embankment calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name 10 H _ H 1000 -250 -16 -25 -18
Young's modulus E = 200000 N/mm²
Inertia sectional moment I_0 = 806700 cm⁴
Sectional factor Z_0 = 11980 cm³

Corrosion margin t_1 = 1.00 mm (riverside) t_2 = 1.00 mm (landside)

Corrosion rate (to I_0) η = 0.87
Corrosion rate (to Z_0) η = 0.89
Section efficiency (to I_0) μ = 1.00
Section efficiency (to Z_0) μ = 1.00

Round unit of SSP length 0.50 m

Allowable stress σ_a = 180 N/mm (Normal)
σ_a ' = 270 N/mm (Seismic)

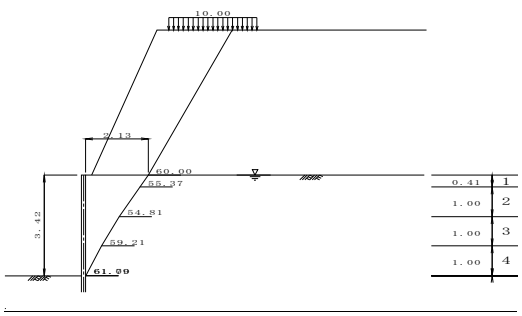
Allowable displacement δ_a = 50.0 mm (Normal)
δ_a ' = 75.0 mm (Seismic)

Bending of cantilever beam calculated as distributed load of each layer

Reduction of material modulus Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σ γ h kN/m2	Q kN/m2	γ whw kN/m2	Angle of Rupture ζ degree
1	3.42 ~ 3.41	Sand	36.6	15.0	0.0	26.33	108.77	33.52	61.09
2	3.41 ~ 2.41	Sand	37.6	15.0	0.0	26.26	108.77	33.42	61.70
3	2.41 ~ 1.41	Sand	33.6	15.0	0.0	18.56	108.77	23.62	59.21
4	1.41 ~ 0.41	Sand	27.0	15.0	0.0	10.86	108.77	13.82	54.81
5	0.41 ~ 0.00	Sand	27.8	15.0	0.0	3.16	108.77	4.02	55.37
6		embankment	30.0	———	0.0	93.67	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°
Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = $\tan^{-1}$k or θ = $\tan^{-1}$k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of the major collapse line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	61.09	0.01	0.00	0.00	0.01	0.01
2	61.70	1.00	0.01	0.01	0.54	1.01
3	59.21	1.00	0.54	1.01	1.14	2.01
4	54.81	1.00	1.14	2.01	1.85	3.01
5	55.37	0.41	1.85	3.01	2.13	3.42
6	60.00	4.93	2.13	3.42	4.97	8.35

From the above table, the loading width (L) on the ground surface is 2.13 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	11.05	209.96
Σ			209.96

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	2.15	21.55
Σ			21.55

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

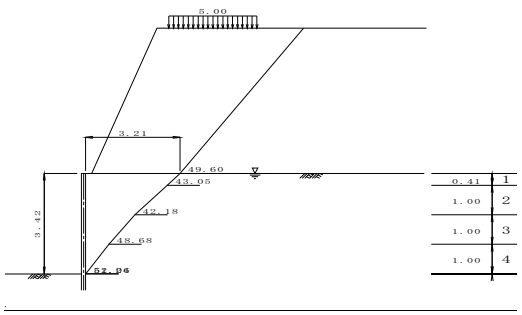
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{209.96 + 21.55 + 0.00}{2.13}$$

$$= 108.77 \text{ kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	3.42 ~ 3.41	Sand	36.6	15.0	0.0	26.33	121.33	33.52	0.200	11.31	51.24
2	3.41 ~ 2.41	Sand	37.6	15.0	0.0	26.26	121.33	33.42	0.200	11.31	52.06
3	2.41 ~ 1.41	Sand	33.6	15.0	0.0	18.56	121.33	23.62	0.200	11.31	48.68
4	1.41 ~ 0.41	Sand	27.0	15.0	0.0	10.86	121.33	13.82	0.200	11.31	42.18
5	0.41 ~ 0.00	Sand	27.8	15.0	0.0	3.16	121.33	4.02	0.200	11.31	43.05
6		embankment	30.0	———	0.0	93.67	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h + Q}$$

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C : cohesive force of soil (kN/m²)

2.2.2 Coordinates of the major collapse line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	51.24	0.01	0.00	0.00	0.01	0.01
2	52.06	1.00	0.01	0.01	0.79	1.01
3	48.68	1.00	0.79	1.01	1.67	2.01
4	42.18	1.00	1.67	2.01	2.77	3.01
5	43.05	0.41	2.77	3.01	3.21	3.42
6	49.60	4.93	3.21	3.42	7.40	8.35

From the above table, the loading width (L) on the ground surface is 3.21 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	19.70	374.39
Σ			374.39

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.00	15.00
Σ			15.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

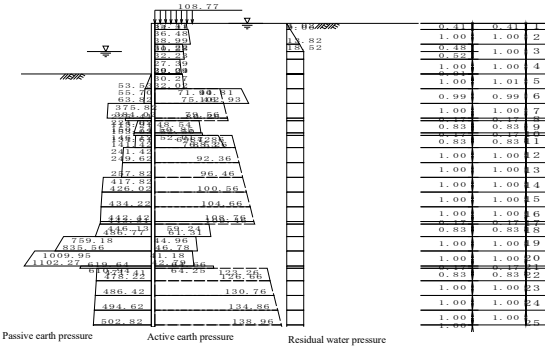
$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times l)+\Sigma P}{L}$$

$$= \frac{374.39 + 15.00 + 0.00}{3.21}$$

$$= 121.33\ \text{kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 0.41	Sand	7.7	27.8	——— ———	108.774 111.931	0.32749 0.32749	0.31633 0.31633
2	0.41~ 1.41	Sand	7.7	27.0	——— ———	111.931 119.631	0.33738 0.33738	0.32589 0.32589
3	1.41~ 1.89	Sand	7.7	33.6	——— ———	119.631 123.327	0.26205 0.26205	0.25312 0.25312
4	1.89~ 2.41	Sand	7.7	33.6	——— ———	123.327 127.331	0.26205 0.26205	0.25312 0.25312
5	2.41~ 3.41	Sand	7.7	37.6	——— ———	127.331 135.031	0.22267 0.22267	0.21508 0.21508
6	3.41~ 3.42	Sand	7.7	36.6	——— ———	135.031 135.108	0.23211 0.23211	0.22420 0.22420
7	3.42~ 4.42	Sand	7.7	36.6	——— ———	135.108 142.808	0.23211 0.23211	0.22420 0.22420
8	4.42~ 5.41	Clay	8.2	———	24.0 24.0	142.808 150.926	——— ———	——— ———
9	5.41~ 6.41	Clay	8.2	———	180.0 180.0	150.926 159.126	——— ———	——— ———
10	6.41~ 6.58	Clay	8.2	———	100.0 100.0	159.126 160.520	——— ———	——— ———
11	6.58~ 7.41	Sand	9.2	29.0	——— ———	160.520 168.156	0.31307 0.31307	0.30240 0.30240
12	7.41~ 7.58	Sand	9.2	28.4	——— ———	168.156 169.720	0.32022 0.32022	0.30931 0.30931
13	7.58~ 8.41	Clay	8.2	———	50.0 50.0	169.720 176.526	——— ———	——— ———
14	8.41~ 9.41	Clay	8.2	———	100.0 100.0	176.526 184.726	——— ———	——— ———
15	9.41~ 10.41	Clay	8.2	———	100.0 100.0	184.726 192.926	——— ———	——— ———
16	10.41~ 11.41	Clay	8.2	———	180.0 180.0	192.926 201.126	——— ———	——— ———
17	11.41~ 12.41	Clay	8.2	———	180.0 180.0	201.126 209.326	——— ———	——— ———
18	12.41~ 13.41	Clay	8.2	———	180.0 180.0	209.326 217.526	——— ———	——— ———
19	13.41~ 13.58	Clay	8.2	———	180.0 180.0	217.526 218.920	——— ———	——— ———
20	13.58~ 14.41	Sand	9.2	31.9	——— ———	218.920 226.556	0.28015 0.28015	0.27060 0.27060
21	14.41~ 15.41	Sand	9.2	39.5	——— ———	226.556 235.756	0.20544 0.20544	0.19844 0.19844
22	15.41~ 16.41	Sand	9.2	42.4	——— ———	235.756 244.956	0.18084 0.18084	0.17468 0.17468
23	16.41~ 16.58	Sand	9.2	32.7	——— ———	244.956 246.520	0.27152 0.27152	0.26227 0.26227
24	16.58~ 17.41	Clay	8.2	———	180.0 180.0	246.520 253.326	——— ———	——— ———
25	17.41~ 18.41	Clay	8.2	———	180.0 180.0	253.326 261.526	——— ———	——— ———
26	18.41~ 19.41	Clay	8.2	———	180.0 180.0	261.526 269.726	——— ———	——— ———
27	19.41~ 20.41	Clay	8.2	———	180.0 180.0	269.726 277.926	——— ———	——— ———
28	20.41~ 21.41	Clay	8.2	———	180.0 180.0	277.926 286.126	——— ———	——— ———
29	21.41~ 22.41	Clay	8.2	———	180.0 180.0	286.126 294.326	——— ———	——— ———
30	22.41~ 23.41	Clay	8.2	———	180.0 180.0	294.326 302.526	——— ———	——— ———
31	23.41~ 24.41	Clay	8.2	———	250.0 250.0	302.526 310.726	——— ———	——— ———
32	24.41~ 33.10	Clay	7.2	———	1000.0 1000.0	310.726 373.294	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ = 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
7	3.42~ 4.42	Sand	7.7	36.6	——— ———	0.000 7.700	7.19709 7.19709	6.95185 6.95185

8	4.42~ 5.41	Clay	8.2	0.0	24.0 24.0	7.700 15.818	——— ———	——— ———
9	5.41~ 6.41	Clay	8.2	0.0	180.0 180.0	15.818 24.018	——— ———	——— ———
10	6.41~ 6.58	Clay	8.2	0.0	100.0 100.0	24.018 25.412	——— ———	——— ———
11	6.58~ 7.41	Sand	9.2	29.0	——— ———	25.412 33.048	4.72202 4.72202	4.56112 4.56112
12	7.41~ 7.58	Sand	9.2	28.4	——— ———	33.048 34.612	4.57728 4.57728	4.42131 4.42131
13	7.58~ 8.41	Clay	8.2	0.0	50.0 50.0	34.612 41.418	——— ———	——— ———
14	8.41~ 9.41	Clay	8.2	0.0	100.0 100.0	41.418 49.618	——— ———	——— ———
15	9.41~ 10.41	Clay	8.2	0.0	100.0 100.0	49.618 57.818	——— ———	——— ———
16	10.41~ 11.41	Clay	8.2	0.0	180.0 180.0	57.818 66.018	——— ———	——— ———
17	11.41~ 12.41	Clay	8.2	0.0	180.0 180.0	66.018 74.218	——— ———	——— ———
18	12.41~ 13.41	Clay	8.2	0.0	180.0 180.0	74.218 82.418	——— ———	——— ———
19	13.41~ 13.58	Clay	8.2	0.0	180.0 180.0	82.418 83.812	——— ———	——— ———
20	13.58~ 14.41	Sand	9.2	31.9	——— ———	83.812 91.448	5.51072 5.51072	5.32295 5.32295
21	14.41~ 15.41	Sand	9.2	39.5	——— ———	91.448 100.648	8.59467 8.59467	8.30181 8.30181
22	15.41~ 16.41	Sand	9.2	42.4	——— ———	100.648 109.848	10.38845 10.38845	10.03447 10.03447
23	16.41~ 16.58	Sand	9.2	32.7	——— ———	109.848 111.412	5.75791 5.75791	5.56172 5.56172
24	16.58~ 17.41	Clay	8.2	0.0	180.0 180.0	111.412 118.218	——— ———	——— ———
25	17.41~ 18.41	Clay	8.2	0.0	180.0 180.0	118.218 126.418	——— ———	——— ———
26	18.41~ 19.41	Clay	8.2	0.0	180.0 180.0	126.418 134.618	——— ———	——— ———
27	19.41~ 20.41	Clay	8.2	0.0	180.0 180.0	134.618 142.818	——— ———	——— ———
28	20.41~ 21.41	Clay	8.2	0.0	180.0 180.0	142.818 151.018	——— ———	——— ———
29	21.41~ 22.41	Clay	8.2	0.0	180.0 180.0	151.018 159.218	——— ———	——— ———
30	22.41~ 23.41	Clay	8.2	0.0	180.0 180.0	159.218 167.418	——— ———	——— ———
31	23.41~ 24.41	Clay	8.2	0.0	250.0 250.0	167.418 175.618	——— ———	——— ———
32	24.41~ 33.10	Clay	7.2	30.0	1000.0 1000.0	175.618 238.186	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.41	34.41 35.41	——— ———	34.41 35.41	0.00 4.02	——— ———
2	0.41~ 1.41	36.48 38.99	——— ———	36.48 38.99	4.02 13.82	——— ———
3	1.41~ 1.89	30.28 31.22	——— ———	30.28 31.22	13.82 18.52	——— ———
4	1.89~ 2.41	31.22 32.23	——— ———	31.22 32.23	18.52 18.52	——— ———
5	2.41~ 3.41	27.39 29.04	——— ———	27.39 29.04	18.52 18.52	——— ———
6	3.41~ 3.42	30.27 30.29	——— ———	30.27 30.29	18.52 18.52	——— ———
7	3.42~ 4.42	30.29 32.02	——— ———	30.29 32.02	18.52 18.52	0.00 53.53
8	4.42~ 5.41	94.81 102.93	71.40 75.46	94.81 102.93	18.52 18.52	55.70 63.82
9	5.41~ 6.41	-209.07 -200.87	75.46 79.56	75.46 79.56	18.52 18.52	375.82 384.02
10	6.41~ 6.58	-40.87 -39.48	79.56 80.26	79.56 80.26	18.52 18.52	224.02 225.41
11	6.58~ 7.41	48.54 50.85	——— ———	48.54 50.85	18.52 18.52	115.91 150.74
12	7.41~ 7.58	52.01 52.50	——— ———	52.01 52.50	18.52 18.52	146.12 153.03
13	7.58~ 8.41	69.72 76.53	84.86 88.26	84.86 88.26	18.52 18.52	134.61 141.42
14	8.41~ 9.41	-23.47 -15.27	88.26 92.36	88.26 92.36	18.52 18.52	241.42 249.62
15	9.41~ 10.41	-15.27 -7.07	92.36 96.46	92.36 96.46	18.52 18.52	249.62 257.82
16	10.41~ 11.41	-167.07 -158.87	96.46 100.56	96.46 100.56	18.52 18.52	417.82 426.02
17	11.41~ 12.41	-158.87 -150.67	100.56 104.66	100.56 104.66	18.52 18.52	426.02 434.22
18	12.41~ 13.41	-150.67 -142.47	104.66 108.76	104.66 108.76	18.52 18.52	434.22 442.42
19	13.41~ 13.58	-142.47 -141.08	108.76 109.46	108.76 109.46	18.52 18.52	442.42 443.81
20	13.58~ 14.41	59.24 61.31	——— ———	59.24 61.31	18.52 18.52	446.13 486.77

21	14.41~ 15.41	44.96 46.78	——— ———	44.96 46.78	18.52 18.52	759.18 835.56
22	15.41~ 16.41	41.18 42.79	——— ———	41.18 42.79	18.52 18.52	1009.95 1102.27
23	16.41~ 16.58	64.25 64.66	——— ———	64.25 64.66	18.52 18.52	610.94 619.64
24	16.58~ 17.41	-113.48 -106.67	123.26 126.66	123.26 126.66	18.52 18.52	471.41 478.22
25	17.41~ 18.41	-106.67 -98.47	126.66 130.76	126.66 130.76	18.52 18.52	478.22 486.42
26	18.41~ 19.41	-98.47 -90.27	130.76 134.86	130.76 134.86	18.52 18.52	486.42 494.62
27	19.41~ 20.41	-90.27 -82.07	134.86 138.96	134.86 138.96	18.52 18.52	494.62 502.82
28	20.41~ 21.41	-82.07 -73.87	138.96 143.06	138.96 143.06	18.52 18.52	502.82 511.02
29	21.41~ 22.41	-73.87 -65.67	143.06 147.16	143.06 147.16	18.52 18.52	511.02 519.22
30	22.41~ 23.41	-65.67 -57.47	147.16 151.26	147.16 151.26	18.52 18.52	519.22 527.42
31	23.41~ 24.41	-197.47 -189.27	151.26 155.36	151.26 155.36	18.52 18.52	667.42 675.62
32	24.41~ 33.10	-1689.27 -1626.71	155.36 186.65	155.36 186.65	18.52 18.52	2175.62 2238.19

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \dfrac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

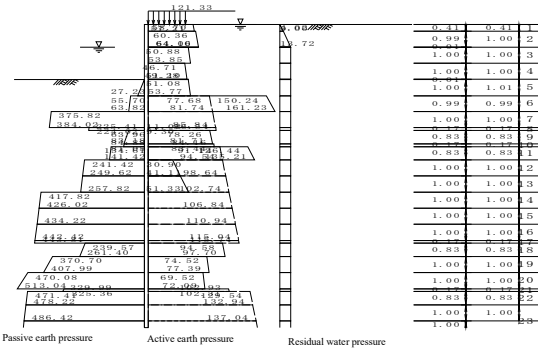
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \dfrac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cos δ	ζ degree
1	0.00~ 0.41	Sand	7.7	27.8	——— ———	121.33 124.49	0.00 4.02	0.200 0.200	11.31 11.31	0.48814 0.48814	0.47151 0.47151	——— ———
2	0.41~ 1.40	Sand	7.7	27.0	——— ———	124.49 132.11	4.02 13.72	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
3	1.40~ 1.41	Sand	7.7	27.0	——— ———	132.11 132.19	13.72 13.82	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
4	1.41~ 2.41	Sand	7.7	33.6	——— ———	132.19 139.89	13.82 23.62	0.200 0.200	11.31 11.31	0.39850 0.39850	0.38492 0.38492	——— ———
5	2.41~ 3.41	Sand	7.7	37.6	——— ———	139.89 147.59	23.62 33.42	0.200 0.200	11.31 11.31	0.34567 0.34567	0.33389 0.33389	——— ———
6	3.41~ 3.42	Sand	7.7	36.6	——— ———	147.59 147.67	33.42 33.52	0.200 0.200	11.31 11.31	0.35829 0.35829	0.34608 0.34608	——— ———
7	3.42~ 4.42	Sand	7.7	36.6	——— ———	147.67 155.37	33.52 43.32	0.200 0.200	11.31 11.31	0.35829 0.35829	0.34608 0.34608	——— ———
8	4.42~ 5.41	Clay	8.2	———	24.0 24.0	155.37 163.48	43.32 53.02	0.200 0.200	11.31 11.31	——— ———	——— ———	33.43 33.05
9	5.41~ 6.41	Clay	8.2	———	180.0 180.0	163.48 171.68	53.02 62.82	0.200 0.200	11.31 11.31	——— ———	——— ———	42.61 42.50
10	6.41~ 6.58	Clay	8.2	———	100.0 100.0	171.68 173.08	62.82 64.48	0.200 0.200	11.31 11.31	——— ———	——— ———	40.79 40.76
11	6.58~ 7.41	Sand	9.2	29.0	——— ———	173.08 180.71	64.48 72.62	0.200 0.200	11.31 11.31	0.46809 0.46809	0.45214 0.45214	——— ———
12	7.41~ 7.58	Sand	9.2	28.4	——— ———	180.71 182.28	72.62 74.28	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	——— ———
13	7.58~ 8.41	Clay	8.2	———	50.0 50.0	182.28 189.08	74.28 82.42	0.200 0.200	11.31 11.31	——— ———	——— ———	37.25 37.04
14	8.41~ 9.41	Clay	8.2	———	100.0 100.0	189.08 197.28	82.42 92.22	0.200 0.200	11.31 11.31	——— ———	——— ———	40.43 40.26

15	9.41~ 10.41	Clay	8.2	——	100.0 100.0	197.28 205.48	92.22 102.02	0.200 0.200	11.31 11.31	——	——	40.26 40.09
16	10.41~ 11.41	Clay	8.2	——	180.0 180.0	205.48 213.68	102.02 111.82	0.200 0.200	11.31 11.31	——	——	42.06 41.95
17	11.41~ 12.41	Clay	8.2	——	180.0 180.0	213.68 221.88	111.82 121.62	0.200 0.200	11.31 11.31	——	——	41.95 41.85
18	12.41~ 13.41	Clay	8.2	——	180.0 180.0	221.88 230.08	121.62 131.42	0.200 0.200	11.31 11.31	——	——	41.85 41.75
19	13.41~ 13.58	Clay	8.2	——	180.0 180.0	230.08 231.48	131.42 133.08	0.200 0.200	11.31 11.31	——	——	41.75 41.73
20	13.58~ 14.41	Sand	9.2	31.9	—— ——	231.48 239.11	133.08 141.22	0.200 0.200	11.31 11.31	0.42299 0.42299	0.40858 0.40858	—— ——
21	14.41~ 15.41	Sand	9.2	39.5	—— ——	239.11 248.31	141.22 151.02	0.200 0.200	11.31 11.31	0.32266 0.32266	0.31166 0.31166	—— ——
22	15.41~ 16.41	Sand	9.2	42.4	—— ——	248.31 257.51	151.02 160.82	0.200 0.200	11.31 11.31	0.28983 0.28983	0.27995 0.27995	—— ——
23	16.41~ 16.58	Sand	9.2	32.7	—— ——	257.51 259.08	160.82 162.48	0.200 0.200	11.31 11.31	0.41130 0.41130	0.39729 0.39729	—— ——
24	16.58~ 17.41	Clay	8.2	——	180.0 180.0	259.08 265.88	162.48 170.62	0.200 0.200	11.31 11.31	——	——	41.39 41.30
25	17.41~ 18.41	Clay	8.2	——	180.0 180.0	265.88 274.08	170.62 180.42	0.200 0.200	11.31 11.31	——	——	41.30 41.20
26	18.41~ 19.41	Clay	8.2	——	180.0 180.0	274.08 282.28	180.42 190.22	0.200 0.200	11.31 11.31	——	——	41.20 41.10
27	19.41~ 20.41	Clay	8.2	——	180.0 180.0	282.28 290.48	190.22 200.02	0.200 0.200	11.31 11.31	——	——	41.10 41.01
28	20.41~ 21.02	Clay	8.2	——	180.0 180.0	290.48 295.51	200.02<——	0.200<——	11.31<——	——	——	41.01<——
29	21.02~ 21.41	Clay	8.2	——	180.0 180.0	295.51 298.68	—— 209.82	—— 0.200	—— 11.31	——	——	—— 40.91
30	21.41~ 22.41	Clay	8.2	——	180.0 180.0	298.68 306.88	209.82 219.62	0.200 0.200	11.31 11.31	——	——	40.91 40.81
31	22.41~ 23.41	Clay	8.2	——	180.0 180.0	306.88 315.08	219.62 229.42	0.200 0.200	11.31 11.31	——	——	40.81 40.72
32	23.41~ 24.41	Clay	8.2	——	250.0 250.0	315.08 323.28	229.42 239.22	0.200 0.200	11.31 11.31	——	——	41.79 41.71
33	24.41~ 33.10	Clay	7.2	——	1000.0 1000.0	323.28 385.85	239.22 324.38	0.200 0.200	11.31 11.31	——	——	44.10 43.94

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β= 0.00、θ= 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h+Q}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k³)	θ degree	Kp	Kp × cos δ
7	3.42~ 4.42	Sand	7.70	36.6	—— ——	0.000 7.700	0.00 9.80	0.200 0.200	11.31 11.31	3.53610 3.53610	3.53610 3.53610
8	4.42~ 5.41	Clay	8.20	0.0	24.0 24.0	7.700 15.818	9.80 19.50	0.200 0.200	11.31 11.31	——	——
9	5.41~ 6.41	Clay	8.20	0.0	180.0 180.0	15.818 24.018	19.50 29.30	0.200 0.200	11.31 11.31	——	——
10	6.41~ 6.58	Clay	8.20	0.0	100.0 100.0	24.018 25.412	29.30 30.97	0.200 0.200	11.31 11.31	——	——
11	6.58~ 7.41	Sand	9.20	29.0	—— ——	25.412 33.048	30.97 39.10	0.200 0.200	11.31 11.31	2.51705 2.51705	2.51705 2.51705
12	7.41~ 7.58	Sand	9.20	28.4	—— ——	33.048 34.612	39.10 40.77	0.200 0.200	11.31 11.31	2.45242 2.45242	2.45242 2.45242
13	7.58~ 8.41	Clay	8.20	0.0	50.0 50.0	34.612 41.418	40.77 48.90	0.200 0.200	11.31 11.31	——	——
14	8.41~ 9.41	Clay	8.20	0.0	100.0 100.0	41.418 49.618	48.90 58.70	0.200 0.200	11.31 11.31	——	——
15	9.41~ 10.41	Clay	8.20	0.0	100.0 100.0	49.618 57.818	58.70 68.50	0.200 0.200	11.31 11.31	——	——
16	10.41~ 11.41	Clay	8.20	0.0	180.0 180.0	57.818 66.018	68.50 78.30	0.200 0.200	11.31 11.31	——	——
17	11.41~ 12.41	Clay	8.20	0.0	180.0 180.0	66.018 74.218	78.30 88.10	0.200 0.200	11.31 11.31	——	——
18	12.41~ 13.41	Clay	8.20	0.0	180.0 180.0	74.218 82.418	88.10 97.90	0.200 0.200	11.31 11.31	——	——
19	13.41~ 13.58	Clay	8.20	0.0	180.0 180.0	82.418 83.812	97.90 99.57	0.200 0.200	11.31 11.31	——	——
20	13.58~ 14.41	Sand	9.20	31.9	—— ——	83.812 91.448	99.57 107.70	0.200 0.200	11.31 11.31	2.85840 2.85840	2.85840 2.85840
21	14.41~ 15.41	Sand	9.20	39.5	—— ——	91.448 100.648	107.70 117.50	0.200 0.200	11.31 11.31	4.05365 4.05365	4.05365 4.05365
22	15.41~ 16.41	Sand	9.20	42.4	—— ——	100.648 109.848	117.50 127.30	0.200 0.200	11.31 11.31	4.67049 4.67049	4.67049 4.67049
23	16.41~ 16.58	Sand	9.20	32.7	—— ——	109.848 111.412	127.30 128.97	0.200 0.200	11.31 11.31	2.96192 2.96192	2.96192 2.96192
24	16.58~ 17.41	Clay	8.20	0.0	180.0 180.0	111.412 118.218	128.97 137.10	0.200 0.200	11.31 11.31	——	——
25	17.41~ 18.41	Clay	8.20	0.0	180.0 180.0	118.218 126.418	137.10 146.90	0.200 0.200	11.31 11.31	——	——
26	18.41~ 19.41	Clay	8.20	0.0	180.0 180.0	126.418 134.618	146.90 156.70	0.200 0.200	11.31 11.31	——	——
27	19.41~ 20.41	Clay	8.20	0.0	180.0 180.0	134.618 142.818	156.70 166.50	0.200 0.200	11.31 11.31	——	——
28	20.41~ 21.02	Clay	8.20	0.0	180.0 180.0	142.818 147.850	166.50<——	0.200<——	11.31<——	——	——
29	21.02~ 21.41	Clay	8.20	0.0	180.0 180.0	147.850 151.018	—— 176.30	—— 0.200	—— 11.31	—— ——	—— ——
30	21.41~ 22.41	Clay	8.20	0.0	180.0 180.0	151.018 159.218	176.30 186.10	0.200 0.200	11.31 11.31	——	——

31	22.41~ 23.41	Clay	8.20	0.0	180.0 180.0	159.218 167.418	186.10 195.90	0.200 0.200	11.31 11.31	——	——
32	23.41~ 24.41	Clay	8.20	0.0	250.0 250.0	167.418 175.618	195.90 205.70	0.200 0.200	11.31 11.31	——	——
33	24.41~ 33.10	Clay	7.20	30.0	1000.0 1000.0	175.618 238.186	205.70 290.86	0.200 0.200	11.31 11.31	——	——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.41	57.21 58.70	—— ——	57.21 58.70	0.00 4.02	—— ——
2	0.41~ 1.40	60.36 64.06	—— ——	60.36 64.06	4.02 13.72	—— ——
3	1.40~ 1.41	64.06 64.10	—— ——	64.06 64.10	13.72 13.72	—— ——
4	1.41~ 2.41	50.88 53.85	—— ——	50.88 53.85	13.72 13.72	—— ——
5	2.41~ 3.41	46.71 49.28	—— ——	46.71 49.28	13.72 13.72	—— ——
6	3.41~ 3.42	51.08 51.10	—— ——	51.08 51.10	13.72 13.72	—— ——
7	3.42~ 4.42	51.10 53.77	—— ——	51.10 53.77	13.72 13.72	0.00 27.23
8	4.42~ 5.41	150.24 161.23	77.68 81.74	150.24 161.23	13.72 13.72	55.70 63.82
9	5.41~ 6.41	-162.23 -152.22	81.74 85.84	81.74 85.84	13.72 13.72	375.82 384.02
10	6.41~ 6.58	9.30 11.03	85.84 86.54	85.84 86.54	13.72 13.72	224.02 225.41
11	6.58~ 7.41	78.26 81.71	—— ——	78.26 81.71	13.72 13.72	63.96 83.18
12	7.41~ 7.58	83.44 84.16	—— ——	83.44 84.16	13.72 13.72	81.05 84.88
13	7.58~ 8.41	126.44 135.21	91.14 94.54	126.44 135.21	13.72 13.72	134.61 141.42
14	8.41~ 9.41	30.90 41.11	94.54 98.64	94.54 98.64	13.72 13.72	241.42 249.62
15	9.41~ 10.41	41.11 51.33	98.64 102.74	98.64 102.74	13.72 13.72	249.62 257.82
16	10.41~ 11.41	-110.88 -100.82	102.74 106.84	102.74 106.84	13.72 13.72	417.82 426.02
17	11.41~ 12.41	-100.82 -90.76	106.84 110.94	106.84 110.94	13.72 13.72	426.02 434.22
18	12.41~ 13.41	-90.76 -80.69	110.94 115.04	110.94 115.04	13.72 13.72	434.22 442.42
19	13.41~ 13.58	-80.69 -78.97	115.04 115.74	115.04 115.74	13.72 13.72	442.42 443.81
20	13.58~ 14.41	94.58 97.70	—— ——	94.58 97.70	13.72 13.72	239.57 261.40
21	14.41~ 15.41	74.52 77.39	—— ——	74.52 77.39	13.72 13.72	370.70 407.99
22	15.41~ 16.41	69.52 72.09	—— ——	69.52 72.09	13.72 13.72	470.08 513.04
23	16.41~ 16.58	102.31 102.93	—— ——	102.31 102.93	13.72 13.72	325.36 329.99
24	16.58~ 17.41	-45.01 -36.61	129.54 132.94	129.54 132.94	13.72 13.72	471.41 478.22
25	17.41~ 18.41	-36.61 -26.49	132.94 137.04	132.94 137.04	13.72 13.72	478.22 486.42
26	18.41~ 19.41	-26.49 -16.36	137.04 141.14	137.04 141.14	13.72 13.72	486.42 494.62
27	19.41~ 20.41	-16.36 -6.23	141.14 145.24	141.14 145.24	13.72 13.72	494.62 502.82
28	20.41~ 21.02	-6.23 0.00	145.24 147.76	145.24 147.76	13.72 13.72	502.82 507.85
29	21.02~ 21.41	0.00 3.92	147.76 149.34	147.76 149.34	13.72 13.72	507.85 511.02
30	21.41~ 22.41	3.92 14.08	149.34 153.44	149.34 153.44	13.72 13.72	511.02 519.22
31	22.41~ 23.41	14.08 24.24	153.44 157.54	153.44 157.54	13.72 13.72	519.22 527.42
32	23.41~ 24.41	-117.57 -107.49	157.54 161.64	157.54 161.64	13.72 13.72	667.42 675.62
33	24.41~ 33.10	-1610.98 -1535.44	161.64 192.93	161.64 192.93	13.72 13.72	2175.62 2238.19

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

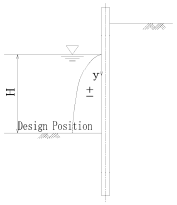
3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.40	0.00	0.00
2	2.40	1.00	2.44
3	3.40	2.00	3.45
4	3.42	2.02	3.46

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

Where,

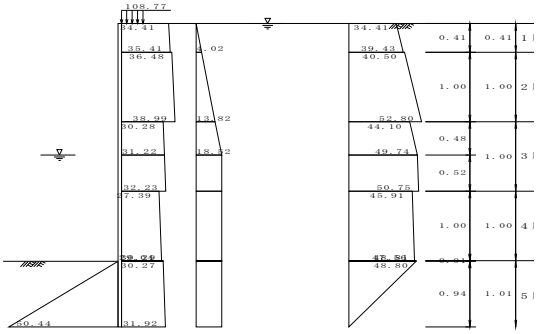
k_{hs}: design seismic coefficient
γ_w : unit weight of water
H : water depth of riverside
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition

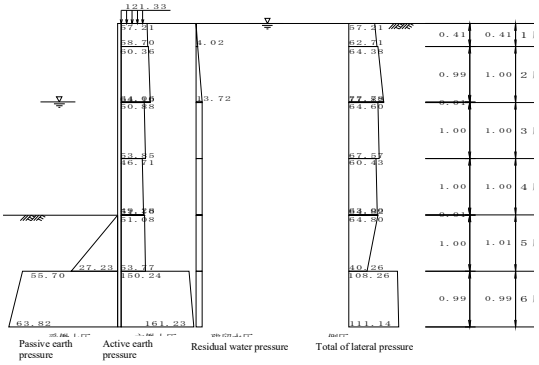


No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.41	34.41 35.41	0.00 4.02	——— ———	34.41 39.43
2	0.41~ 1.41	36.48 38.99	4.02 13.82	——— ———	40.50 52.80
3	1.41~ 1.89	30.28 31.22	13.82 18.52	——— ———	44.10 49.74
4	1.89~ 2.41	31.22 32.23	18.52 18.52	——— ———	49.74 50.75
5	2.41~ 3.41	27.39 29.04	18.52 18.52	——— ———	45.91 47.56
6	3.41~ 3.42	30.27 30.29	18.52 18.52	——— ———	48.80 48.81
7	3.42~ 4.36	30.29 31.92	18.52 18.52	0.00 50.44	48.81 0.00
8	4.36~ 4.42	31.92 32.02	18.52 18.52	50.44 53.53	0.00 -2.99

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.94 m (GL -4.36 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.41	57.21 58.70	0.00 4.02	——— ———	57.21 62.71
2	0.41~ 1.40	60.36 64.06	4.02 13.72	——— ———	64.38 77.78
3	1.40~ 1.41	64.06 64.10	13.72 13.72	——— ———	77.78 77.82
4	1.41~ 2.41	50.88 53.85	13.72 13.72	——— ———	64.60 67.57
5	2.41~ 3.41	46.71 49.28	13.72 13.72	——— ———	60.43 63.00
6	3.41~ 3.42	51.08 51.10	13.72 13.72	——— ———	64.80 64.82
7	3.42~ 4.42	51.10 53.77	13.72 13.72	0.00 27.23	64.82 40.26
8	4.42~ 5.41	150.24 161.23	13.72 13.72	55.70 63.82	108.26 111.14
9	5.41~ 6.41	81.74 85.84	13.72 13.72	375.82 384.02	-280.36 -284.46

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 1.99 m (GL -5.41 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_{ll}}{0.3}\right)^{-3/4} \qquad (B_{ll}=10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1,\ \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name	10 H _ H 1000 -250 -16 -25 -18		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	806700 cm^4(original condition)
	I	=	701829 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 701829 \times 10^{-8} = 1.404 \times 10^6$

No	Depth m	N Value
1	0.91	5
2	1.91	23
3	2.91	34
4	3.91	31
5	4.91	3
6	5.91	19
7	6.91	13
8	7.91	6
9	8.91	12
10	9.91	12

No	Depth m	N Value
11	10.91	18
12	11.91	19
13	12.91	16
14	13.91	19
15	14.91	40
16	15.91	50
17	16.91	21
18	17.91	26
19	18.91	30
20	19.91	25

No	Depth m	N Value
21	20.91	25
22	21.91	16
23	22.91	24
24	23.91	31
25	24.91	50

5.2 Normal Condition

Assuming Kh = 7656 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.192\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 5.20\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -4.36 m) to 5.20 m depth (GL -9.57 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	4.36	0.55	18.3	3.0	5.84
2	4.91	1.00	3.0	19.0	11.00
3	5.91	1.00	19.0	13.0	16.00
4	6.91	1.00	13.0	6.0	9.50
5	7.91	1.00	6.0	12.0	9.00
6	8.91	0.66	12.0	12.0	7.87
	L = Σh = 5.20		Σ A =	59.22	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L}$

$= \frac{59.22}{5.20}$

$= 11.38$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 11.38 = 31864$ kN/m²

$K_{h0} = \frac{1}{0.3} \times \alpha \times 31864 = 106212$ kN/m³ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 106212(10.00/0.3)^{-3/4} = 7656$ kN/m³

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 7656 kN/m3.

5.3 Seismic Condition

Assuming Kh = 16147 kN/m3,

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.232$ m⁻¹

$L = \frac{1}{\beta} = 4.32$ m

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.41 m) and 4.32 m depth (GL -9.73 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.41	0.50	11.0	19.0	7.50
2	5.91	1.00	19.0	13.0	16.00
3	6.91	1.00	13.0	6.0	9.50
4	7.91	1.00	6.0	12.0	9.00
5	8.91	0.82	12.0	12.0	9.82
	L = Σh = 4.32		Σ A =	51.82	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L}$

$= \frac{51.82}{4.32}$

$= 12.00$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 12.00 = 33600$ kN/m²

$K_{h0} = \frac{1}{0.3} \times \alpha \times 33600 = 224000$ kN/m³ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 224000(10.00/0.3)^{-3/4} = 16147$ kN/m³

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 16147 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.41	0.41	34.41 39.43	7.05 8.08	4.23 4.09	29.81 33.05
2	0.41~ 1.41	1.00	40.50 52.80	20.25 26.40	3.62 3.29	73.27 86.75
3	1.41~ 1.89	0.48	44.10 49.74	10.58 11.94	2.79 2.63	29.55 31.42
4	1.89~ 2.41	0.52	49.74 50.75	12.93 13.20	2.30 2.13	29.73 28.05
5	2.41~ 3.41	1.00	45.91 47.56	22.95 23.78	1.62 1.29	37.16 30.57
6	3.41~ 3.42	0.01	48.80 48.81	0.24 0.24	0.95 0.95	0.23 0.23
7	3.42~ 4.36	0.94	48.81 0.00	23.00 0.00	0.63 0.31	14.45 0.00
			Σ P = 180.66		Σ M = 424.28	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	37.2 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	1.2 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	3.42 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.94 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m = 163.48$ kN・m

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t}$

$= \frac{587.75}{217.86} = 2.70$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 217.86}{4.36} = 99.88$ kN/m

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.41	0.41	57.21 62.71	11.73 12.86	5.27 5.14	61.84 66.04
2	0.41~ 1.40	0.99	64.38 77.78	31.87 38.50	4.67 4.34	148.83 167.10
3	1.40~ 1.41	0.01	77.78 77.82	0.39 0.39	4.01 4.00	1.56 1.56
4	1.41~ 2.41	1.00	64.60 67.57	32.30 33.78	3.67 3.33	118.44 112.61
5	2.41~ 3.41	1.00	60.43 63.00	30.21 31.50	2.67 2.33	80.57 73.50
6	3.41~ 3.42	0.01	64.80 64.82	0.32 0.32	2.00 1.99	0.65 0.65
7	3.42~ 4.42	1.00	64.82 40.26	32.41 20.13	1.66 1.32	53.70 26.64
8	4.42~ 5.41	0.99	108.26 111.14	53.59 55.01	0.66 0.33	35.37 18.15
			Σ P = 385.32		Σ M = 967.19	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	90.4 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	87.9 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	3.42 m
Depth of Imaginary riverbed from riverbed	L_k	=	1.99 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m = 576.96$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	1.40~ 2.40	1.00	0.0 2.4	0.00 1.22	3.68 3.34	0.00 4.07
2	2.40~ 3.40	1.00	2.4 3.4	1.22 1.72	2.68 2.34	3.26 4.04
3	3.40~ 3.42	0.02	3.4 3.5	0.03 0.03	2.00 2.00	0.07 0.07
			Σ Pdw = 4.23		Σ Mdw = 11.51	

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}}$

$= \frac{1555.66}{479.95} = 3.24$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 479.95}{5.41} = 177.43$ kN/m

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name			10 H _ H 1000 -250 -16 -25 -18
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	806700 cm⁴ (original condition)
	I	=	701829 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 701829 × 10⁻⁸		=	1.404 × 10⁶

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$

$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp(-\tan^{-1}\frac{1}{1+2\beta h_0})$

$M_{max} = M_0 \cdot \phi_m$

$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$

$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$

$M(x) = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	7656 kN/m³
calculated value	β	=	0.19216 m⁻¹
resultant earth force (lateral)	P_0	=	217.86 kN/m

height of acting position of load	h_0	=	2.70	m
moment	M_0	=	587.75	kN･m/m
in consideration of ψ_m = 1.387,				
maximum moment	M_{max}	=	814.93	kN･m/m
depth of generated position of M_{max}	l_m	=	2.375	m
depth of 1st fixed point	l_i	=	6.462	m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	16147	kN/m³
calculated value	β	=	0.23158	m⁻¹
resultant earth force (lateral)	P_0	=	479.95	kN/m
height of acting position of load	h_0	=	3.24	m
moment	M_0	=	1555.66	kN･m/m
in consideration of ψ_m = 1.227,				
maximum moment	M_{max}	=	1908.29	kN･m/m
depth of generated position of M_{max}	l_m	=	1.642	m
depth of 1st fixed point	l_i	=	5.034	m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 1000 -250 -16 -25 -18		
Corrosion margin	t_1 = 1.00 mm (active side)	t_2 = 1.00 mm (passive side)	
Corrosion rate	η = 0.89		
Section efficiency	μ = 1.00		
Module of section	Z_0 = 11980 cm³ (original condition)		
	Z = 10662 cm³ (after reduction by corrosion and section)		

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{814.93\times10^6}{10662\times10^3} = 76\ N/mm^2 \leqq \sigma_a = 180\ N/mm^2$$

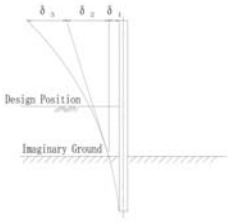
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1908.29\times10^6}{10662\times10^3} = 179\ N/mm^2 \leqq \sigma_a = 270\ N/mm^2$$

6.4 Displacement Calculation

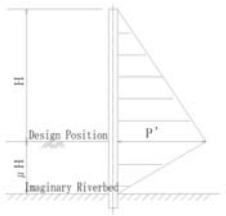
6.4.1 Normal Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.1922\times2.70)\times217.86}{2\times2.00\times10^8\times701829\times10^{-8}\times0.1922^3} = 0.01661\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.1922\times2.70)\times217.86}{2\times2.00\times10^8\times701829\times10^{-8}\times0.1922^2}\times(3.42+0.94) = 0.01867\ m$$



$$\mu = \frac{L_k}{H} = \frac{0.94}{3.42} = 0.276$$

$$\delta_3 = \frac{P'H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{99.88\times3.42^4}{120\times2.00\times10^8\times701829\times10^{-8}}(4+20\times0.276+40\times0.276^2+35\times0.276^3+11\times0.276^4)$$

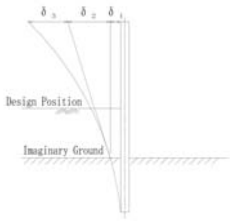
$$= 0.00108\ m$$

$\delta = \delta1 + \delta2 + \delta3$
= 0.01661 + 0.01867 + 0.00108
= 0.03636 m
Size = 36.36 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

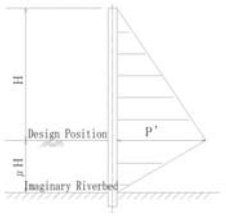
6.4.2 Seismic Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.2316\times3.24)\times479.95}{2\times2.00\times10^8\times701829\times10^{-8}\times0.2316^3} = 0.02410\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.2316\times3.24)\times479.95}{2\times2.00\times10^8\times701829\times10^{-8}\times0.2316^2}\times(3.42+1.99) = 0.04314\ m$$



$$\mu = \frac{L_k}{H} = \frac{1.99}{3.42} = 0.582$$

$$\delta_3 = \frac{P'H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{177.43\times3.42^4}{120\times2.00\times10^8\times701829\times10^{-8}}(4+20\times0.582+40\times0.582^2+35\times0.582^3+11\times0.582^4)$$

$$= 0.00538\ m$$

$\delta = \delta1 + \delta2 + \delta3$
= 0.02410 + 0.04314 + 0.00538
= 0.07262 m
Size = 72.62 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name	10 H _ H 1000 -250 -16 -25 -18		
Unit width	B = 1.0000 m		
Corrosion rate	η = 1.00		
Section efficiency	μ = 1.00		
Young's modulus	E = 200000 N/mm²		
Inertia sectional moment	I_0 = 806700 cm⁴ (original condition)		
	I = 806700 cm⁴ (after reduction by corrosion and section)		
EI = 200000 × 10³ × 806700 × 10⁻⁸	= 1.613 × 10⁶		

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h\cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction	K_h	=	7656 kN/m³
Calculated value	β	=	0.18559 m⁻¹
Penetration length of SSP	D	=	0.94 + 3 / 0.186 = 17.11 m
Whole length of SSP	L	=	3.42 − 0.40 + 17.11 = 20.13 m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction / Calculated value: $K_h = 16147\ kN/m^3$, $\beta = 0.22365\ m^{-1}$

Penetration length of SSP: $D = 1.99 + \frac{3}{0.224} = 15.40\ m$

Whole length of SSP: $L = 3.42 - 0.40 + 15.40 = 18.42\ m$

Therefore, the total length of the sheet pile is 20.50 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile 10H 1000 -250 -16 -25 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	806700		
Sectional Modulus	Z (cm3)	11980		
Maximum bending moment	Mmax (kN・m・m)		814.93	1908.29
Stress intensity	σ (N/mm2)		76 (180)	179 (270)
Lateral displacement	δ (mm)		36.36 (50.0)	72.62 (75.0)
Penetration depths	D (m)		17.11	15.40
Whole length of SSP	L (m)	20.50		

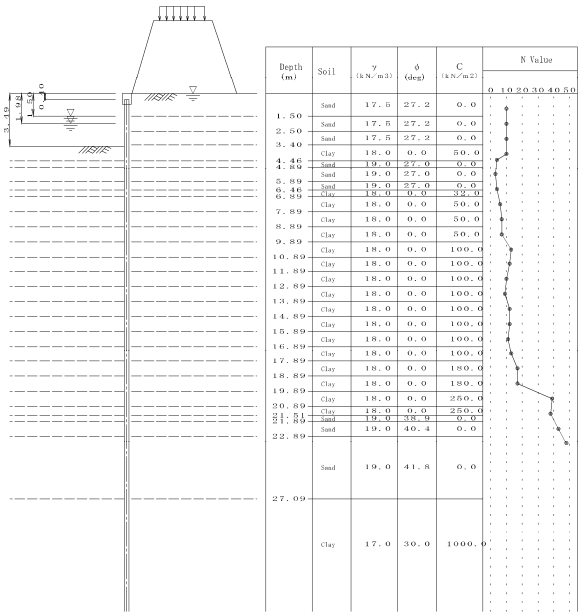
Block No. : L-6
Sta. : 7+480~7+820

Design Cross Section : Sta 7+520
Boring Name : DD-BH-L03

Specification : SSP SP-10H
(Combined) : H 1000-250-16-25-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	3.49 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_h	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	1.98 m (Normal Condition)
	L_{wp}'	=	1.50 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress: Chang's formula

Penetration depths: $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water: $\gamma_w = 9.8\ kN/m^3$

Type of water pressure: trapezoidal water pressure

Lateral pressure: calculated in consideration of site conditions

Study case:
- Normal Condition
- Seismic Condition

Design earthquake intensity: k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load

Horizontal load	Pt	=	44.8 kN/m	(Normal Condition)
	Pt'	=	105.5 kN/m	(Seismic Condition)
Depth of acting point	Ht	=	0.0 m	(Normal Condition)
	Ht'	=	0.0 m	(Seismic Condition)
Moment	Mm	=	11.9 kN・m/m	(Normal Condition)
	Mm'	=	122.9 kN・m/m	(Seismic Condition)
Depth of acting point	Hm'	=	0.00 m	(Seismic Condition)
	Hm	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load: not considered

Minimum angle of rupture: $\zeta_0 = 10$ degrees

Rear side angle of slope: not considered

Angle of rupture (clayey soil): $\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C} \cdot \tan\theta}$

Equilibrium factor of compression: $K_c = 0.50$ (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$B_H = 10.00$ m
$E_0 = 2800$N

Average N-value: calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value
1	1.00	10	11	10.39	13	21	20.39	39
2	2.00	10	12	11.39	12	22	21.39	38
3	3.00	10	13	12.39	10	23	22.39	43
4	4.00	10	14	13.39	9	24	23.39	48
5	4.39	4	15	14.39	12			
6	5.39	3	16	15.39	12			
7	6.39	4	17	16.39	11			
8	7.39	6	18	17.39	13			
9	8.39	7	19	18.39	17			
10	9.39	7	20	19.39	17			

1.6 Vertical Load

Vertical load on landside　　calculated in consideration of embankment shape on landside

Vertical load on riverside　　not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	1.50	1.50
2	2.50	1.00
3	3.40	0.90
4	4.46	1.06
5	4.89	0.43
6	5.89	1.00
7	6.46	0.57
8	6.89	0.43
9	7.89	1.00
10	8.89	1.00
11	9.89	1.00
12	10.89	1.00
13	11.89	1.00
14	12.89	1.00
15	13.89	1.00
16	14.89	1.00
17	15.89	1.00
18	16.89	1.00
19	17.89	1.00
20	18.89	1.00
21	19.89	1.00
22	20.89	1.00
23	21.51	0.62
24	21.89	0.38
25	22.89	1.00
26	27.09	4.20
27	33.20	6.11

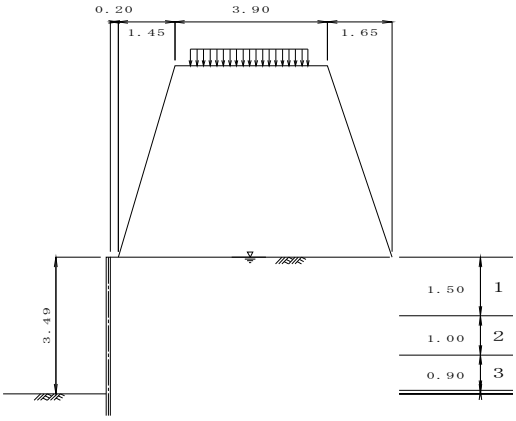
No	Depth m	earth Soil	N Value	γ kN/m3	γ ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	1.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
2	2.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
3	3.40	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
4	4.46	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
5	4.89	S	4.0	19.00	9.20	27.0	0.0	0.0	0.200	Auto	Auto
6	5.89	S	3.0	19.00	9.20	27.0	0.0	0.0	0.200	Auto	Auto
7	6.46	S	4.0	19.00	9.20	27.0	0.0	0.0	0.200	Auto	Auto
8	6.89	C	4.0	18.00	8.20	0.0	32.0	0.0	0.200	Auto	Auto
9	7.89	C	5.5	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
10	8.89	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
11	9.89	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
12	10.89	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
13	11.89	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
14	12.89	C	10.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
15	13.89	C	9.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
16	14.89	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
17	15.89	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
18	16.89	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
19	17.89	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
20	18.89	C	17.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
21	19.89	C	17.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
22	20.89	C	39.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
23	21.51	C	38.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
24	21.89	S	38.0	19.00	9.20	38.9	0.0	0.0	0.200	Auto	Auto
25	22.89	S	43.0	19.00	9.20	40.4	0.0	0.0	0.200	Auto	Auto
26	27.09	S	48.0	19.00	9.20	41.8	0.0	0.0	0.200	Auto	Auto
27	33.20	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note)　depth : from top of coping to bottom of the layer　　C_o : soil adhesion
soil : sandy(S), clayey(C), mixed (M)　　a : slope of soil adhesion
N-value : average N-value in the layer　　k' : design seismic coefficient (underwater)
γ : wet unit weight of soil　　ζ : angle of active rupture
γ' : saturated unit weight of soil　　kh : modulus of subgrade reaction
φ : internal friction angle of soil

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	0.20	1.65	5.55	7.20	4.90	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	End point m	load strength Normal Condition kN/m2	Seismic Condition kN/m2
1	2.05	5.05	10.0	5.0

Angle of rapture in embankment　　calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name　　10 H _ H 1000 -250 -16 -25 -18
Young's modulus　　E = 200000 N/mm^2
Inertia sectional moment　　I_0 = 806700 cm^4
Sectional factor　　Z_0 = 11980 cm^3

Corrosion margin　　t_1 = 1.00 mm (riverside)　　t_2 = 1.00 mm (landside)

Corrosion rate (to I_0)　　η = 0.87
Corrosion rate (to Z_0)　　η = 0.89
Section efficiency (to I_0)　　μ = 1.00
Section efficiency (to Z_0)　　μ = 1.00

Round unit of SSP length　　0.50 m

Allowable stress　　σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

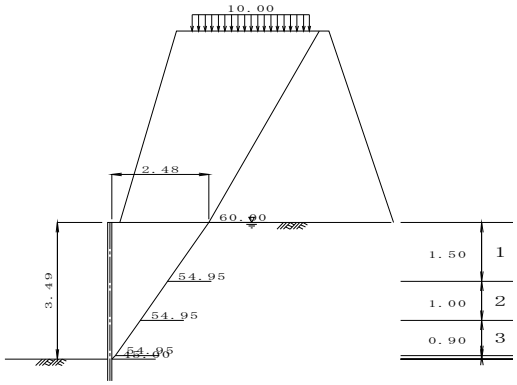
Allowable displacement　　δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam　　calculated as distributed load of each layer

Reduction of material modulus　　Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γ wbw kN/m2	Angle of Rupture ζ degree
1	3.49 ~ 3.40	Clay	0.0	15.0	50.0	26.92	123.63	34.20	45.00
2	3.40 ~ 2.50	Sand	27.2	15.0	0.0	26.18	123.63	33.32	54.95
3	2.50 ~ 1.50	Sand	27.2	15.0	0.0	19.25	123.63	24.50	54.95
4	1.50 ~ 0.00	Sand	27.2	15.0	0.0	11.55	123.63	14.70	54.95
5		embankment	30.0	———	0.0	93.10	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,
ζ : angle of active rupture (degree, ζ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan^{-1}k or θ = tan^{-1}k'
γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m^2)
C : cohesive force of soil (kN/m^2)

2.1.2 Coordinates of the major collapse line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	45.00	0.09	0.00	0.00	0.09	0.09
2	54.95	0.90	0.09	0.09	0.72	0.99
3	54.95	1.00	0.72	0.99	1.42	1.99
4	54.95	1.50	1.42	1.99	2.48	3.49
5	60.00	4.90	2.48	3.49	5.30	8.39

From the above table, the loading width (L) on the ground surface is 2.48 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	14.53	276.01
Σ			276.01

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	3.00	30.00
Σ			30.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

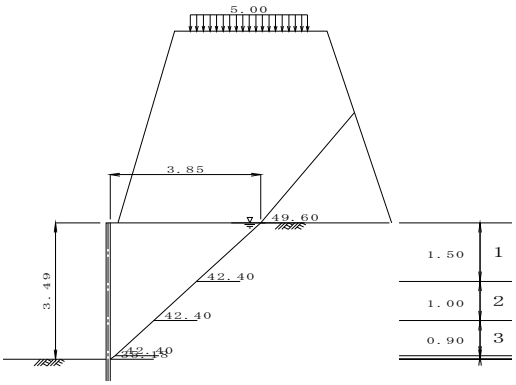
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{276.01 + 30.00 + 0.00}{2.48}$$

$$= 123.63 \ kN/m^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	3.49 ~ 3.40	Clay	0.0	15.0	50.0	26.92	112.35	34.20	0.200	11.31	35.18
2	3.40 ~ 2.50	Sand	27.2	15.0	0.0	26.18	112.35	33.32	0.200	11.31	42.40
3	2.50 ~ 1.50	Sand	27.2	15.0	0.0	19.25	112.35	24.50	0.200	11.31	42.40
4	1.50 ~ 0.00	Sand	27.2	15.0	0.0	11.55	112.35	14.70	0.200	11.31	42.40
5		embankment	30.0	——	0.0	93.10	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C : cohesive force of soil (kN/m²)

2.2.2 Coordinates of the major collapse line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	35.18	0.09	0.00	0.00	0.13	0.09
2	42.40	0.90	0.13	0.09	1.11	0.99
3	42.40	1.00	1.11	0.99	2.21	1.99
4	42.40	1.50	2.21	1.99	3.85	3.49
5	49.60	2.82	3.85	3.49	6.25	6.31

From the above table, the loading width (L) on the ground surface is 3.85 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	21.98	417.69
Σ			417.69

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.00	15.00
Σ			15.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

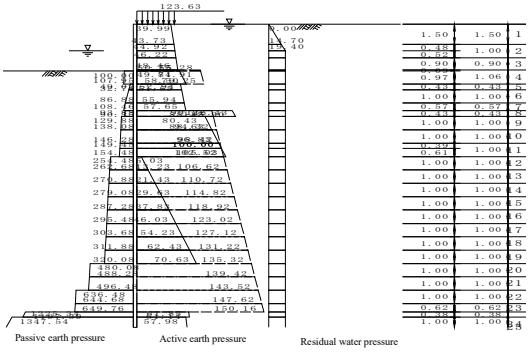
$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{417.69 + 15.00 + 0.00}{3.85}$$

$$= 112.35 \ kN/m^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 1.50	Sand	7.7	27.2	—— ——	123.632 135.182	0.33489 0.33489	0.32348 0.32348
2	1.50~ 1.98	Sand	7.7	27.2	—— ——	135.182 138.878	0.33489 0.33489	0.32348 0.32348
3	1.98~ 2.50	Sand	7.7	27.2	—— ——	138.878 142.882	0.33489 0.33489	0.32348 0.32348
4	2.50~ 3.40	Sand	7.7	27.2	—— ——	142.882 149.813	0.33489 0.33489	0.32348 0.32348
5	3.40~ 3.49	Clay	8.2	——	50.0 50.0	149.813 150.551	—— ——	—— ——
6	3.49~ 4.46	Clay	8.2	——	50.0 50.0	150.551 158.505	—— ——	—— ——
7	4.46~ 4.89	Sand	9.2	27.0	—— ——	158.505 162.460	0.33738 0.33738	0.32589 0.32589
8	4.89~ 5.89	Sand	9.2	27.0	—— ——	162.460 171.660	0.33738 0.33738	0.32589 0.32589
9	5.89~ 6.46	Sand	9.2	27.0	—— ——	171.660 176.904	0.33738 0.33738	0.32589 0.32589
10	6.46~ 6.89	Clay	8.2	——	32.0 32.0	176.904 180.430	—— ——	—— ——
11	6.89~ 7.89	Clay	8.2	——	50.0 50.0	180.430 188.630	—— ——	—— ——
12	7.89~ 8.89	Clay	8.2	——	50.0 50.0	188.630 196.830	—— ——	—— ——
13	8.89~ 9.28	Clay	8.2	——	50.0 50.0	196.830 200.000	—— ——	—— ——
14	9.28~ 9.89	Clay	8.2	——	50.0 50.0	200.000 205.030	—— ——	—— ——
15	9.89~ 10.89	Clay	8.2	——	100.0 100.0	205.030 213.230	—— ——	—— ——
16	10.89~ 11.89	Clay	8.2	——	100.0 100.0	213.230 221.430	—— ——	—— ——
17	11.89~ 12.89	Clay	8.2	——	100.0 100.0	221.430 229.630	—— ——	—— ——
18	12.89~ 13.89	Clay	8.2	——	100.0 100.0	229.630 237.830	—— ——	—— ——
19	13.89~ 14.89	Clay	8.2	——	100.0 100.0	237.830 246.030	—— ——	—— ——
20	14.89~ 15.89	Clay	8.2	——	100.0 100.0	246.030 254.230	—— ——	—— ——
21	15.89~ 16.89	Clay	8.2	——	100.0 100.0	254.230 262.430	—— ——	—— ——
22	16.89~ 17.89	Clay	8.2	——	100.0 100.0	262.430 270.630	—— ——	—— ——
23	17.89~ 18.89	Clay	8.2	——	180.0 180.0	270.630 278.830	—— ——	—— ——
24	18.89~ 19.89	Clay	8.2	——	180.0 180.0	278.830 287.030	—— ——	—— ——
25	19.89~ 20.89	Clay	8.2	——	250.0 250.0	287.030 295.230	—— ——	—— ——

26	20.89~ 21.51	Clay	8.2	———	250.0 250.0	295.230 300.315	———	———
27	21.51~ 21.89	Sand	9.2	38.9	——— ———	300.315 303.811	0.21078 0.21078	0.20360 0.20360
28	21.89~ 22.89	Sand	9.2	40.4	——— ———	303.811 313.011	0.19759 0.19759	0.19085 0.19085
29	22.89~ 27.09	Sand	9.2	41.8	——— ———	313.011 351.651	0.18576 0.18576	0.17943 0.17943
30	27.09~ 33.20	Clay	7.2	———	1000.0 1000.0	351.651 395.643	———	———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
6	3.49~ 4.46	Clay	8.2	0.0	50.0 50.0	0.000 7.954	———	———
7	4.46~ 4.89	Sand	9.2	27.0	——— ———	7.954 11.910	4.26080 4.26080	4.11561 4.11561
8	4.89~ 5.89	Sand	9.2	27.0	———	11.910 21.110	4.26080 4.26080	4.11561 4.11561
9	5.89~ 6.46	Sand	9.2	27.0	——— ———	21.110 26.354	4.26080 4.26080	4.11561 4.11561
10	6.46~ 6.89	Clay	8.2	0.0	32.0 32.0	26.354 29.880	———	———
11	6.89~ 7.89	Clay	8.2	0.0	50.0 50.0	29.880 38.080	———	———
12	7.89~ 8.89	Clay	8.2	0.0	50.0 50.0	38.080 46.280	———	———
13	8.89~ 9.28	Clay	8.2	0.0	50.0 50.0	46.280 49.450	———	———
14	9.28~ 9.89	Clay	8.2	0.0	50.0 50.0	49.450 54.480	———	———
15	9.89~ 10.89	Clay	8.2	0.0	100.0 100.0	54.480 62.680	———	———
16	10.89~ 11.89	Clay	8.2	0.0	100.0 100.0	62.680 70.880	———	———
17	11.89~ 12.89	Clay	8.2	0.0	100.0 100.0	70.880 79.080	———	———
18	12.89~ 13.89	Clay	8.2	0.0	100.0 100.0	79.080 87.280	———	———
19	13.89~ 14.89	Clay	8.2	0.0	100.0 100.0	87.280 95.480	———	———
20	14.89~ 15.89	Clay	8.2	0.0	100.0 100.0	95.480 103.680	———	———
21	15.89~ 16.89	Clay	8.2	0.0	100.0 100.0	103.680 111.880	———	———
22	16.89~ 17.89	Clay	8.2	0.0	100.0 100.0	111.880 120.080	———	———
23	17.89~ 18.89	Clay	8.2	0.0	180.0 180.0	120.080 128.280	———	———
24	18.89~ 19.89	Clay	8.2	0.0	180.0 180.0	128.280 136.480	———	———
25	19.89~ 20.89	Clay	8.2	0.0	250.0 250.0	136.480 144.680	———	———
26	20.89~ 21.51	Clay	8.2	0.0	250.0 250.0	144.680 149.764	———	———
27	21.51~ 21.89	Sand	9.2	38.9	——— ———	149.764 153.260	8.27722 8.27722	7.99518 7.99518
28	21.89~ 22.89	Sand	9.2	40.4	——— ———	153.260 162.460	9.10266 9.10266	8.79250 8.79250
29	22.89~ 27.09	Sand	9.2	41.8	——— ———	162.460 201.100	9.97786 9.97786	9.63787 9.63787
30	27.09~ 33.20	Clay	7.2	30.0	1000.0 1000.0	201.100 245.092	———	———

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.50	39.99 43.73	——— ———	39.99 43.73	0.00 14.70	——— ———
2	1.50~ 1.98	43.73 44.92	——— ———	43.73 44.92	14.70 19.40	——— ———
3	1.98~ 2.50	44.92 46.22	——— ———	44.92 46.22	19.40 19.40	——— ———
4	2.50~ 3.40	46.22 48.46	——— ———	46.22 48.46	19.40 19.40	———
5	3.40~ 3.49	49.81 50.55	74.91 75.28	74.91 75.28	19.40 19.40	——— ———
6	3.49~ 4.46	50.55 58.50	75.28 79.25	75.28 79.25	19.40 19.40	100.00 107.95
7	4.46~ 4.89	51.65 52.94	——— ———	51.65 52.94	19.40 19.40	32.74 49.02
8	4.89~ 5.89	52.94 55.94	——— ———	52.94 55.94	19.40 19.40	49.02 86.88
9	5.89~ 6.46	55.94 57.65	——— ———	55.94 57.65	19.40 19.40	86.88 108.46
10	6.46~ 6.89	112.90 116.43	88.45 90.22	112.90 116.43	19.40 19.40	90.35 93.88
11	6.89~ 7.89	80.43 88.63	90.22 94.32	90.22 94.32	19.40 19.40	129.88 138.08
12	7.89~ 8.89	88.63 96.83	94.32 98.42	94.32 98.42	19.40 19.40	138.08 146.28
13	8.89~ 9.28	96.83 100.00	98.42 100.00	98.42 100.00	19.40 19.40	146.28 149.45
14	9.28~ 9.89	100.00 105.03	100.00 102.52	100.00 105.03	19.40 19.40	149.45 154.48
15	9.89~ 10.89	5.03 13.23	102.52 106.62	102.52 106.62	19.40 19.40	254.48 262.68
16	10.89~ 11.89	13.23 21.43	106.62 110.72	106.62 110.72	19.40 19.40	262.68 270.88
17	11.89~ 12.89	21.43 29.63	110.72 114.82	110.72 114.82	19.40 19.40	270.88 279.08
18	12.89~ 13.89	29.63 37.83	114.82 118.92	114.82 118.92	19.40 19.40	279.08 287.28
19	13.89~ 14.89	37.83 46.03	118.92 123.02	118.92 123.02	19.40 19.40	287.28 295.48
20	14.89~ 15.89	46.03 54.23	123.02 127.12	123.02 127.12	19.40 19.40	295.48 303.68
21	15.89~ 16.89	54.23 62.43	127.12 131.22	127.12 131.22	19.40 19.40	303.68 311.88
22	16.89~ 17.89	62.43 70.63	131.22 135.32	131.22 135.32	19.40 19.40	311.88 320.08
23	17.89~ 18.89	-89.37 -81.17	135.32 139.42	135.32 139.42	19.40 19.40	480.08 488.28
24	18.89~ 19.89	-81.17 -72.97	139.42 143.52	139.42 143.52	19.40 19.40	488.28 496.48
25	19.89~ 20.89	-212.97 -204.77	143.52 147.62	143.52 147.62	19.40 19.40	636.48 644.68
26	20.89~ 21.51	-204.77 -199.69	147.62 150.16	147.62 150.16	19.40 19.40	644.68 649.76
27	21.51~ 21.89	61.14 61.85	——— ———	61.14 61.85	19.40 19.40	1197.39 1225.34
28	21.89~ 22.89	57.98 59.74	——— ———	57.98 59.74	19.40 19.40	1347.54 1428.43
29	22.89~ 27.09	56.16 63.10	——— ———	56.16 63.10	19.40 19.40	1565.77 1938.18
30	27.09~ 33.20	-1648.35 -1604.36	175.83 197.82	175.83 197.82	19.40 19.40	2201.10 2245.09

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

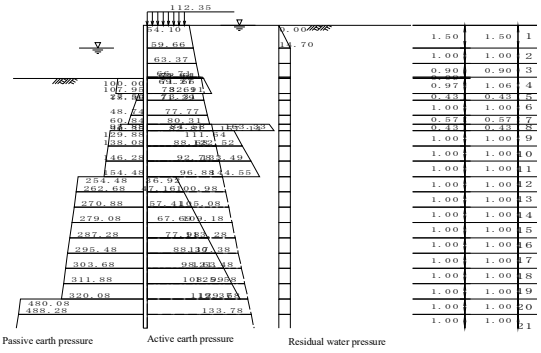
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cos δ	ζ degree
1	0.00~ 1.50	Sand	7.7	27.2	——— ———	112.36 123.91	0.00 14.70	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
2	1.50~ 2.50	Sand	7.7	27.2	———	123.91 131.61	14.70 24.50	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	———
3	2.50~ 3.40	Sand	7.7	27.2	———	131.61 138.54	24.50 33.32	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	———
4	3.40~ 3.49	Clay	8.2	———	50.0 50.0	138.54 139.27	33.32 34.20	0.200 0.200	11.31 11.31	——— ———	——— ———	35.22 35.18
5	3.49~ 4.46	Clay	8.2	———	50.0 50.0	139.27 147.23	34.20 43.71	0.200 0.200	11.31 11.31	——— ———	——— ———	35.18 34.74
6	4.46~ 4.89	Sand	9.2	27.0	——— ———	147.23 151.18	43.71 47.92	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	———
7	4.89~ 5.89	Sand	9.2	27.0	———	151.18 160.38	47.92 57.72	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	———
8	5.89~ 6.46	Sand	9.2	27.0	——— ———	160.38 165.63	57.72 63.31	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	———
9	6.46~ 6.89	Clay	8.2	———	32.0 32.0	165.63 169.15	63.31 67.52	0.200 0.200	11.31 11.31	——— ———	——— ———	19.92 19.13
10	6.89~ 7.89	Clay	8.2	———	50.0 50.0	169.15 177.35	67.52 77.32	0.200 0.200	11.31 11.31	——— ———	——— ———	33.47 32.96
11	7.89~ 8.89	Clay	8.2	———	50.0 50.0	177.35 185.55	77.32 87.12	0.200 0.200	11.31 11.31	——— ———	——— ———	32.96 32.45
12	8.89~ 9.89	Clay	8.2	———	50.0 50.0	185.55 193.75	87.12 96.92	0.200 0.200	11.31 11.31	——— ———	——— ———	32.45 31.91

13	9.89~ 10.89	Clay	8.2	——	100.0 100.0	193.75 201.95	96.92 106.72	0.200 0.200	11.31 11.31	—— ——	—— ——	39.79 39.63
14	10.89~ 11.89	Clay	8.2	——	100.0 100.0	201.95 210.15	106.72 116.52	0.200 0.200	11.31 11.31	—— ——	—— ——	39.63 39.46
15	11.89~ 12.89	Clay	8.2	——	100.0 100.0	210.15 218.35	116.52 126.32	0.200 0.200	11.31 11.31	—— ——	—— ——	39.46 39.29
16	12.89~ 13.89	Clay	8.2	——	100.0 100.0	218.35 226.55	126.32 136.12	0.200 0.200	11.31 11.31	—— ——	—— ——	39.29 39.11
17	13.89~ 14.89	Clay	8.2	——	100.0 100.0	226.55 234.75	136.12 145.92	0.200 0.200	11.31 11.31	—— ——	—— ——	39.11 38.94
18	14.89~ 15.89	Clay	8.2	——	100.0 100.0	234.75 242.95	145.92 155.72	0.200 0.200	11.31 11.31	—— ——	—— ——	38.94 38.76
19	15.89~ 16.89	Clay	8.2	——	100.0 100.0	242.95 251.15	155.72 165.52	0.200 0.200	11.31 11.31	—— ——	—— ——	38.76 38.58
20	16.89~ 17.89	Clay	8.2	——	100.0 100.0	251.15 259.35	165.52 175.32	0.200 0.200	11.31 11.31	—— ——	—— ——	38.58 38.40
21	17.89~ 18.89	Clay	8.2	——	180.0 180.0	259.35 267.55	175.32 185.12	0.200 0.200	11.31 11.31	—— ——	—— ——	41.69 41.61
22	18.89~ 19.89	Clay	8.2	——	180.0 180.0	267.55 275.75	185.12 194.92	0.200 0.200	11.31 11.31	—— ——	—— ——	41.61 41.53
23	19.89~ 20.89	Clay	8.2	——	250.0 250.0	275.75 283.95	194.92 204.72	0.200 0.200	11.31 11.31	—— ——	—— ——	42.59 42.53
24	20.89~ 21.51	Clay	8.2	——	250.0 250.0	283.95 289.04	204.72 210.80	0.200 0.200	11.31 11.31	—— ——	—— ——	42.53 42.50
25	21.51~ 21.89	Sand	9.2	38.9	—— ——	289.04 292.53	210.80 214.52	0.200 0.200	11.31 11.31	0.32979 0.32979	0.31855 0.31855	—— ——
26	21.89~ 22.89	Sand	9.2	40.4	—— ——	292.53 301.73	214.52 224.32	0.200 0.200	11.31 11.31	0.31219 0.31219	0.30155 0.30155	—— ——
27	22.89~ 27.09	Sand	9.2	41.8	—— ——	301.73 340.37	224.32 265.48	0.200 0.200	11.31 11.31	0.29641 0.29641	0.28631 0.28631	—— ——
28	27.09~ 33.20	Clay	7.2	——	1000.0 1000.0	340.37 384.37	265.48 325.36	0.200 0.200	11.31 11.31	—— ——	—— ——	44.34 44.27

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cos δ
5	3.49~ 4.46	Clay	8.20	0.0	50.0 50.0	0.000 7.954	0.00 9.51	0.200 0.200	11.31 11.31	—— ——	—— ——
6	4.46~ 4.89	Sand	9.20	27.0	—— ——	7.954 11.910	9.51 13.72	0.200 0.200	11.31 11.31	2.30874 2.30874	2.30874 2.30874

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.50	54.10 59.66	—— ——	54.10 59.66	0.00 14.70	—— ——
2	1.50~ 2.50	59.66 63.37	—— ——	59.66 63.37	14.70 14.70	—— ——
3	2.50~ 3.40	63.37 66.71	—— ——	63.37 66.71	14.70 14.70	—— ——
4	3.40~ 3.49	71.66 72.61	69.27 69.64	71.66 72.61	14.70 14.70	—— ——
5	3.49~ 4.46	72.61 82.91	69.64 73.61	72.61 82.91	14.70 14.70	100.00 107.95
6	4.46~ 4.89	71.39 73.31	—— ——	71.39 73.31	14.70 14.70	18.36 27.50
7	4.89~ 5.89	73.31 77.77	—— ——	73.31 77.77	14.70 14.70	27.50 48.74
8	5.89~ 6.46	77.77 80.31	—— ——	77.77 80.31	14.70 14.70	48.74 60.84
9	6.46~ 6.89	157.14 163.33	82.81 84.58	157.14 163.33	14.70 14.70	90.35 93.88
10	6.89~ 7.89	111.64 122.52	84.58 88.68	111.64 122.52	14.70 14.70	129.88 138.08
11	7.89~ 8.89	122.52 133.49	88.68 92.78	122.52 133.49	14.70 14.70	138.08 146.28
12	8.89~ 9.89	133.49 144.55	92.78 96.88	133.49 144.55	14.70 14.70	146.28 154.48
13	9.89~ 10.89	36.92 47.16	96.88 100.98	96.88 100.98	14.70 14.70	254.48 262.68
14	10.89~ 11.89	47.16 57.41	100.98 105.08	100.98 105.08	14.70 14.70	262.68 270.88
15	11.89~ 12.89	57.41 67.69	105.08 109.18	105.08 109.18	14.70 14.70	270.88 279.08
16	12.89~ 13.89	67.69 77.98	109.18 113.28	109.18 113.28	14.70 14.70	279.08 287.28
17	13.89~ 14.89	77.98 88.30	113.28 117.38	113.28 117.38	14.70 14.70	287.28 295.48
18	14.89~ 15.89	88.30 98.63	117.38 121.48	117.38 121.48	14.70 14.70	295.48 303.68
19	15.89~ 16.89	98.63 108.99	121.48 125.58	121.48 125.58	14.70 14.70	303.68 311.88
20	16.89~ 17.89	108.99 119.37	125.58 129.68	125.58 129.68	14.70 14.70	311.88 320.08
21	17.89~ 18.89	-44.83 -34.74	129.68 133.78	129.68 133.78	14.70 14.70	480.08 488.28
22	18.89~ 19.89	-34.74 -24.63	133.78 137.88	133.78 137.88	14.70 14.70	488.28 496.48
23	19.89~ 20.89	-166.02 -156.00	137.88 141.98	137.88 141.98	14.70 14.70	636.48 644.68
24	20.89~ 21.51	-156.00 -149.79	141.98 144.52	141.98 144.52	14.70 14.70	644.68 649.76

7	4.89~ 5.89	Sand	9.20	27.0	—— ——	11.910 21.110	13.72 23.52	0.200 0.200	11.31 11.31	2.30874 2.30874	2.30874 2.30874
8	5.89~ 6.46	Sand	9.20	27.0	—— ——	21.110 26.354	23.52 29.11	0.200 0.200	11.31 11.31	2.30874 2.30874	2.30874 2.30874
9	6.46~ 6.89	Clay	8.20	0.0	32.0 32.0	26.354 29.880	29.11 33.32	0.200 0.200	11.31 11.31	—— ——	—— ——
10	6.89~ 7.89	Clay	8.20	0.0	50.0 50.0	29.880 38.080	33.32 43.12	0.200 0.200	11.31 11.31	—— ——	—— ——
11	7.89~ 8.89	Clay	8.20	0.0	50.0 50.0	38.080 46.280	43.12 52.92	0.200 0.200	11.31 11.31	—— ——	—— ——
12	8.89~ 9.89	Clay	8.20	0.0	50.0 50.0	46.280 54.480	52.92 62.72	0.200 0.200	11.31 11.31	—— ——	—— ——
13	9.89~ 10.89	Clay	8.20	0.0	100.0 100.0	54.480 62.680	62.72 72.52	0.200 0.200	11.31 11.31	—— ——	—— ——
14	10.89~ 11.89	Clay	8.20	0.0	100.0 100.0	62.680 70.880	72.52 82.32	0.200 0.200	11.31 11.31	—— ——	—— ——
15	11.89~ 12.89	Clay	8.20	0.0	100.0 100.0	70.880 79.080	82.32 92.12	0.200 0.200	11.31 11.31	—— ——	—— ——
16	12.89~ 13.89	Clay	8.20	0.0	100.0 100.0	79.080 87.280	92.12 101.92	0.200 0.200	11.31 11.31	—— ——	—— ——
17	13.89~ 14.89	Clay	8.20	0.0	100.0 100.0	87.280 95.480	101.92 111.72	0.200 0.200	11.31 11.31	—— ——	—— ——
18	14.89~ 15.89	Clay	8.20	0.0	100.0 100.0	95.480 103.680	111.72 121.52	0.200 0.200	11.31 11.31	—— ——	—— ——
19	15.89~ 16.89	Clay	8.20	0.0	100.0 100.0	103.680 111.880	121.52 131.32	0.200 0.200	11.31 11.31	—— ——	—— ——
20	16.89~ 17.89	Clay	8.20	0.0	100.0 100.0	111.880 120.080	131.32 141.12	0.200 0.200	11.31 11.31	—— ——	—— ——
21	17.89~ 18.89	Clay	8.20	0.0	180.0 180.0	120.080 128.280	141.12 150.92	0.200 0.200	11.31 11.31	—— ——	—— ——
22	18.89~ 19.89	Clay	8.20	0.0	180.0 180.0	128.280 136.480	150.92 160.72	0.200 0.200	11.31 11.31	—— ——	—— ——
23	19.89~ 20.89	Clay	8.20	0.0	250.0 250.0	136.480 144.680	160.72 170.52	0.200 0.200	11.31 11.31	—— ——	—— ——
24	20.89~ 21.51	Clay	8.20	0.0	250.0 250.0	144.680 149.764	170.52 176.60	0.200 0.200	11.31 11.31	—— ——	—— ——
25	21.51~ 21.89	Sand	9.20	38.9	—— ——	149.764 153.260	176.60 180.32	0.200 0.200	11.31 11.31	3.93917 3.93917	3.93917 3.93917
26	21.89~ 22.89	Sand	9.20	40.4	—— ——	153.260 162.460	180.32 190.12	0.200 0.200	11.31 11.31	4.23335 4.23335	4.23335 4.23335
27	22.89~ 27.09	Sand	9.20	41.8	—— ——	162.460 201.100	190.12 231.28	0.200 0.200	11.31 11.31	4.53352 4.53352	4.53352 4.53352
28	27.09~ 33.20	Clay	7.20	30.0	1000.0 1000.0	201.100 245.092	231.28 291.16	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

25	21.51~ 21.89	92.07 93.19	——	92.07 93.19	14.70 14.70	589.95 603.72
26	21.89~ 22.89	88.21 90.99	——	88.21 90.99	14.70 14.70	648.80 687.75
27	22.89~ 27.09	86.39 97.45	——	86.39 97.45	14.70 14.70	736.52 911.69
28	27.09~ 33.20	-1590.49 -1537.43	170.19 192.18	170.19 192.18	14.70 14.70	2201.10 2245.09

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.50	0.00	0.00
2	2.50	1.00	2.42
3	3.49	1.99	3.41

$$p_{dw} = \pm\frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

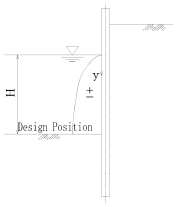
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

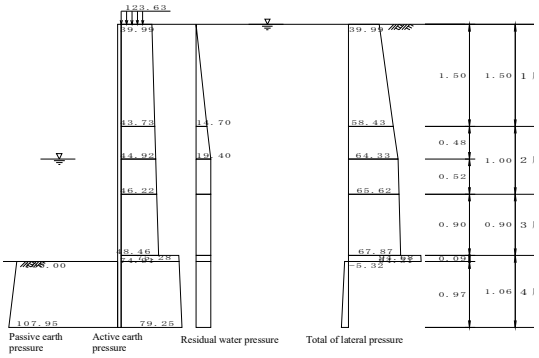
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition

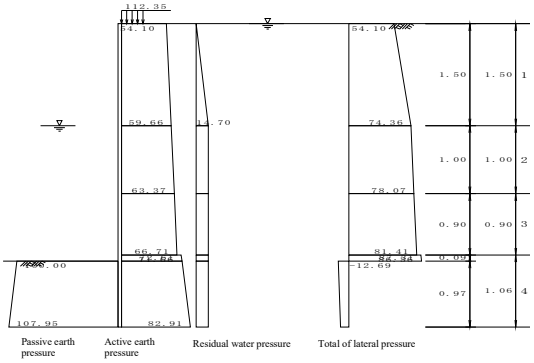


No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	39.99 43.73	0.00 14.70	——— ———	39.99 58.43
2	1.50~ 1.98	43.73 44.92	14.70 19.40	——— ———	58.43 64.33
3	1.98~ 2.50	44.92 46.22	19.40 19.40	——— ———	64.33 65.62
4	2.50~ 3.40	46.22 48.46	19.40 19.40	——— ———	65.62 67.87
5	3.40~ 3.49	74.91 75.28	19.40 19.40	——— ———	94.31 94.68
6	3.49~ 4.46	75.28 79.25	19.40 19.40	100.00 107.95	-5.32 -9.30

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -3.49 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	54.10 59.66	0.00 14.70	——— ———	54.10 74.36
2	1.50~ 2.50	59.66 63.37	14.70 14.70	——— ———	74.36 78.07
3	2.50~ 3.40	63.37 66.71	14.70 14.70	——— ———	78.07 81.41
4	3.40~ 3.49	71.66 72.61	14.70 14.70	——— ———	86.36 87.31
5	3.49~ 4.46	72.61 82.91	14.70 14.70	100.00 107.95	-12.69 -10.34

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -3.49 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_{II}}{0.3}\right)^{-3/4} \qquad (B_{II}=10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name 10 H _ H 1000 -250 -16 -25 -18
Unit width B = 1.0000 m
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.87
Section efficiency μ = 1.00
Young's modulus E = 200000 N/mm^2
Inertia sectional moment I_0 = 806700 cm^4(original condition)
I = 701829 cm^4(after reduction by corrosion and section)
Inertia sectional moment EI = $200000 \times 10^3 \times 701829 \times 10^{-8} = 1.404 \times 10^6$

No	Depth m	N Value
1	1.00	10
2	2.00	10
3	3.00	10
4	4.00	10
5	4.39	4
6	5.39	3
7	6.39	4
8	7.39	6
9	8.39	7
10	9.39	7

No	Depth m	N Value
11	10.39	13
12	11.39	12
13	12.39	10
14	13.39	9
15	14.39	12
16	15.39	12
17	16.39	11
18	17.39	13
19	18.39	17
20	19.39	17

No	Depth m	N Value
21	20.39	39
22	21.39	38
23	22.39	43
24	23.39	48

5.2 Normal Condition

Assuming Kh = 3866 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.162 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 6.17 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -3.49 m) to 6.17 m depth (GL -9.66 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	3.49	0.51	10.0	10.0	5.10
2	4.00	0.39	10.0	4.0	2.73
3	4.39	1.00	4.0	3.0	3.50
4	5.39	1.00	3.0	4.0	3.50
5	6.39	1.00	4.0	6.0	5.00
6	7.39	1.00	6.0	7.0	6.50
7	8.39	1.00	7.0	7.0	7.00
8	9.39	0.27	7.0	8.6	2.14
		L = Σh = 6.17		Σ A =	35.47

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{35.47}{6.17} = 5.75$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 5.75 = 16088 \text{ kN/m}^2$
$K_{h0} = \frac{1}{0.3} \times \alpha \times 16088 = 53626 \text{ kN/m}^3$ (α :Normal Condition =1, Seismi Condition =2)
$K_h = K_{h0}(B_{II}/0.3)^{-3/4} = 53626(10.00/0.3)^{-3/4} = 3866 \text{ kN/m}^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 3866 kN/m3.

5.3 Seismic Condition

Assuming Kh = 7377 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.190 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 5.25 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -3.49 m) and 5.25 m depth (GL -8.74 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	3.49	0.51	10.0	10.0	5.10
2	4.00	0.39	10.0	4.0	2.73
3	4.39	1.00	4.0	3.0	3.50
4	5.39	1.00	3.0	4.0	3.50
5	6.39	1.00	4.0	6.0	5.00
6	7.39	1.00	6.0	7.0	6.50
7	8.39	0.35	7.0	7.0	2.47
		L = Σh = 5.25		Σ A =	28.80

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{28.80}{5.25} = 5.48$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 5.48 = 15351$ kN/m²

$K_{h0} = \frac{1}{0.3} \times \alpha \times 15351 = 102342$ kN/m³ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_h/0.3)^{-3/4} = 102342(10.00/0.3)^{-3/4} = 7377$ kN/m³

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 7377 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	39.99 58.43	29.99 43.82	2.99 2.49	89.68 109.12
2	1.50~ 1.98	0.48	58.43 64.33	14.02 15.44	1.83 1.67	25.66 25.78
3	1.98~ 2.50	0.52	64.33 65.62	16.73 17.06	1.34 1.16	22.36 19.85
4	2.50~ 3.40	0.90	65.62 67.87	29.53 30.54	0.69 0.39	20.38 11.91
5	3.40~ 3.49	0.09	94.31 94.68	4.24 4.26	0.06 0.03	0.25 0.13
				ΣP = 205.64	ΣM = 325.12	

Ps : active earth pressure + residual water pressure - passive earth pressure
P : load Ps x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 44.8 kN/m
depth to acting position H_t = 0.0 m
moment M_m = 11.9 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 3.49 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m = 168.25$ kN・m

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{493.37}{250.44} = 1.97$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 250.44}{3.49} = 143.52$ kN/m

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	54.10 74.36	40.58 55.77	2.99 2.49	121.32 138.87
2	1.50~ 2.50	1.00	74.36 78.07	37.18 39.03	1.66 1.32	61.60 51.66
3	2.50~ 3.40	0.90	78.07 81.41	35.13 36.63	0.69 0.39	24.24 14.29
4	3.40~ 3.49	0.09	86.36 87.31	3.89 3.93	0.06 0.03	0.23 0.12
				ΣP = 252.14	ΣM = 412.32	

Ps : active earth pressure + residual water pressure - passive earth pressure
P : load Ps x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 105.5 kN/m
depth to acting position H_t = 0.00 m
moment M_m = 122.9 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 3.49 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m = 491.10$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	1.50~ 2.50	1.00	0.0 2.4	0.00 1.21	1.66 1.32	0.00 1.60
2	2.50~ 3.49	0.99	2.4 3.4	1.20 1.69	0.66 0.33	0.79 0.56
				ΣPdw = 4.10	ΣMdw = 2.95	

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{906.37}{361.74} = 2.51$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 361.74}{3.49} = 207.30$ kN/m

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name 10 H _ H 1000 -250 -16 -25 -18
Unit width B = 1.0000 m
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.87
Section efficiency μ = 1.00
Young's modulus E = 200000 N/mm²
Inertia sectional moment I_0 = 806700cm⁴ (original condition)
I = 701829 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 701829 × 10⁻⁸ = 1.404 × 10⁶

$\beta = 4\sqrt{\frac{K_h \cdot B}{4EI}}$

$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp(-\tan^{-1}\frac{1}{1+2\beta h_0})$

$M_{max} = M_0 \cdot \phi_m$

$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$

$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$

$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x}(\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$

6.2.1 Normal Condition

modulus of lateral subgrade reaction K_h = 3866 kN/m³
calculated value β = 0.16198 m⁻¹
resultant earth force (lateral) P_0 = 250.44 kN/m
height of acting position of load h_0 = 1.97 m
moment M_0 = 493.37 kN・m/m

in consideration of ψ_m = 1.738,
maximum moment M_{max} = 857.70 kN・m/m
depth of generated position of M_{max} l_m = 3.383 m
depth of 1st fixed point l_i = 8.232 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction K_h = 7377 kN/m³
calculated value β = 0.19039 m⁻¹
resultant earth force (lateral) P_0 = 361.74 kN/m
height of acting position of load h_0 = 2.51 m
moment M_0 = 906.37 kN・m/m

in consideration of ψ_m = 1.434,
maximum moment M_{max} = 1299.42 kN・m/m
depth of generated position of M_{max} l_m = 2.484 m
depth of 1st fixed point l_i = 6.610 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name 10 H _ H 1000 -250 -16 -25 -18
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.89
Section efficiency μ = 1.00
Module of section Z_0 = 11980 cm³ (original condition)
Z = 10662 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$\sigma = \frac{M_{max}}{Z} = \frac{857.70 \times 10^6}{10662 \times 10^3} = 80$ N/mm² ≦ σ_a = 180 N/mm²

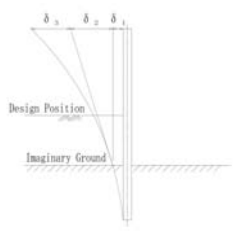
6.3.2 Seismic Condition

$\sigma = \frac{M_{max}}{Z} = \frac{1299.42 \times 10^6}{10662 \times 10^3} = 122$ N/mm² ≦ σ_a = 270 N/mm²

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation

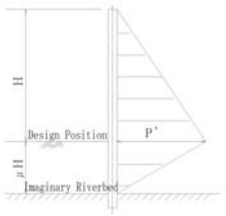


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.1620\times 1.97)\times 250.44}{2\times 2.00\times 10^8\times 701829\times 10^{-8}\times 0.1620^3} = 0.02769 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.1620\times 1.97)\times 250.44}{2\times 2.00\times 10^8\times 701829\times 10^{-8}\times 0.1620^2}\times(3.49+0.00) = 0.01944 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{3.49} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{143.52\times 3.49^4}{120\times 2.00\times 10^8\times 701829\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

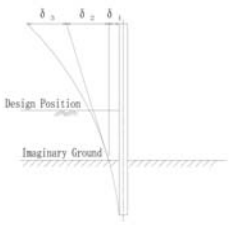
$$= 0.00051 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.02769 + 0.01944 + 0.00051
= 0.04763 m
Size = 47.63 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

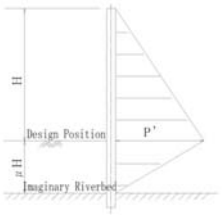


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.1904\times 2.51)\times 361.74}{2\times 2.00\times 10^8\times 701829\times 10^{-8}\times 0.1904^3} = 0.02758 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.1904\times 2.51)\times 361.74}{2\times 2.00\times 10^8\times 701829\times 10^{-8}\times 0.1904^2}\times(3.49+0.00) = 0.02424 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{3.49} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{207.30\times 3.49^4}{120\times 2.00\times 10^8\times 701829\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

$$= 0.00073 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.02758 + 0.02424 + 0.00073

= 0.05255 m
Size = 52.55 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name			10 H _ H 1000 -250 -16 -25 -18
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	806700 cm⁴ (original condition)
	I	=	806700 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 806700 × 10⁻⁸		=	1.613 × 10⁶

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_k + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 3866 kN/m³
Calculated value β = 0.15644 m⁻¹

Penetration length of SSP $D = 0.00 + \frac{3}{0.156} = 19.18$ m
Whole length of SSP $L = 3.49 - 0.40 + 19.18 = 22.27$ m

7.1.1 Seismic Condition

Modules of lateral subgrade reaction K_h = 7377 kN/m³
Calculated value β = 0.18388 m⁻¹

Penetration length of SSP $D = 0.00 + \frac{3}{0.184} = 16.32$ m
Whole length of SSP $L = 3.49 - 0.40 + 16.32 = 19.41$ m

Therefore, the total length of the sheet pile is 22.50 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile 10H 1000 -250 -16 -25 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	806700		
Sectional Modulus	Z (cm3)	11980		
Maximum bending moment	Mmax (kN・m・m)		857.70	1299.42
Stress intensity	σ (N/mm2)		80 (180)	122 (270)
Lateral displacement	δ (mm)		47.63 (50.0)	52.55 (75.0)
Penetration depths	D (m)		19.18	16.32
Whole length of SSP	L (m)	22.50		

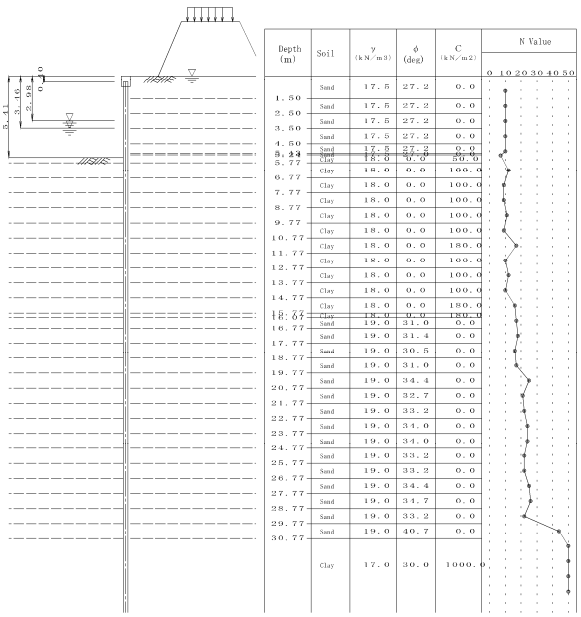
Block No. : L-7
Sta. : 7+820~7+940

Design Cross Section : Sta 7+860
Boring Name : DD-BH-L04

Specification : SSP SP-10H
（Combined） : H 1000-250-16-28-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.41 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_R	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.46 m (Normal Condition)
	L_{wp}'	=	2.98 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress Chang's formula

Penetration depths $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water γ_w = 9.8 kN/m³

Type of water pressure trapezoidal water pressure

Lateral pressure calculated in consideration of site conditions

Study case
- Normal Condition
- Seismic Condition

Design earthquake intensity k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	23.4 kN/m	(Normal Condition)
		Pt'	=	62.8 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	Mm	=	0.0 kN･m/m	(Normal Condition)
		Mm'	=	33.9 kN･m/m	(Seismic Condition)
	Depth of acting point	Hm'	=	0.00 m	(Seismic Condition)
		Hm	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load not considered

Minimum angle of rupture ζ_θ = 10 degrees

Rear side angle of slope not considered

Angle of rupture (clayey soil) $\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C} \cdot \tan\theta}$

Equilibrium factor of compression K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula $K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$

$K_{h0} = \frac{1}{0.3} \alpha E_0$ (α :Normal Condition =1, Seismi Condition =2)

B_H = 10.00 m

E_0 = 2800N

Average N-value calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value
1	1.00	10	11	10.27	9	21	20.27	25	31	30.27	44
2	2.00	10	12	11.27	17	22	21.27	21	32	31.27	50
3	3.00	10	13	12.27	10	23	22.27	22	33	32.27	50
4	4.00	10	14	13.27	12	24	23.27	24	34	33.27	50
5	5.00	10	15	14.27	10	25	24.27	24	35	34.27	50
6	5.27	7	16	15.27	16	26	25.27	22			
7	6.27	12	17	16.27	17	27	26.27	22			
8	7.27	9	18	17.27	18	28	27.27	25			
9	8.27	9	19	18.27	16	29	28.27	26			
10	9.27	11	20	19.27	17	30	29.27	22			

1.6 Vertical Load

Vertical load on landside calculated in consideration of embankment shape on landside

Vertical load on riverside not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	1.50	1.50
2	2.50	1.00
3	3.50	1.00
4	4.50	1.00
5	5.13	0.63
6	5.24	0.11
7	5.77	0.53
8	6.77	1.00
9	7.77	1.00
10	8.77	1.00
11	9.77	1.00
12	10.77	1.00
13	11.77	1.00
14	12.77	1.00
15	13.77	1.00
16	14.77	1.00
17	15.77	1.00
18	16.07	0.30
19	16.77	0.70
20	17.77	1.00
21	18.77	1.00
22	19.77	1.00
23	20.77	1.00
24	21.77	1.00
25	22.77	1.00
26	23.77	1.00
27	24.77	1.00
28	25.77	1.00
29	26.77	1.00
30	27.77	1.00
31	28.77	1.00
32	29.77	1.00
33	30.77	1.00
34	34.27	3.50

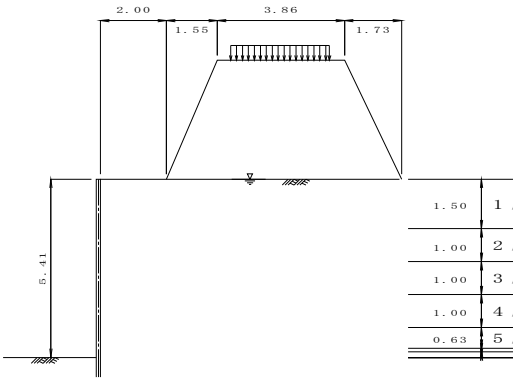
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	1.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
2	2.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
3	3.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
4	4.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
5	5.13	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
6	5.24	S	7.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
7	5.77	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
8	6.77	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
9	7.77	C	9.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
10	8.77	C	9.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
11	9.77	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
12	10.77	C	9.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
13	11.77	C	17.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
14	12.77	C	10.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
15	13.77	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
16	14.77	C	10.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
17	15.77	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
18	16.07	C	17.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
19	16.77	S	17.0	19.00	9.20	31.0	0.0	0.0	0.200	Auto	Auto
20	17.77	S	18.0	19.00	9.20	31.4	0.0	0.0	0.200	Auto	Auto
21	18.77	S	16.0	19.00	9.20	30.5	0.0	0.0	0.200	Auto	Auto
22	19.77	S	17.0	19.00	9.20	31.0	0.0	0.0	0.200	Auto	Auto
23	20.77	S	25.0	19.00	9.20	34.4	0.0	0.0	0.200	Auto	Auto
24	21.77	S	21.0	19.00	9.20	32.7	0.0	0.0	0.200	Auto	Auto
25	22.77	S	22.0	19.00	9.20	33.2	0.0	0.0	0.200	Auto	Auto
26	23.77	S	24.0	19.00	9.20	34.0	0.0	0.0	0.200	Auto	Auto
27	24.77	S	24.0	19.00	9.20	34.0	0.0	0.0	0.200	Auto	Auto
28	25.77	S	22.0	19.00	9.20	33.2	0.0	0.0	0.200	Auto	Auto
29	26.77	S	22.0	19.00	9.20	33.2	0.0	0.0	0.200	Auto	Auto
30	27.77	S	25.0	19.00	9.20	34.4	0.0	0.0	0.200	Auto	Auto
31	28.77	S	26.0	19.00	9.20	34.7	0.0	0.0	0.200	Auto	Auto
32	29.77	S	22.0	19.00	9.20	33.2	0.0	0.0	0.200	Auto	Auto
33	30.77	S	44.0	19.00	9.20	40.7	0.0	0.0	0.200	Auto	Auto
34	34.27	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
φ : internal friction angle of soil
Co : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	2.00	3.55	7.41	9.14	3.61	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	End point m	load strength Normal Condition kN/m2	Seismic Condition kN/m2
1	3.95	6.95	10.0	5.0

Angle of rapture in embankment calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name 10 H _ H 1000 -250 -16 -28 -18
Young's modulus E = 200000 N/mm²
Inertia sectional moment I_0 = 845700 cm⁴
Sectional factor Z_0 = 12670 cm³

Corrosion margin t_1 = 1.00 mm (riverside) t_2 = 1.00 mm (landside)

Corrosion rate (to I_0) η = 0.87
Corrosion rate (to Z_0) η = 0.89
Section efficiency (to I_0) μ = 1.00
Section efficiency (to Z_0) μ = 1.00

Round unit of SSP length 0.50 m

Allowable stress σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

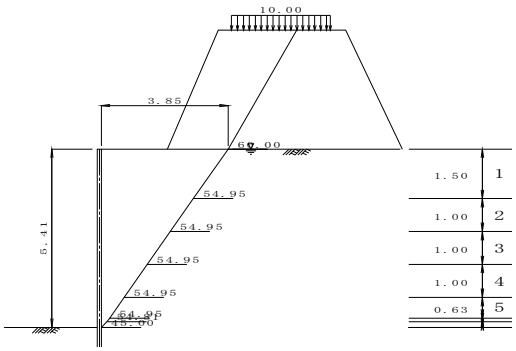
Allowable displacement δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam calculated as distributed load of each layer

Reduction of material modulus Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rapture ζ degree
1	5.41 ~ 5.24	Clay	0.0	15.0	50.0	41.74	42.84	53.02	45.00
2	5.24 ~ 5.13	Sand	27.0	15.0	0.0	40.35	42.84	51.35	54.81
3	5.13 ~ 4.50	Sand	27.2	15.0	0.0	39.50	42.84	50.27	54.95
4	4.50 ~ 3.50	Sand	27.2	15.0	0.0	34.65	42.84	44.10	54.95
5	3.50 ~ 2.50	Sand	27.2	15.0	0.0	26.95	42.84	34.30	54.95
6	2.50 ~ 1.50	Sand	27.2	15.0	0.0	19.25	42.84	24.50	54.95
7	1.50 ~ 0.00	Sand	27.2	15.0	0.0	11.55	42.84	14.70	54.95
8		embankment	30.0	——	0.0	68.59	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°
Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of the major collapse line

No	Angle of Rapture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	45.00	0.17	0.00	0.00	0.17	0.17
2	54.81	0.11	0.17	0.17	0.25	0.28
3	54.95	0.63	0.25	0.28	0.69	0.91
4	54.95	1.00	0.69	0.91	1.39	1.91
5	54.95	1.00	1.39	1.91	2.09	2.91
6	54.95	1.00	2.09	2.91	2.79	3.91
7	54.95	1.50	2.79	3.91	3.85	5.41
8	60.00	3.61	3.85	5.41	5.93	9.02

From the above table, the loading width (L) on the ground surface is 3.85 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	7.63	144.96
Σ			144.96

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	1.98	19.81
Σ			19.81

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

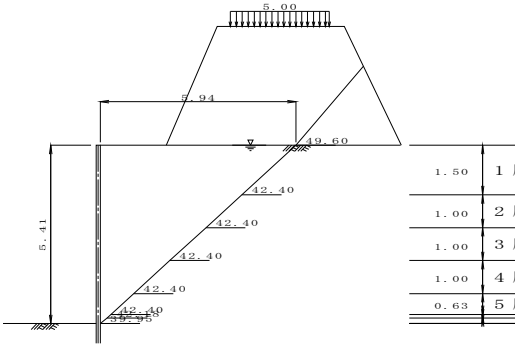
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{144.96 + 19.81 + 0.00}{3.85}$$

$$= 42.84 \text{ kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.41 ~ 5.24	Clay	0.0	15.0	50.0	41.74	53.72	53.02	0.200	11.31	39.95
2	5.24 ~ 5.13	Sand	27.0	15.0	0.0	40.35	53.72	51.35	0.200	11.31	42.18
3	5.13 ~ 4.50	Sand	27.2	15.0	0.0	39.50	53.72	50.27	0.200	11.31	42.40
4	4.50 ~ 3.50	Sand	27.2	15.0	0.0	34.65	53.72	44.10	0.200	11.31	42.40
5	3.50 ~ 2.50	Sand	27.2	15.0	0.0	26.95	53.72	34.30	0.200	11.31	42.40
6	2.50 ~ 1.50	Sand	27.2	15.0	0.0	19.25	53.72	24.50	0.200	11.31	42.40
7	1.50 ~ 0.00	Sand	27.2	15.0	0.0	11.55	53.72	14.70	0.200	11.31	42.40
8		embankment	30.0	———	0.0	68.59	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,
- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C : cohesive force of soil (kN/m²)

2.2.2 Coordinates of the major collapse line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	39.95	0.17	0.00	0.00	0.20	0.17
2	42.18	0.11	0.20	0.17	0.32	0.28
3	42.40	0.63	0.32	0.28	1.01	0.91
4	42.40	1.00	1.01	0.91	2.11	1.91
5	42.40	1.00	2.11	1.91	3.20	2.91
6	42.40	1.00	3.20	2.91	4.30	3.91
7	42.40	1.50	4.30	3.91	5.94	5.41
8	49.60	2.40	5.94	5.41	7.99	7.81

From the above table, the loading width (L) on the ground surface is 5.94 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	16.01	304.22
Σ			304.22

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.00	15.00
Σ			15.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

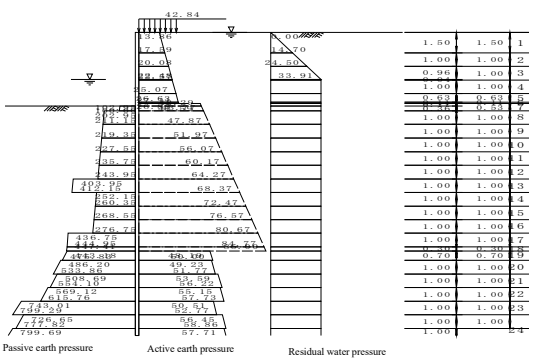
$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{304.22 + 15.00 + 0.00}{5.94}$$

$$= 53.72 \text{ kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition


42.84
5.00
14.70
31.50
33.91
1.50
1.00
1.00
1.00
0.63
1.00
1.00
1.00

26	20.77~ 21.77	Sand	9.2	32.7	——— ———	215.232 224.432	0.27152 0.27152	0.26227 0.26227
27	21.77~ 22.77	Sand	9.2	33.2	——— ———	224.432 233.632	0.26623 0.26623	0.25716 0.25716
28	22.77~ 23.77	Sand	9.2	34.0	——— ———	233.632 242.832	0.25791 0.25791	0.24912 0.24912
29	23.77~ 24.77	Sand	9.2	34.0	——— ———	242.832 252.032	0.25791 0.25791	0.24912 0.24912
30	24.77~ 25.77	Sand	9.2	33.2	——— ———	252.032 261.232	0.26623 0.26623	0.25716 0.25716
31	25.77~ 26.77	Sand	9.2	33.2	——— ———	261.232 270.432	0.26623 0.26623	0.25716 0.25716
32	26.77~ 27.77	Sand	9.2	34.4	——— ———	270.432 279.632	0.25382 0.25382	0.24517 0.24517
33	27.77~ 28.77	Sand	9.2	34.7	——— ———	279.632 288.832	0.25078 0.25078	0.24223 0.24223
34	28.77~ 29.77	Sand	9.2	33.2	——— ———	288.832 298.032	0.26623 0.26623	0.25716 0.25716
35	29.77~ 30.77	Sand	9.2	40.7	——— ———	298.032 307.232	0.19501 0.19501	0.18837 0.18837
36	30.77~ 34.27	Clay	7.2	———	1000.0 1000.0	307.232 332.432	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	$\Sigma\gamma h+Qp$ kN/m2	Kp	Kp × cos δ
9	5.41~ 5.77	Clay	8.2	0.0	50.0 50.0	0.000 2.952	——— ———	——— ———
10	5.77~ 6.77	Clay	8.2	0.0	100.0 100.0	2.952 11.152	——— ———	——— ———
11	6.77~ 7.77	Clay	8.2	0.0	100.0 100.0	11.152 19.352	——— ———	——— ———
12	7.77~ 8.77	Clay	8.2	0.0	100.0 100.0	19.352 27.552	——— ———	——— ———
13	8.77~ 9.77	Clay	8.2	0.0	100.0 100.0	27.552 35.752	——— ———	——— ———
14	9.77~ 10.77	Clay	8.2	0.0	100.0 100.0	35.752 43.952	——— ———	——— ———
15	10.77~ 11.77	Clay	8.2	0.0	180.0 180.0	43.952 52.152	——— ———	——— ———
16	11.77~ 12.77	Clay	8.2	0.0	100.0 100.0	52.152 60.352	——— ———	——— ———
17	12.77~ 13.77	Clay	8.2	0.0	100.0 100.0	60.352 68.552	——— ———	——— ———
18	13.77~ 14.77	Clay	8.2	0.0	100.0 100.0	68.552 76.752	——— ———	——— ———
19	14.77~ 15.77	Clay	8.2	0.0	180.0 180.0	76.752 84.952	——— ———	——— ———
20	15.77~ 16.07	Clay	8.2	0.0	180.0 180.0	84.952 87.412	——— ———	——— ———
21	16.07~ 16.77	Sand	9.2	31.0	——— ———	87.412 93.852	5.24888 5.24888	5.07003 5.07003
22	16.77~ 17.77	Sand	9.2	31.4	——— ———	93.852 103.052	5.36321 5.36321	5.18047 5.18047
23	17.77~ 18.77	Sand	9.2	30.5	——— ———	103.052 112.252	5.11035 5.11035	4.93622 4.93622
24	18.77~ 19.77	Sand	9.2	31.0	——— ———	112.252 121.452	5.24888 5.24888	5.07003 5.07003
25	19.77~ 20.77	Sand	9.2	34.4	——— ———	121.452 130.652	6.33351 6.33351	6.11770 6.11770
26	20.77~ 21.77	Sand	9.2	32.7	——— ———	130.652 139.852	5.75791 5.75791	5.56172 5.56172
27	21.77~ 22.77	Sand	9.2	33.2	——— ———	139.852 149.052	5.91981 5.91981	5.71809 5.71809
28	22.77~ 23.77	Sand	9.2	34.0	——— ———	149.052 158.252	6.19149 6.19149	5.98052 5.98052
29	23.77~ 24.77	Sand	9.2	34.0	——— ———	158.252 167.452	6.19149 6.19149	5.98052 5.98052
30	24.77~ 25.77	Sand	9.2	33.2	——— ———	167.452 176.652	5.91981 5.91981	5.71809 5.71809
31	25.77~ 26.77	Sand	9.2	33.2	——— ———	176.652 185.852	5.91981 5.91981	5.71809 5.71809
32	26.77~ 27.77	Sand	9.2	34.4	——— ———	185.852 195.052	6.33351 6.33351	6.11770 6.11770
33	27.77~ 28.77	Sand	9.2	34.7	——— ———	195.052 204.252	6.44286 6.44286	6.22332 6.22332
34	28.77~ 29.77	Sand	9.2	33.2	——— ———	204.252 213.452	5.91981 5.91981	5.71809 5.71809
35	29.77~ 30.77	Sand	9.2	40.7	——— ———	213.452 222.652	9.28109 9.28109	8.96485 8.96485
36	30.77~ 34.27	Clay	7.2	30.0	1000.0 1000.0	222.652 247.852	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.50	13.86 17.59	——— ———	13.86 17.59	0.00 14.70	——— ———
2	1.50~ 2.50	17.59 20.08	——— ———	17.59 20.08	14.70 24.50	——— ———
3	2.50~ 3.46	20.08 22.48	——— ———	20.08 22.48	24.50 33.91	——— ———
4	3.46~ 3.50	22.48 22.57	——— ———	22.48 22.57	33.91 33.91	——— ———
5	3.50~ 4.50	22.57 25.07	——— ———	22.57 25.07	33.91 33.91	——— ———
6	4.50~ 5.13	25.07 26.63	——— ———	25.07 26.63	33.91 33.91	——— ———
7	5.13~ 5.24	26.83 27.11	——— ———	26.83 27.11	33.91 33.91	——— ———
8	5.24~ 5.41	-16.81 -15.42	41.59 42.29	41.59 42.29	33.91 33.91	——— ———
9	5.41~ 5.77	-15.42 -12.47	42.29 43.77	42.29 43.77	33.91 33.91	100.00 102.95
10	5.77~ 6.77	-112.47 -104.27	43.77 47.87	43.77 47.87	33.91 33.91	202.95 211.15
11	6.77~ 7.77	-104.27 -96.07	47.87 51.97	47.87 51.97	33.91 33.91	211.15 219.35
12	7.77~ 8.77	-96.07 -87.87	51.97 56.07	51.97 56.07	33.91 33.91	219.35 227.55
13	8.77~ 9.77	-87.87 -79.67	56.07 60.17	56.07 60.17	33.91 33.91	227.55 235.75
14	9.77~ 10.77	-79.67 -71.47	60.17 64.27	60.17 64.27	33.91 33.91	235.75 243.95
15	10.77~ 11.77	-231.47 -223.27	64.27 68.37	64.27 68.37	33.91 33.91	403.95 412.15
16	11.77~ 12.77	-63.27 -55.07	68.37 72.47	68.37 72.47	33.91 33.91	252.15 260.35
17	12.77~ 13.77	-55.07 -46.87	72.47 76.57	72.47 76.57	33.91 33.91	260.35 268.55
18	13.77~ 14.77	-46.87 -38.67	76.57 80.67	76.57 80.67	33.91 33.91	268.55 276.75
19	14.77~ 15.77	-198.67 -190.47	80.67 84.77	80.67 84.77	33.91 33.91	436.75 444.95
20	15.77~ 16.07	-190.47 -188.01	84.77 86.00	84.77 86.00	33.91 33.91	444.95 447.41
21	16.07~ 16.77	48.19 50.00	——— ———	48.19 50.00	33.91 33.91	443.18 475.83
22	16.77~ 17.77	49.23 51.77	——— ———	49.23 51.77	33.91 33.91	486.20 533.86
23	17.77~ 18.77	53.59 56.22	——— ———	53.59 56.22	33.91 33.91	508.69 554.10
24	18.77~ 19.77	55.15 57.73	——— ———	55.15 57.73	33.91 33.91	569.12 615.76
25	19.77~ 20.77	50.51 52.77	——— ———	50.51 52.77	33.91 33.91	743.01 799.29
26	20.77~ 21.77	56.45 58.86	——— ———	56.45 58.86	33.91 33.91	726.65 777.82
27	21.77~ 22.77	57.71 60.08	——— ———	57.71 60.08	33.91 33.91	799.69 852.29
28	22.77~ 23.77	58.20 60.49	——— ———	58.20 60.49	33.91 33.91	891.41 946.43
29	23.77~ 24.77	60.49 62.79	——— ———	60.49 62.79	33.91 33.91	946.43 1001.45
30	24.77~ 25.77	64.81 67.18	——— ———	64.81 67.18	33.91 33.91	957.51 1010.11
31	25.77~ 26.77	67.18 69.54	——— ———	67.18 69.54	33.91 33.91	1010.11 1062.72
32	26.77~ 27.77	66.30 68.56	——— ———	66.30 68.56	33.91 33.91	1136.99 1193.27
33	27.77~ 28.77	67.74 69.96	——— ———	67.74 69.96	33.91 33.91	1213.87 1271.13
34	28.77~ 29.77	74.28 76.64	——— ———	74.28 76.64	33.91 33.91	1167.93 1220.54
35	29.77~ 30.77	56.14 57.87	——— ———	56.14 57.87	33.91 33.91	1913.56 1996.04
36	30.77~ 34.27	-1692.77 -1667.57	153.62 166.22	153.62 166.22	33.91 33.91	2222.65 2247.85

- Formula for active earth pressure

Sand $P_{a1}=K_a\cdot\left[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_{a1}=\Sigma\gamma h+Q-2C$

$P_{a2}=K_a\cdot(\Sigma\gamma h+Q)$

K_a : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1}=\left[K_a(\Sigma\gamma h+Q)-2C\sqrt{K_a}\right]\cdot\cos\delta$

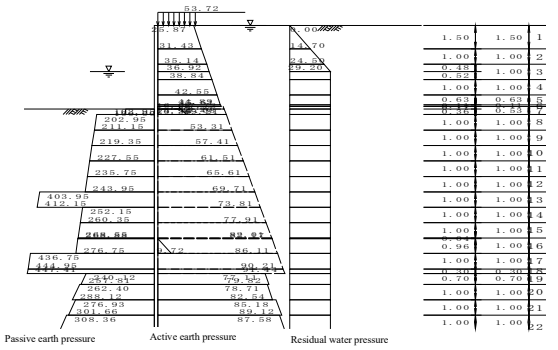
- Formula for passive earth pressure

Sand $P_p=K_p\cdot\left[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_p=\Sigma\gamma h+Q+2C$

Mixed soil $P_p=\left[K_p(\Sigma\gamma h+Q)+2C\sqrt{K_p}\right]\cdot\cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 1.50	Sand	7.7	27.2	——— ———	53.72 65.27	0.00 14.70	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
2	1.50~ 2.50	Sand	7.7	27.2	——— ———	65.27 72.97	14.70 24.50	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
3	2.50~ 2.98	Sand	7.7	27.2	——— ———	72.97 76.67	24.50 29.20	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
4	2.98~ 3.50	Sand	7.7	27.2	——— ———	76.67 80.67	29.20 34.30	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
5	3.50~ 4.50	Sand	7.7	27.2	——— ———	80.67 88.37	34.30 44.10	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
6	4.50~ 5.13	Sand	7.7	27.2	——— ———	88.37 93.22	44.10 50.27	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
7	5.13~ 5.24	Sand	7.7	27.0	——— ———	93.22 94.07	50.27 51.35	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
8	5.24~ 5.41	Clay	8.2	———	50.0 50.0	94.07 95.46	51.35 53.02	0.200 0.200	11.31 11.31	——— ———	——— ———	40.01 39.95
9	5.41~ 5.77	Clay	8.2	———	50.0 50.0	95.46 98.41	53.02 56.55	0.200 0.200	11.31 11.31	——— ———	——— ———	39.95 39.83
10	5.77~ 6.77	Clay	8.2	———	100.0 100.0	98.41 106.61	56.55 66.35	0.200 0.200	11.31 11.31	——— ———	——— ———	42.64 42.50
11	6.77~ 7.77	Clay	8.2	———	100.0 100.0	106.61 114.81	66.35 76.15	0.200 0.200	11.31 11.31	——— ———	——— ———	42.50 42.36
12	7.77~ 8.77	Clay	8.2	———	100.0 100.0	114.81 123.01	76.15 85.95	0.200 0.200	11.31 11.31	——— ———	——— ———	42.36 42.22
13	8.77~ 9.77	Clay	8.2	———	100.0 100.0	123.01 131.21	85.95 95.75	0.200 0.200	11.31 11.31	——— ———	——— ———	42.22 42.08
14	9.77~ 10.77	Clay	8.2	———	100.0 100.0	131.21 139.41	95.75 105.55	0.200 0.200	11.31 11.31	——— ———	——— ———	42.08 41.93
15	10.77~ 11.77	Clay	8.2	———	180.0 180.0	139.41 147.61	105.55 115.35	0.200 0.200	11.31 11.31	——— ———	——— ———	43.38 43.30
16	11.77~ 12.77	Clay	8.2	———	100.0 100.0	147.61 155.81	115.35 125.15	0.200 0.200	11.31 11.31	——— ———	——— ———	41.79 41.64
17	12.77~ 13.77	Clay	8.2	———	100.0 100.0	155.81 164.01	125.15 134.95	0.200 0.200	11.31 11.31	——— ———	——— ———	41.64 41.49
18	13.77~ 13.81	Clay	8.2	———	100.0 100.0	164.01 164.34	134.95 ———	0.200 ———	11.31 ———	——— ———	——— ———	41.49 ———
19	13.81~ 14.77	Clay	8.2	———	100.0 100.0	164.34 172.21	——— 144.75	——— 0.200	——— 11.31	——— ———	——— ———	——— 41.34
20	14.77~ 15.77	Clay	8.2	———	180.0 180.0	172.21 180.41	144.75 154.55	0.200 0.200	11.31 11.31	——— ———	——— ———	43.08 43.01
21	15.77~ 16.07	Clay	8.2	———	180.0 180.0	180.41 182.87	154.55 157.49	0.200 0.200	11.31 11.31	——— ———	——— ———	43.01 42.98
22	16.07~ 16.77	Sand	9.2	31.0 ———	——— 189.31	182.87 189.31	157.49 164.35	0.200 0.200	11.31 11.31	0.43652 0.43652	0.42164 0.42164	——— ———
23	16.77~ 17.77	Sand	9.2	31.4 ——— ———	——— 198.51	189.31 198.51	164.35 174.15	0.200 0.200	11.31 11.31	0.43046 0.43046	0.41579 0.41579	——— ———
24	17.77~ 18.77	Sand	9.2	30.5 ——— ———	——— 207.71	198.51 207.71	174.15 183.95	0.200 0.200	11.31 11.31	0.44421 0.44421	0.42907 0.42907	——— ———
25	18.77~ 19.77	Sand	9.2	31.0 ——— ———	——— 216.91	207.71 216.91	183.95 193.75	0.200 0.200	11.31 11.31	0.43652 0.43652	0.42164 0.42164	——— ———
26	19.77~ 20.77	Sand	9.2	34.4 ——— ———	——— 226.11	216.91 226.11	193.75 203.55	0.200 0.200	11.31 11.31	0.38741 0.38741	0.37421 0.37421	——— ———
27	20.77~ 21.77	Sand	9.2	32.7 ——— ———	——— 235.31	226.11 235.31	203.55 213.35	0.200 0.200	11.31 11.31	0.41130 0.41130	0.39729 0.39729	——— ———
28	21.77~ 22.77	Sand	9.2	33.2 ——— ———	——— 244.51	235.31 244.51	213.35 223.15	0.200 0.200	11.31 11.31	0.40414 0.40414	0.39037 0.39037	——— ———
29	22.77~ 23.77	Sand	9.2	34.0 ——— ———	——— 253.71	244.51 253.71	223.15 232.95	0.200 0.200	11.31 11.31	0.39292 0.39292	0.37953 0.37953	——— ———
30	23.77~ 24.77	Sand	9.2	34.0 ——— ———	——— 262.91	253.71 262.91	232.95 242.75	0.200 0.200	11.31 11.31	0.39292 0.39292	0.37953 0.37953	——— ———
31	24.77~ 25.77	Sand	9.2	33.2 ——— ———	——— 272.11	262.91 272.11	242.75 252.55	0.200 0.200	11.31 11.31	0.40414 0.40414	0.39037 0.39037	——— ———
32	25.77~ 26.77	Sand	9.2	33.2 ——— ———	——— 281.31	272.11 281.31	252.55 262.35	0.200 0.200	11.31 11.31	0.40414 0.40414	0.39037 0.39037	——— ———
33	26.77~ 27.77	Sand	9.2	34.4 ——— ———	——— 290.51	281.31 290.51	262.35 272.15	0.200 0.200	11.31 11.31	0.38741 0.38741	0.37421 0.37421	——— ———
34	27.77~ 28.77	Sand	9.2	34.7 ——— ———	——— 299.71	290.51 299.71	272.15 281.95	0.200 0.200	11.31 11.31	0.38333 0.38333	0.37027 0.37027	——— ———
35	28.77~ 29.77	Sand	9.2	33.2 ——— ———	——— 308.91	299.71 308.91	281.95 291.75	0.200 0.200	11.31 11.31	0.40414 0.40414	0.39037 0.39037	——— ———
36	29.77~ 30.77	Sand	9.2	40.7 ——— ———	——— 318.11	308.91 318.11	291.75 301.55	0.200 0.200	11.31 11.31	0.30875 0.30875	0.29823 0.29823	——— ———
37	30.77~ 34.27	Clay	7.2	———	1000.0 1000.0	318.11 343.31	301.55 335.85	0.200 0.200	11.31 11.31	——— ———	——— ———	44.46 44.42

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}}\cdot\tan\theta$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
9	5.41~ 5.77	Clay	8.20	0.0	50.0 50.0	0.000 2.952	0.00 3.53	0.200 0.200	11.31 11.31	——— ———	——— ———
10	5.77~ 6.77	Clay	8.20	0.0	100.0 100.0	2.952 11.152	3.53 13.33	0.200 0.200	11.31 11.31	——— ———	——— ———
11	6.77~ 7.77	Clay	8.20	0.0	100.0 100.0	11.152 19.352	13.33 23.13	0.200 0.200	11.31 11.31	——— ———	——— ———
12	7.77~ 8.77	Clay	8.20	0.0	100.0 100.0	19.352 27.552	23.13 32.93	0.200 0.200	11.31 11.31	——— ———	——— ———
13	8.77~ 9.77	Clay	8.20	0.0	100.0 100.0	27.552 35.752	32.93 42.73	0.200 0.200	11.31 11.31	——— ———	——— ———
14	9.77~ 10.77	Clay	8.20	0.0	100.0 100.0	35.752 43.952	42.73 52.53	0.200 0.200	11.31 11.31	——— ———	——— ———
15	10.77~ 11.77	Clay	8.20	0.0	180.0 180.0	43.952 52.152	52.53 62.33	0.200 0.200	11.31 11.31	——— ———	——— ———
16	11.77~ 12.77	Clay	8.20	0.0	100.0 100.0	52.152 60.352	62.33 72.13	0.200 0.200	11.31 11.31	——— ———	——— ———
17	12.77~ 13.77	Clay	8.20	0.0	100.0 100.0	60.352 68.552	72.13 81.93	0.200 0.200	11.31 11.31	——— ———	——— ———
18	13.77~ 13.81	Clay	8.20	0.0	100.0 100.0	68.552 68.883	81.93 ———	0.200 ———	11.31 ———	——— ———	——— ———
19	13.81~ 14.77	Clay	8.20	0.0	100.0 100.0	68.883 76.752	——— 91.73	——— 0.200	——— 11.31	——— ———	——— ———
20	14.77~ 15.77	Clay	8.20	0.0	180.0 180.0	76.752 84.952	91.73 101.53	0.200 0.200	11.31 11.31	——— ———	——— ———
21	15.77~ 16.07	Clay	8.20	0.0	180.0 180.0	84.952 87.412	101.53 104.47	0.200 0.200	11.31 11.31	——— ———	——— ———
22	16.07~ 16.77	Sand	9.20	31.0 ———	——— 87.412	87.412 93.852	104.47 111.33	0.200 0.200	11.31 11.31	2.74701 2.74701	2.74701 2.74701
23	16.77~ 17.77	Sand	9.20	31.4 ——— ———	——— 93.852	93.852 103.052	111.33 121.13	0.200 0.200	11.31 11.31	2.79588 2.79588	2.79588 2.79588
24	17.77~ 18.77	Sand	9.20	30.5 ——— ———	——— 103.052	103.052 112.252	121.13 130.93	0.200 0.200	11.31 11.31	2.68732 2.68732	2.68732 2.68732
25	18.77~ 19.77	Sand	9.20	31.0 ——— ———	——— 112.252	112.252 121.452	130.93 140.73	0.200 0.200	11.31 11.31	2.74701 2.74701	2.74701 2.74701
26	19.77~ 20.77	Sand	9.20	34.4 ——— ———	——— 121.452	121.452 130.652	140.73 150.53	0.200 0.200	11.31 11.31	3.19714 3.19714	3.19714 3.19714
27	20.77~ 21.77	Sand	9.20	32.7 ——— ———	——— 130.652	130.652 139.852	150.53 160.33	0.200 0.200	11.31 11.31	2.96192 2.96192	2.96192 2.96192
28	21.77~ 22.77	Sand	9.20	33.2 ——— ———	——— 139.852	139.852 149.052	160.33 170.13	0.200 0.200	11.31 11.31	3.02888 3.02888	3.02888 3.02888
29	22.77~ 23.77	Sand	9.20	34.0 ——— ———	——— 149.052	149.052 158.252	170.13 179.93	0.200 0.200	11.31 11.31	3.13983 3.13983	3.13983 3.13983
30	23.77~ 24.77	Sand	9.20	34.0 ——— ———	——— 158.252	158.252 167.452	179.93 189.73	0.200 0.200	11.31 11.31	3.13983 3.13983	3.13983 3.13983
31	24.77~ 25.77	Sand	9.20	33.2 ——— ———	——— 167.452	167.452 176.652	189.73 199.53	0.200 0.200	11.31 11.31	3.02888 3.02888	3.02888 3.02888
32	25.77~ 26.77	Sand	9.20	33.2 ——— ———	——— 176.652	176.652 185.852	199.53 209.33	0.200 0.200	11.31 11.31	3.02888 3.02888	3.02888 3.02888
33	26.77~ 27.77	Sand	9.20	34.4 ——— ———	——— 185.852	185.852 195.052	209.33 219.13	0.200 0.200	11.31 11.31	3.19714 3.19714	3.19714 3.19714
34	27.77~ 28.77	Sand	9.20	34.7 ——— ———	——— 195.052	195.052 204.252	219.13 228.93	0.200 0.200	11.31 11.31	3.24095 3.24095	3.24095 3.24095
35	28.77~ 29.77	Sand	9.20	33.2 ——— ———	——— 204.252	204.252 213.452	228.93 238.73	0.200 0.200	11.31 11.31	3.02888 3.02888	3.02888 3.02888
36	29.77~ 30.77	Sand	9.20	40.7 ——— ———	——— 213.452	213.452 222.652	238.73 248.53	0.200 0.200	11.31 11.31	4.29549 4.29549	4.29549 4.29549
37	30.77~ 34.27	Clay	7.20	30.0	1000.0 1000.0	222.652 247.852	248.53 282.83	0.200 0.200	11.31 11.31	——— ———	——— ———

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.
δ = 0.00 degrees, β = 0.00 degrees
Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 1.50	25.87 31.43	——— ———	25.87 31.43	0.00 14.70	——— ———
2	1.50~ 2.50	31.43 35.14	——— ———	31.43 35.14	14.70 24.50	——— ———
3	2.50~ 2.98	35.14 36.92	——— ———	35.14 36.92	24.50 29.20	——— ———
4	2.98~ 3.50	36.92 38.84	——— ———	36.92 38.84	29.20 29.20	——— ———
5	3.50~ 4.50	38.84 42.55	——— ———	38.84 42.55	29.20 29.20	——— ———
6	4.50~ 5.13	42.55 44.89	——— ———	42.55 44.89	29.20 29.20	——— ———
7	5.13~ 5.24	45.20 45.61	——— ———	45.20 45.61	29.20 29.20	——— ———
8	5.24~ 5.41	14.94 16.68	47.03 47.73	47.03 47.73	29.20 29.20	——— ———

9	5.41~ 5.77	16.68 20.36	47.73 49.21	47.73 49.21	29.20 29.20	100.00 102.95
10	5.77~ 6.77	-80.89 -70.88	49.21 53.31	49.21 53.31	29.20 29.20	202.95 211.15
11	6.77~ 7.77	-70.88 -60.86	53.31 57.41	53.31 57.41	29.20 29.20	211.15 219.35
12	7.77~ 8.77	-60.86 -50.82	57.41 61.51	57.41 61.51	29.20 29.20	219.35 227.55
13	8.77~ 9.77	-50.82 -40.77	61.51 65.61	61.51 65.61	29.20 29.20	227.55 235.75
14	9.77~ 10.77	-40.77 -30.70	65.61 69.71	65.61 69.71	29.20 29.20	235.75 243.95
15	10.77~ 11.77	-191.66 -181.69	69.71 73.81	69.71 73.81	29.20 29.20	403.95 412.15
16	11.77~ 12.77	-20.62 -10.52	73.81 77.91	73.81 77.91	29.20 29.20	252.15 260.35
17	12.77~ 13.77	-10.52 -0.41	77.91 82.01	77.91 82.01	29.20 29.20	260.35 268.55
18	13.77~ 13.81	-0.41 0.00	82.01 82.17	82.01 82.17	29.20 29.20	268.55 268.88
19	13.81~ 14.77	0.00 9.72	82.17 86.11	82.17 86.11	29.20 29.20	268.88 276.75
20	14.77~ 15.77	-151.76 -141.77	86.11 90.21	86.11 90.21	29.20 29.20	436.75 444.95
21	15.77~ 16.07	-141.77 -138.78	90.21 91.44	90.21 91.44	29.20 29.20	444.95 447.41
22	16.07~ 16.77	77.11 79.82	—— ——	77.11 79.82	29.20 29.20	240.12 257.81
23	16.77~ 17.77	78.71 82.54	—— ——	78.71 82.54	29.20 29.20	262.40 288.12
24	17.77~ 18.77	85.18 89.12	—— ——	85.18 89.12	29.20 29.20	276.93 301.66
25	18.77~ 19.77	87.58 91.46	—— ——	87.58 91.46	29.20 29.20	308.36 333.63
26	19.77~ 20.77	81.17 84.61	—— ——	81.17 84.61	29.20 29.20	388.30 417.71
27	20.77~ 21.77	89.83 93.49	—— ——	89.83 93.49	29.20 29.20	386.98 414.23
28	21.77~ 22.77	91.86 95.45	—— ——	91.86 95.45	29.20 29.20	423.59 451.46
29	22.77~ 23.77	92.80 96.29	—— ——	92.80 96.29	29.20 29.20	468.00 496.88
30	23.77~ 24.77	96.29 99.78	—— ——	96.29 99.78	29.20 29.20	496.88 525.77
31	24.77~ 25.77	102.63 106.23	—— ——	102.63 106.23	29.20 29.20	507.19 535.06
32	25.77~ 26.77	106.23 109.82	—— ——	106.23 109.82	29.20 29.20	535.06 562.92
33	26.77~ 27.77	105.27 108.71	—— ——	105.27 108.71	29.20 29.20	594.19 623.61
34	27.77~ 28.77	107.57 110.97	—— ——	107.57 110.97	29.20 29.20	632.15 661.97

35	28.77~ 29.77	117.00 120.59	—— ——	117.00 120.59	29.20 29.20	618.65 646.52
36	29.77~ 30.77	92.13 94.87	—— ——	92.13 94.87	29.20 29.20	916.88 956.40
37	30.77~ 34.27	-1617.41 -1587.03	159.06 171.66	159.06 171.66	29.20 29.20	2222.65 2247.85

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$

$P_{a2} = K_a \cdot (\Sigma \gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	2.98	0.00	0.00
2	3.98	1.00	2.67
3	4.98	2.00	3.78
4	5.41	2.43	4.17

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

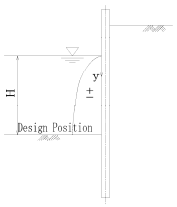
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

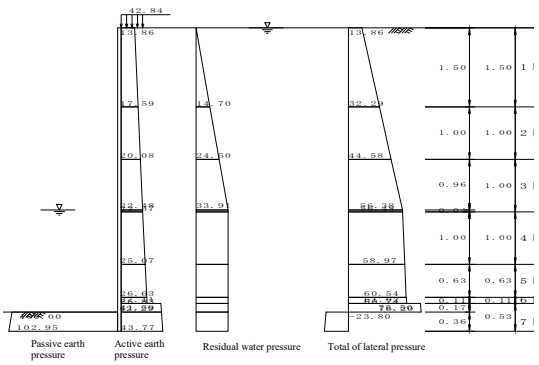
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	13.86 17.59	0.00 14.70	—— ——	13.86 32.29
2	1.50~ 2.50	17.59 20.08	14.70 24.50	—— ——	32.29 44.58
3	2.50~ 3.46	20.08 22.48	24.50 33.91	—— ——	44.58 56.38
4	3.46~ 3.50	22.48 22.57	33.91 33.91	—— ——	56.38 56.48
5	3.50~ 4.50	22.57 25.07	33.91 33.91	—— ——	56.48 58.97
6	4.50~ 5.13	25.07 26.63	33.91 33.91	—— ——	58.97 60.54
7	5.13~ 5.24	26.83 27.11	33.91 33.91	—— ——	60.74 61.02
8	5.24~ 5.41	41.59 42.29	33.91 33.91	—— ——	75.50 76.20
9	5.41~ 5.77	42.29 43.77	33.91 33.91	100.00 102.95	-23.80 -25.28

P_a : Active earth pressure

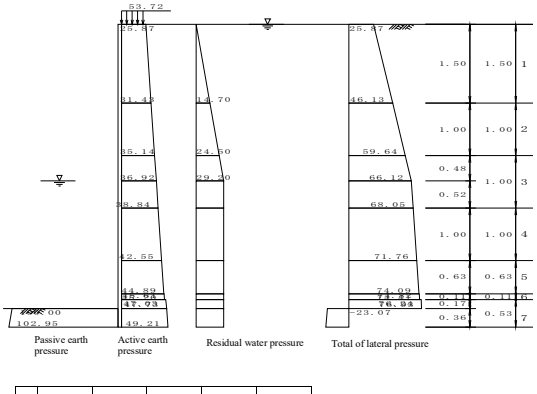
P_w : Residual water pressure

P_p : Passive earth pressure

P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.41 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	25.87 31.43	0.00 14.70	—— ——	25.87 46.13
2	1.50~ 2.50	31.43 35.14	14.70 24.50	—— ——	46.13 59.64
3	2.50~ 2.98	35.14 36.92	24.50 29.20	—— ——	59.64 66.12
4	2.98~ 3.50	36.92 38.84	29.20 29.20	—— ——	66.12 68.05
5	3.50~ 4.50	38.84 42.55	29.20 29.20	—— ——	68.05 71.76

6	4.50~ 5.13	42.55 44.89	29.20 29.20	——— ———	71.76 74.09
7	5.13~ 5.24	45.20 45.61	29.20 29.20	——— ———	74.41 74.82
8	5.24~ 5.41	47.03 47.73	29.20 29.20	——— ———	76.24 76.93
9	5.41~ 5.77	47.73 49.21	29.20 29.20	100.00 102.95	-23.07 -24.54

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.41 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\,\alpha\,E_0 \qquad (\alpha : \text{Normal Condition} = 1,\ \text{Seismi Condition} = 2)$$

$$E_h = 2800\,N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4\,E\,I}}$$

Material Name		10 H _ H 1000 -250 -16 -28 -18	
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	845700 cm^4(original condition)
	I	=	735759 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 735759 \times 10^{-8} = 1.472 \times 10^6$

No	Depth m	N Value
1	1.00	10
2	2.00	10
3	3.00	10
4	4.00	10
5	5.00	10
6	5.27	7
7	6.27	12
8	7.27	9
9	8.27	9
10	9.27	11

No	Depth m	N Value
11	10.27	9
12	11.27	17
13	12.27	10
14	13.27	12
15	14.27	10
16	15.27	16
17	16.27	17
18	17.27	18
19	18.27	16
20	19.27	17

No	Depth m	N Value
21	20.27	25
22	21.27	21
23	22.27	22
24	23.27	24
25	24.27	24
26	25.27	22
27	26.27	22
28	27.27	25
29	28.27	26
30	29.27	22

No	Depth m	N Value
31	30.27	44
32	31.27	50
33	32.27	50
34	33.27	50
35	34.27	50

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.41	0.86	7.7	12.0	8.47
2	6.27	1.00	12.0	9.0	10.50
3	7.27	1.00	9.0	9.0	9.00
4	8.27	1.00	9.0	11.0	10.00
5	9.27	0.72	11.0	9.6	7.44
L =		Σh = 4.58	ΣA =	45.41	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \dfrac{\Sigma A}{L} = \dfrac{45.41}{4.58} = 9.91$

Kh is recalculated from the calculated average N value.

$E_0 = 2800\,N' = 2800 \times 9.91 = 27738$ kN/m^2
$K_{h0} = \dfrac{1}{0.3} \times \alpha \times 27738 = 184920$ kN/m^3 (α :Normal Condition =1, Seismi Condition =2)
$K_h = K_{h0}(B_H/0.3)^{-3/4} = 184920\,(10.00/0.3)^{-3/4} = 13330$ kN/m^3

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 13330 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	13.86 32.29	10.39 24.22	4.91 4.41	51.03 106.81
2	1.50~ 2.50	1.00	32.29 44.58	16.15 22.29	3.58 3.24	57.75 72.30
3	2.50~ 3.46	0.96	44.58 56.38	21.40 27.06	2.59 2.27	55.43 61.44
4	3.46~ 3.50	0.04	56.38 56.48	1.13 1.13	1.94 1.92	2.18 2.17
5	3.50~ 4.50	1.00	56.48 58.97	28.24 29.49	1.58 1.24	44.53 36.66
6	4.50~ 5.13	0.63	58.97 60.54	18.58 19.07	0.70 0.49	13.00 9.34
7	5.13~ 5.24	0.11	60.74 61.02	3.34 3.36	0.24 0.21	0.81 0.69

5.2 Normal Condition

Assuming Kh = 6743 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4\,E\,I}} = 0.184\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 5.44\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.41 m) to 5.44 m depth (GL -10.85 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.41	0.86	7.7	12.0	8.47
2	6.27	1.00	12.0	9.0	10.50
3	7.27	1.00	9.0	9.0	9.00
4	8.27	1.00	9.0	11.0	10.00
5	9.27	1.00	11.0	9.0	10.00
6	10.27	0.58	9.0	13.6	6.51
L =		Σh = 5.44	ΣA =	54.48	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \dfrac{\Sigma A}{L} = \dfrac{54.48}{5.44} = 10.02$

Kh is recalculated from the calculated average N value.

$E_0 = 2800\,N' = 2800 \times 10.02 = 28062$ kN/m^2
$K_{h0} = \dfrac{1}{0.3} \times \alpha \times 28062 = 93541$ kN/m^3 (α :Normal Condition =1, Seismi Condition =2)
$K_h = K_{h0}(B_H/0.3)^{-3/4} = 93541\,(10.00/0.3)^{-3/4} = 6743$ kN/m^3

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 6743 kN/m3.

5.3 Seismic Condition

Assuming Kh = 13330 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4\,E\,I}} = 0.218\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 4.58\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.41 m) and 4.58 m depth (GL -9.99 m).

8	5.24~ 5.41	0.17	75.50 76.20	6.42 6.48	0.11 0.06	0.73 0.37
			ΣP = 238.74		ΣM = 515.25	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	23.4 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.41 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 126.59$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{641.84}{262.14} = 2.45\ \text{m}$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 262.14}{5.41} = 96.91\ \text{kN/m}$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	25.87 46.13	19.40 34.60	4.91 4.41	95.25 152.57
2	1.50~ 2.50	1.00	46.13 59.64	23.06 29.82	3.58 3.24	82.49 96.71
3	2.50~ 2.98	0.48	59.64 66.12	14.31 15.87	2.75 2.59	39.36 41.10
4	2.98~ 3.50	0.52	66.12 68.05	17.19 17.69	2.26 2.08	38.79 36.86
5	3.50~ 4.50	1.00	68.05 71.76	34.02 35.88	1.58 1.24	53.64 44.61
6	4.50~ 5.13	0.63	71.76 74.09	22.60 23.34	0.70 0.49	15.82 11.44
7	5.13~ 5.24	0.11	74.41 74.82	4.09 4.11	0.24 0.21	1.00 0.85
8	5.24~ 5.41	0.17	76.24 76.93	6.48 6.54	0.11 0.06	0.73 0.37
			ΣP = 309.01		ΣM = 711.60	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load		P_t	=	62.8 kN/m
	depth to acting position	H_t	=	0.00 m
	moment	M_m	=	33.9 kN･m/m
	depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping		H	=	5.41 m
Depth of Imaginary riverbed from riverbed		L_k	=	0.00 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m = 373.65$ kN･m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Louds Pdw kN	Arm length Y' m	Moment Mdw kN ・ m
1	2.98~ 3.98	1.00	0.0 2.7	0.00 1.34	2.10 1.76	0.00 2.36
2	3.98~ 4.98	1.00	2.7 3.8	1.34 1.89	1.10 0.76	1.47 1.44
3	4.98~ 5.41	0.43	3.8 4.2	0.81 0.90	0.29 0.14	0.23 0.13
			Σ Pdw =	6.27	Σ Mdw =	5.63

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1090.88}{378.09} = 2.89 \text{ m}$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 378.09}{5.41} = 139.77 \text{ kN/m}$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name		10 H _ H 1000 -250 -16 -28 -18		
Unit width	B	=	1.0000 m	
Corrosion margin	t_1	=	1.00 mm (active side)	t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87	
Section efficiency	μ	=	1.00	
Young's modulus	E	=	200000 N/mm^2	
Inertia sectional moment	I_0	=	845700cm^4 (original condition)	
	I	=	735759 cm^4 (after reduction by corrosion and section)	

$EI = 200000 \times 10^3 \times 735759 \times 10^{-8} = 1.472 \times 10^6$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	6743	kN/m^3
calculated value	β	=	0.18397	m^{-1}
resultant earth force (lateral)	P_0	=	262.14	kN/m
height of acting position of load	h_0	=	2.45	m
moment	M_0	=	641.84	kN･m/m
in consideration of ψ_m = 1.469,				
maximum moment	M_{max}	=	942.85	kN･m/m
depth of generated position of M_{max}	l_m	=	2.632	m
depth of 1st fixed point	l_i	=	6.901	m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	13330	kN/m^3
calculated value	β	=	0.21815	m^{-1}
resultant earth force (lateral)	P_0	=	378.09	kN/m
height of acting position of load	h_0	=	2.89	m
moment	M_0	=	1090.88	kN･m/m
in consideration of ψ_m = 1.294,				
maximum moment	M_{max}	=	1411.09	kN･m/m
depth of generated position of M_{max}	l_m	=	1.911	m
depth of 1st fixed point	l_i	=	5.511	m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 1000 -250 -16 -28 -18			
Corrosion margin	t_1	=	1.00 mm (active side)	t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.89	
Section efficiency	μ	=	1.00	
Module of section	Z_0	=	12670 cm^3 (original condition)	
	Z	=	11276 cm^3 (after reduction by corrosion and section)	

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{942.85 \times 10^6}{11276 \times 10^3} = 84 \text{ N/mm}^2 \leqq \sigma_a = 180 \text{ N/mm}^2$$

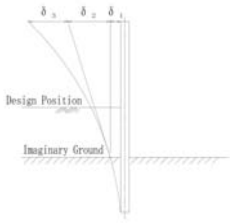
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1411.09 \times 10^6}{11276 \times 10^3} = 125 \text{ N/mm}^2 \leqq \sigma_a = 270 \text{ N/mm}^2$$

6.4 Displacement Calculation

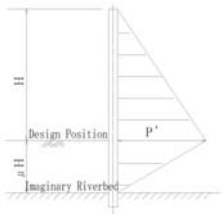
6.4.1 Normal Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0) \times P_0}{2EI\beta^3} = \frac{(1+0.1840 \times 2.45) \times 262.14}{2 \times 2.00 \times 10^8 \times 735759 \times 10^{-8} \times 0.1840^3} = 0.02075 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0) \times P_0}{2EI\beta^2} \times (H+L_k) = \frac{(1+2 \times 0.1840 \times 2.45) \times 262.14}{2 \times 2.00 \times 10^8 \times 735759 \times 10^{-8} \times 0.1840^2} \times (5.41+0.00) = 0.02706 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.41} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{96.91 \times 5.41^4}{120 \times 2.00 \times 10^8 \times 735759 \times 10^{-8}}(4+20 \times 0.000+40 \times 0.000^2+35 \times 0.000^3+11 \times 0.000^4) = 0.00188 \text{ m}$$

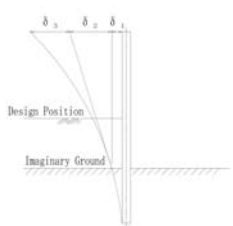
δ = δ1 + δ2 + δ3
= 0.02075 + 0.02706 + 0.00188
= 0.04969 m
Size = 49.69 ≦ δa = 50.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

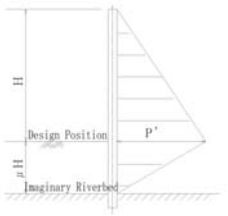


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2182\times 2.89)\times 378.09}{2\times 2.00\times 10^8\times 735759\times 10^{-8}\times 0.2182^3} = 0.02016 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.2182\times 2.89)\times 378.09}{2\times 2.00\times 10^8\times 735759\times 10^{-8}\times 0.2182^2}\times(5.41+0.00) = 0.03299 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.41} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{139.77\times 5.41^4}{120\times 2.00\times 10^8\times 735759\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

$$= 0.00271 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
$= 0.02016 + 0.03299 + 0.00271$
$= 0.05587$ m
Size = 55.87 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name			10 H _ H 1000 -250 -16 -28 -18
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	845700 cm^4 (original condition)
	I	=	845700 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 845700 × 10^{-8}		=	1.691 × 10^6

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$
$$L = H - H_{1t} + D$$
$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction $K_h = 6743$ kN/m^3
Calculated value $\beta = 0.17768$ m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.178} = 16.88$ m
Whole length of SSP $L = 5.41 - 0.40 + 16.88 = 21.89$ m

7.1.1 Seismic Condition

Modules of lateral subgrade reaction $K_h = 13330$ kN/m^3
Calculated value $\beta = 0.21068$ m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.211} = 14.24$ m
Whole length of SSP $L = 5.41 - 0.40 + 14.24 = 19.25$ m

Therefore, the total length of the sheet pile is 22.00 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile 10 H _ H 1000 -250 -16 -28 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	845700		
Sectional Modulus	Z (cm3)	12670		
Maximum bending moment	Mmax (kN・m・m)		942.85	1411.09
Stress intensity	σ (N/mm2)		84 (180)	125 (270)
Lateral displacement	δ (mm)		49.69 (50.0)	55.87 (75.0)
Penetration depths	D (m)		16.88	14.24
Whole length of SSP	L (m)	22.00		

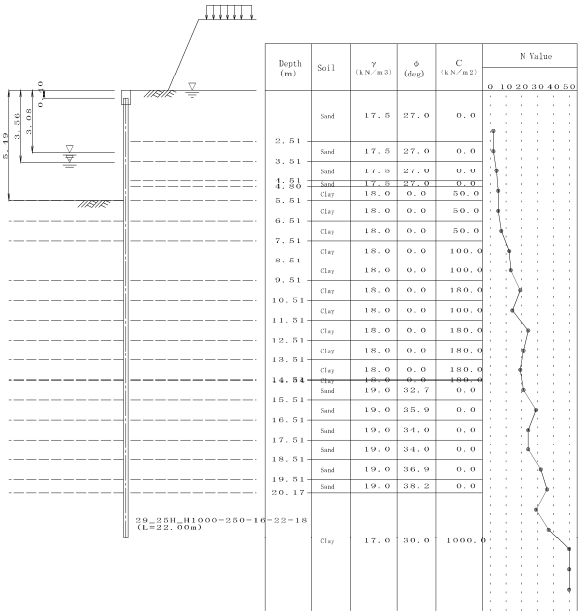
1 Design Condition

Block No. : L-8
Sta. : 7+940~8+120

Design Cross Section : Sta 7+940
Boring Name : BL-13

Specification : SSP SP-25H
(Combined) : H 1000-250-16-22-18

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.49 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_g	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.56 m (Normal Condition)
	L_{wp}'	=	3.08 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress: Chang's formula

Penetration depths: $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water: γ_w = 9.8 kN/m³

Type of water pressure: trapezoidal water pressure

Lateral pressure: calculated in consideration of site conditions

Study case:
- Normal Condition
- Seismic Condition

Design earthquake intensity: k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load

Horizontal load	Pt	=	23.4	kN/m	(Normal Condition)
	Pt'	=	62.8	kN/m	(Seismic Condition)
Depth of acting point	Ht	=	0.0	m	(Normal Condition)
	Ht'	=	0.0	m	(Seismic Condition)
Moment	Mm	=	0.0	kN･m/m	(Normal Condition)
	Mm'	=	33.9	kN･m/m	(Seismic Condition)
Depth of acting point	Hm'	=	0.00	m	(Seismic Condition)
	Hm	=	0.00	m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load: not considered

Minimum angle of rupture: ζ_0 = 10 degrees

Rear side angle of slope: not considered

Angle of rupture (clayey soil): $\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C} \cdot \tan\theta}$

Equilibrium factor of compression: K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m

E_0 = 2800N

Average N-value: calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value
1	2.01	2	11	12.01	24	21	22.01	37
2	3.01	2	12	13.01	21	22	23.01	50
3	4.01	4	13	14.01	19	23	24.01	50
4	5.01	5	14	15.01	21	24	25.01	50
5	6.01	5	15	16.01	29			
6	7.01	7	16	17.01	24			
7	8.01	12	17	18.01	24			
8	9.01	13	18	19.01	32			
9	10.01	19	19	20.01	36			
10	11.01	14	20	21.01	29			

soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
ϕ : internal friction angle of soil
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.6 Vertical Load

Vertical load on landside: calculated in consideration of embankment shape on landside

Vertical load on riverside: not considered

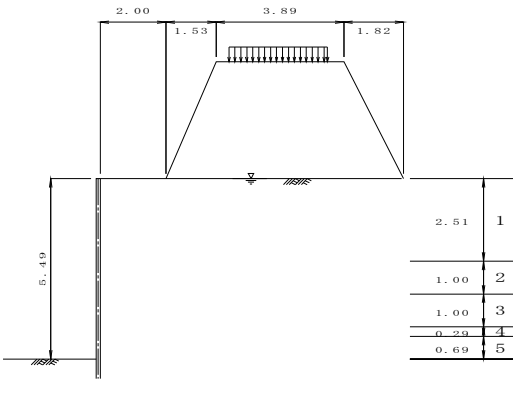
1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	2.51	2.51
2	3.51	1.00
3	4.51	1.00
4	4.80	0.29
5	5.51	0.71
6	6.51	1.00
7	7.51	1.00
8	8.51	1.00
9	9.51	1.00
10	10.51	1.00
11	11.51	1.00
12	12.51	1.00
13	13.51	1.00
14	14.51	1.00
15	14.54	0.03
16	15.51	0.97
17	16.51	1.00
18	17.51	1.00
19	18.51	1.00
20	19.51	1.00
21	20.17	0.66
22	25.01	4.84

No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	ϕ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	2.51	S	2.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
2	3.51	S	2.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
3	4.51	S	3.5	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
4	4.80	S	5.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
5	5.51	C	5.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
6	6.51	C	5.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
7	7.51	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
8	8.51	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
9	9.51	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
10	10.51	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
11	11.51	C	14.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
12	12.51	C	24.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
13	13.51	C	21.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
14	14.51	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
15	14.54	C	21.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
16	15.51	S	21.0	19.00	9.20	32.7	0.0	0.0	0.200	Auto	Auto
17	16.51	S	29.0	19.00	9.20	35.9	0.0	0.0	0.200	Auto	Auto
18	17.51	S	24.0	19.00	9.20	34.0	0.0	0.0	0.200	Auto	Auto
19	18.51	S	24.0	19.00	9.20	34.0	0.0	0.0	0.200	Auto	Auto
20	19.51	S	32.0	19.00	9.20	36.9	0.0	0.0	0.200	Auto	Auto
21	20.17	S	36.0	19.00	9.20	38.2	0.0	0.0	0.200	Auto	Auto
22	25.01	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note) depth : from top of coping to bottom of the layer C_o : soil adhesion

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle ϕ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	2.00	3.53	7.42	9.24	3.56	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	End point m	load strength Normal Condition kN/m2	Seismic Condition kN/m2
1	3.92	6.92	10.0	5.0

Angle of rapture in embankment: calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name: 25 H_H 1000 -250 -16 -22 -18
Young's modulus: E = 200000 N/mm²
Inertia sectional moment: I_0 = 829400 cm⁴
Sectional factor: Z_0 = 12240 cm³

Corrosion margin: t_1 = 1.00 mm (riverside) t_2 = 1.00 mm (landside)

Corrosion rate (to I_0): η = 0.87
Corrosion rate (to Z_0): η = 0.88
Section efficiency (to I_0): μ = 1.00
Section efficiency (to Z_0): μ = 1.00

Round unit of SSP length: 0.50 m

Allowable stress: σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

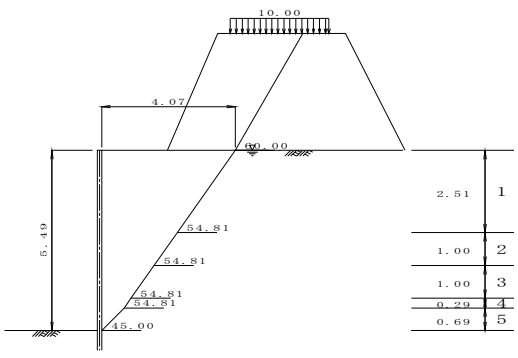
Allowable displacement: δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam: calculated as distributed load of each layer

Reduction of material modulus:
Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	5.49 ~ 4.80	Clay	0.0	15.0	50.0	42.62	44.23	53.80	45.00
2	4.80 ~ 4.51	Sand	27.0	15.0	0.0	36.96	44.23	47.04	54.81
3	4.51 ~ 3.51	Sand	27.0	15.0	0.0	34.73	44.23	44.20	54.81
4	3.51 ~ 2.51	Sand	27.0	15.0	0.0	27.03	44.23	34.40	54.81
5	2.51 ~ 0.00	Sand	27.0	15.0	0.0	19.33	44.23	24.60	54.81
6		embankment	30.0	———	0.0	67.64	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,

ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.00	0.69	0.00	0.00	0.69	0.69
2	54.81	0.29	0.69	0.69	0.89	0.98
3	54.81	1.00	0.89	0.98	1.60	1.98
4	54.81	1.00	1.60	1.98	2.30	2.98
5	54.81	2.51	2.30	2.98	4.07	5.49
6	60.00	3.56	4.07	5.49	6.13	9.05

From the above table, the loading width (L) on the ground surface is 4.07 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	8.32	158.11
Σ			158.11

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	2.21	22.10
Σ			22.10

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

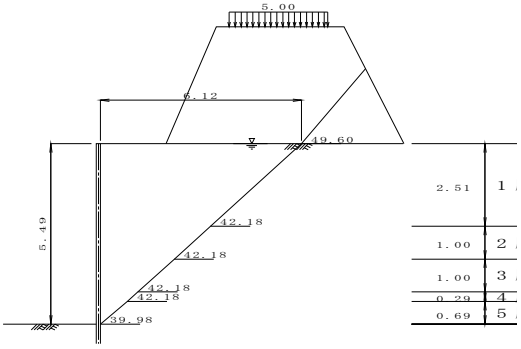
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{158.11 + 22.10 + 0.00}{4.07}$$

$$= 44.23\ \mathrm{kN/m^2}$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.49 ~ 4.80	Clay	0.0	15.0	50.0	42.62	52.86	53.80	0.200	11.31	39.98
2	4.80 ~ 4.51	Sand	27.0	15.0	0.0	36.96	52.86	47.04	0.200	11.31	42.18
3	4.51 ~ 3.51	Sand	27.0	15.0	0.0	34.73	52.86	44.20	0.200	11.31	42.18
4	3.51 ~ 2.51	Sand	27.0	15.0	0.0	27.03	52.86	34.40	0.200	11.31	42.18
5	2.51 ~ 0.00	Sand	27.0	15.0	0.0	19.33	52.86	24.60	0.200	11.31	42.18
6		embankment	30.0	———	0.0	67.64	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,

ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	39.98	0.69	0.00	0.00	0.82	0.69
2	42.18	0.29	0.82	0.69	1.14	0.98
3	42.18	1.00	1.14	0.98	2.25	1.98
4	42.18	1.00	2.25	1.98	3.35	2.98
5	42.18	2.51	3.35	2.98	6.12	5.49
6	49.60	2.29	6.12	5.49	8.07	7.78

From the above table, the loading width (L) on the ground surface is 6.12 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	16.24	308.54
Σ			308.54

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.00	15.00
Σ			15.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

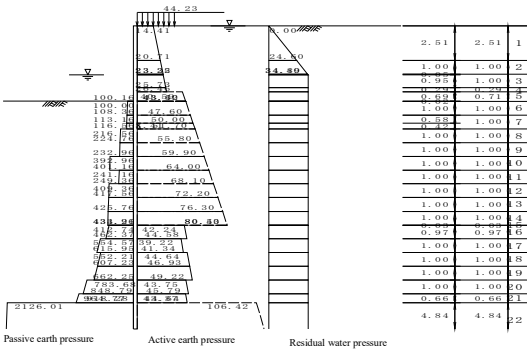
$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{308.54 + 15.00 + 0.00}{6.12}$$

$$= 52.86\ \mathrm{kN/m^2}$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 2.51	Sand	7.7	27.0	——— ———	44.225 63.552	0.33738 0.33738	0.32589 0.32589
2	2.51~ 3.51	Sand	7.7	27.0	——— ———	63.552 71.252	0.33738 0.33738	0.32589 0.32589
3	3.51~ 3.56	Sand	7.7	27.0	——— ———	71.252 71.637	0.33738 0.33738	0.32589 0.32589
4	3.56~ 4.51	Sand	7.7	27.0	——— ———	71.637 78.952	0.33738 0.33738	0.32589 0.32589

5	4.51~ 4.80	Sand	7.7	27.0	—— ——	78.952 81.185	0.33738 0.33738	0.32589 0.32589
6	4.80~ 5.49	Clay	8.2	——	50.0 50.0	81.185 86.843	—— ——	—— ——
7	5.49~ 5.51	Clay	8.2	——	50.0 50.0	86.843 87.007	—— ——	—— ——
8	5.51~ 6.51	Clay	8.2	——	50.0 50.0	87.007 95.207	—— ——	—— ——
9	6.51~ 7.09	Clay	8.2	——	50.0 50.0	95.207 100.000	—— ——	—— ——
10	7.09~ 7.51	Clay	8.2	——	50.0 50.0	100.000 103.407	—— ——	—— ——
11	7.51~ 8.51	Clay	8.2	——	100.0 100.0	103.407 111.607	—— ——	—— ——
12	8.51~ 9.51	Clay	8.2	——	100.0 100.0	111.607 119.807	—— ——	—— ——
13	9.51~ 10.51	Clay	8.2	——	180.0 180.0	119.807 128.007	—— ——	—— ——
14	10.51~ 11.51	Clay	8.2	——	100.0 100.0	128.007 136.207	—— ——	—— ——
15	11.51~ 12.51	Clay	8.2	——	180.0 180.0	136.207 144.407	—— ——	—— ——
16	12.51~ 13.51	Clay	8.2	——	180.0 180.0	144.407 152.607	—— ——	—— ——
17	13.51~ 14.51	Clay	8.2	——	180.0 180.0	152.607 160.807	—— ——	—— ——
18	14.51~ 14.54	Clay	8.2	——	180.0 180.0	160.807 161.053	—— ——	—— ——
19	14.54~ 15.51	Sand	9.2	32.7	—— ——	161.053 169.977	0.27152 0.27152	0.26227 0.26227
20	15.51~ 16.51	Sand	9.2	35.9	—— ——	169.977 179.177	0.23887 0.23887	0.23073 0.23073
21	16.51~ 17.51	Sand	9.2	34.0	—— ——	179.177 188.377	0.25791 0.25791	0.24912 0.24912
22	17.51~ 18.51	Sand	9.2	34.0	—— ——	188.377 197.577	0.25791 0.25791	0.24912 0.24912
23	18.51~ 19.51	Sand	9.2	36.9	—— ——	197.577 206.777	0.22925 0.22925	0.22144 0.22144
24	19.51~ 20.17	Sand	9.2	38.2	—— ——	206.777 212.849	0.21713 0.21713	0.20973 0.20973
25	20.17~ 25.01	Clay	7.2	——	1000.0 1000.0	212.849 247.697	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	$\Sigma\gamma h+Qp$ kN/m2	Kp	Kp × cos δ
7	5.49~ 5.51	Clay	8.2	0.0	50.0 50.0	0.000 0.164	—— ——	—— ——
8	5.51~ 6.51	Clay	8.2	0.0	50.0 50.0	0.164 8.364	—— ——	—— ——
9	6.51~ 7.09	Clay	8.2	0.0	50.0 50.0	8.364 13.157	—— ——	—— ——
10	7.09~ 7.51	Clay	8.2	0.0	50.0 50.0	13.157 16.564	—— ——	—— ——
11	7.51~ 8.51	Clay	8.2	0.0	100.0 100.0	16.564 24.764	—— ——	—— ——
12	8.51~ 9.51	Clay	8.2	0.0	100.0 100.0	24.764 32.964	—— ——	—— ——
13	9.51~ 10.51	Clay	8.2	0.0	180.0 180.0	32.964 41.164	—— ——	—— ——
14	10.51~ 11.51	Clay	8.2	0.0	100.0 100.0	41.164 49.364	—— ——	—— ——
15	11.51~ 12.51	Clay	8.2	0.0	180.0 180.0	49.364 57.564	—— ——	—— ——
16	12.51~ 13.51	Clay	8.2	0.0	180.0 180.0	57.564 65.764	—— ——	—— ——
17	13.51~ 14.51	Clay	8.2	0.0	180.0 180.0	65.764 73.964	—— ——	—— ——
18	14.51~ 14.54	Clay	8.2	0.0	180.0 180.0	73.964 74.210	—— ——	—— ——
19	14.54~ 15.51	Sand	9.2	32.7	—— ——	74.210 83.134	5.75791 5.75791	5.56172 5.56172
20	15.51~ 16.51	Sand	9.2	35.9	—— ——	83.134 92.334	6.90618 6.90618	6.67085 6.67085
21	16.51~ 17.51	Sand	9.2	34.0	—— ——	92.334 101.534	6.19149 6.19149	5.98052 5.98052
22	17.51~ 18.51	Sand	9.2	34.0	—— ——	101.534 110.734	6.19149 6.19149	5.98052 5.98052
23	18.51~ 19.51	Sand	9.2	36.9	—— ——	110.734 119.934	7.32679 7.32679	7.07714 7.07714
24	19.51~ 20.17	Sand	9.2	38.2	—— ——	119.934 126.006	7.92661 7.92661	7.65652 7.65652
25	20.17~ 25.01	Clay	7.2	30.0	1000.0 1000.0	126.006 160.854	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 2.51	14.41 20.71	—— ——	14.41 20.71	0.00 24.60	—— ——
2	2.51~ 3.51	20.71 23.22	—— ——	20.71 23.22	24.60 34.40	—— ——
3	3.51~ 3.56	23.22 23.35	—— ——	23.22 23.35	34.40 34.89	—— ——
4	3.56~ 4.51	23.35 25.73	—— ——	23.35 25.73	34.89 34.89	—— ——
5	4.51~ 4.80	25.73 26.46	—— ——	25.73 26.46	34.89 34.89	—— ——
6	4.80~ 5.49	-18.81 -13.16	40.59 43.42	40.59 43.42	34.89 34.89	—— ——
7	5.49~ 5.51	-13.16 -12.99	43.42 43.50	43.42 43.50	34.89 34.89	100.00 100.16
8	5.51~ 6.51	-12.99 -4.79	43.50 47.60	43.50 47.60	34.89 34.89	100.16 108.36
9	6.51~ 7.09	-4.79 0.00	47.60 50.00	47.60 50.00	34.89 34.89	108.36 113.16
10	7.09~ 7.51	0.00 3.41	50.00 51.70	50.00 51.70	34.89 34.89	113.16 116.56
11	7.51~ 8.51	-96.59 -88.39	51.70 55.80	51.70 55.80	34.89 34.89	216.56 224.76
12	8.51~ 9.51	-88.39 -80.19	55.80 59.90	55.80 59.90	34.89 34.89	224.76 232.96
13	9.51~ 10.51	-240.19 -231.99	59.90 64.00	59.90 64.00	34.89 34.89	392.96 401.16
14	10.51~ 11.51	-71.99 -63.79	64.00 68.10	64.00 68.10	34.89 34.89	241.16 249.36
15	11.51~ 12.51	-223.79 -215.59	68.10 72.20	68.10 72.20	34.89 34.89	409.36 417.56
16	12.51~ 13.51	-215.59 -207.39	72.20 76.30	72.20 76.30	34.89 34.89	417.56 425.76
17	13.51~ 14.51	-207.39 -199.19	76.30 80.40	76.30 80.40	34.89 34.89	425.76 433.96
18	14.51~ 14.54	-199.19 -198.95	80.40 80.53	80.40 80.53	34.89 34.89	433.96 434.21
19	14.54~ 15.51	42.24 44.58	—— ——	42.24 44.58	34.89 34.89	412.74 462.37
20	15.51~ 16.51	39.22 41.34	—— ——	39.22 41.34	34.89 34.89	554.57 615.95
21	16.51~ 17.51	44.64 46.93	—— ——	44.64 46.93	34.89 34.89	552.21 607.23
22	17.51~ 18.51	46.93 49.22	—— ——	46.93 49.22	34.89 34.89	607.23 662.25
23	18.51~ 19.51	43.75 45.79	—— ——	43.75 45.79	34.89 34.89	783.68 848.79
24	19.51~ 20.17	43.37 44.64	—— ——	43.37 44.64	34.89 34.89	918.28 964.77
25	20.17~ 25.01	-1787.15 -1752.30	106.42 123.85	106.42 123.85	34.89 34.89	2126.01 2160.85

- Formula for active earth pressure

Sand $P_{a1}=K_a\cdot\left[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_{a1}=\Sigma\gamma h+Q-2C$
$P_{a2}=K_c\cdot(\Sigma\gamma h+Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1}=\left[K_a(\Sigma\gamma h+Q)-2C\sqrt{K_a}\right]\cdot\cos\delta$

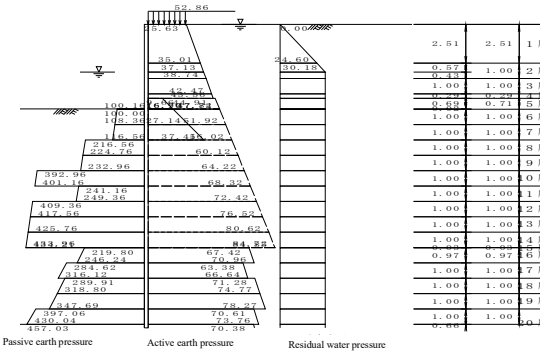
- Formula for passive earth pressure

Sand $P_p=K_p\cdot\left[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_p=\Sigma\gamma h+Q+2C$

Mixed soil $P_p=\left[K_p(\Sigma\gamma h+Q)+2C\sqrt{K_p}\right]\cdot\cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	$\Sigma\gamma h+Q$ kN/m2	γ whw kN/m2	k (k')	θ degree	Ka	Ka × cos δ	ζ degree
1	0.00~ 2.51	Sand	7.7	27.0	—— ——	52.86 72.19	0.00 24.60	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
2	2.51~ 3.08	Sand	7.7	27.0	—— ——	72.19 76.58	24.60 30.18	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——

3	3.08~ 3.51	Sand	7.7	27.0	—— ——	76.58 79.89	30.18 34.40	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
4	3.51~ 4.51	Sand	7.7	27.0	—— ——	79.89 87.59	34.40 44.20	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
5	4.51~ 4.80	Sand	7.7	27.0	—— ——	87.59 89.82	44.20 47.04	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
6	4.80~ 5.49	Clay	8.2	——	50.0 50.0	89.82 95.48	47.04 53.80	0.200 0.200	11.31 11.31	—— ——	—— ——	40.21 39.98
7	5.49~ 5.51	Clay	8.2	——	50.0 50.0	95.48 95.65	53.80 54.00	0.200 0.200	11.31 11.31	—— ——	—— ——	39.98 39.98
8	5.51~ 6.51	Clay	8.2	——	50.0 50.0	95.65 103.85	54.00 63.80	0.200 0.200	11.31 11.31	—— ——	—— ——	39.98 39.65
9	6.51~ 7.51	Clay	8.2	——	50.0 50.0	103.85 112.05	63.80 73.60	0.200 0.200	11.31 11.31	—— ——	—— ——	39.65 39.31
10	7.51~ 8.51	Clay	8.2	——	100.0 100.0	112.05 120.25	73.60 83.40	0.200 0.200	11.31 11.31	—— ——	—— ——	42.42 42.28
11	8.51~ 9.51	Clay	8.2	——	100.0 100.0	120.25 128.45	83.40 93.20	0.200 0.200	11.31 11.31	—— ——	—— ——	42.28 42.14
12	9.51~ 10.51	Clay	8.2	——	180.0 180.0	128.45 136.65	93.20 103.00	0.200 0.200	11.31 11.31	—— ——	—— ——	43.48 43.41
13	10.51~ 11.51	Clay	8.2	——	100.0 100.0	136.65 144.85	103.00 112.80	0.200 0.200	11.31 11.31	—— ——	—— ——	42.00 41.85
14	11.51~ 12.51	Clay	8.2	——	180.0 180.0	144.85 153.05	112.80 122.60	0.200 0.200	11.31 11.31	—— ——	—— ——	43.33 43.26
15	12.51~ 13.51	Clay	8.2	——	180.0 180.0	153.05 161.25	122.60 132.40	0.200 0.200	11.31 11.31	—— ——	—— ——	43.26 43.19
16	13.51~ 14.51	Clay	8.2	——	180.0 180.0	161.25 169.45	132.40 142.20	0.200 0.200	11.31 11.31	—— ——	—— ——	43.19 43.11
17	14.51~ 14.54	Clay	8.2	——	180.0 180.0	169.45 169.69	142.20 142.49	0.200 0.200	11.31 11.31	—— ——	—— ——	43.11 43.11
18	14.54~ 15.51	Sand	9.2	32.7	—— ——	169.69 178.62	142.49 152.00	0.200 0.200	11.31 11.31	0.41130 0.41130	0.39729 0.39729	——
19	15.51~ 16.51	Sand	9.2	35.9	—— ——	178.62 187.82	152.00 161.80	0.200 0.200	11.31 11.31	0.36735 0.36735	0.35483 0.35483	——
20	16.51~ 17.51	Sand	9.2	34.0	—— ——	187.82 197.02	161.80 171.60	0.200 0.200	11.31 11.31	0.39292 0.39292	0.37953 0.37953	——
21	17.51~ 18.51	Sand	9.2	34.0	—— ——	197.02 206.22	171.60 181.40	0.200 0.200	11.31 11.31	0.39292 0.39292	0.37953 0.37953	——
22	18.51~ 19.51	Sand	9.2	36.9	—— ——	206.22 215.42	181.40 191.20	0.200 0.200	11.31 11.31	0.35446 0.35446	0.34239 0.34239	——
23	19.51~ 20.17	Sand	9.2	38.2	—— ——	215.42 221.49	191.20 197.67	0.200 0.200	11.31 11.31	0.33826 0.33826	0.32674 0.32674	——
24	20.17~ 25.01	Clay	7.2	——	1000.0 1000.0	221.49 256.34	197.67 245.10	0.200 0.200	11.31 11.31	——	——	44.60 44.55

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ = 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cos δ
7	5.49~ 5.51	Clay	8.20	0.0	50.0 50.0	0.000 0.164	0.00 0.20	0.200 0.200	11.31 11.31	—— ——	—— ——
8	5.51~ 6.51	Clay	8.20	0.0	50.0 50.0	0.164 8.364	0.20 10.00	0.200 0.200	11.31 11.31	—— ——	—— ——
9	6.51~ 7.51	Clay	8.20	0.0	50.0 50.0	8.364 16.564	10.00 19.80	0.200 0.200	11.31 11.31	—— ——	—— ——
10	7.51~ 8.51	Clay	8.20	0.0	100.0 100.0	16.564 24.764	19.80 29.60	0.200 0.200	11.31 11.31	—— ——	—— ——
11	8.51~ 9.51	Clay	8.20	0.0	100.0 100.0	24.764 32.964	29.60 39.40	0.200 0.200	11.31 11.31	—— ——	—— ——
12	9.51~ 10.51	Clay	8.20	0.0	180.0 180.0	32.964 41.164	39.40 49.20	0.200 0.200	11.31 11.31	—— ——	—— ——
13	10.51~ 11.51	Clay	8.20	0.0	100.0 100.0	41.164 49.364	49.20 59.00	0.200 0.200	11.31 11.31	—— ——	—— ——
14	11.51~ 12.51	Clay	8.20	0.0	180.0 180.0	49.364 57.564	59.00 68.80	0.200 0.200	11.31 11.31	—— ——	—— ——
15	12.51~ 13.51	Clay	8.20	0.0	180.0 180.0	57.564 65.764	68.80 78.60	0.200 0.200	11.31 11.31	—— ——	—— ——
16	13.51~ 14.51	Clay	8.20	0.0	180.0 180.0	65.764 73.964	78.60 88.40	0.200 0.200	11.31 11.31	—— ——	—— ——
17	14.51~ 14.54	Clay	8.20	0.0	180.0 180.0	73.964 74.210	88.40 88.69	0.200 0.200	11.31 11.31	—— ——	—— ——
18	14.54~ 15.51	Sand	9.20	32.7	—— ——	74.210 83.134	88.69 98.20	0.200 0.200	11.31 11.31	2.96192 2.96192	2.96192 2.96192
19	15.51~ 16.51	Sand	9.20	35.9	—— ——	83.134 92.334	98.20 108.00	0.200 0.200	11.31 11.31	3.42367 3.42367	3.42367 3.42367
20	16.51~ 17.51	Sand	9.20	34.0	—— ——	92.334 101.534	108.00 117.80	0.200 0.200	11.31 11.31	3.13983 3.13983	3.13983 3.13983
21	17.51~ 18.51	Sand	9.20	34.0	—— ——	101.534 110.734	117.80 127.60	0.200 0.200	11.31 11.31	3.13983 3.13983	3.13983 3.13983
22	18.51~ 19.51	Sand	9.20	36.9	—— ——	110.734 119.934	127.60 137.40	0.200 0.200	11.31 11.31	3.58567 3.58567	3.58567 3.58567
23	19.51~ 20.17	Sand	9.20	38.2	—— ——	119.934 126.006	137.40 143.86	0.200 0.200	11.31 11.31	3.81070 3.81070	3.81070 3.81070
24	20.17~ 25.01	Clay	7.20	30.0	1000.0 1000.0	126.006 160.854	143.86 191.30	0.200 0.200	11.31 11.31	——	——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 2.51	25.63 35.01	—— ——	25.63 35.01	0.00 24.60	—— ——
2	2.51~ 3.08	35.01 37.13	—— ——	35.01 37.13	24.60 30.18	—— ——
3	3.08~ 3.51	37.13 38.74	—— ——	37.13 38.74	30.18 30.18	——
4	3.51~ 4.51	38.74 42.47	—— ——	38.74 42.47	30.18 30.18	—— ——
5	4.51~ 4.80	42.47 43.56	—— ——	42.47 43.56	30.18 30.18	—— ——
6	4.80~ 5.49	9.66 16.70	44.91 47.74	44.91 47.74	30.18 30.18	—— ——
7	5.49~ 5.51	16.70 16.90	47.74 47.82	47.74 47.82	30.18 30.18	100.00 100.16
8	5.51~ 6.51	16.90 27.14	47.82 51.92	47.82 51.92	30.18 30.18	100.16 108.36
9	6.51~ 7.51	27.14 37.41	51.92 56.02	51.92 56.02	30.18 30.18	108.36 116.56
10	7.51~ 8.51	-64.24 -54.21	56.02 60.12	56.02 60.12	30.18 30.18	216.56 224.76
11	8.51~ 9.51	-54.21 -44.16	60.12 64.22	60.12 64.22	30.18 30.18	224.76 232.96
12	9.51~ 10.51	-204.97 -195.02	64.22 68.32	64.22 68.32	30.18 30.18	392.96 401.16
13	10.51~ 11.51	-34.10 -24.03	68.32 72.42	68.32 72.42	30.18 30.18	241.16 249.36
14	11.51~ 12.51	-185.06 -175.09	72.42 76.52	72.42 76.52	30.18 30.18	409.36 417.56
15	12.51~ 13.51	-175.09 -165.12	76.52 80.62	76.52 80.62	30.18 30.18	417.56 425.76
16	13.51~ 14.51	-165.12 -155.14	80.62 84.72	80.62 84.72	30.18 30.18	425.76 433.96
17	14.51~ 14.54	-155.14 -154.84	84.72 84.85	84.72 84.85	30.18 30.18	433.96 434.21
18	14.54~ 15.51	67.42 70.96	—— ——	67.42 70.96	30.18 30.18	219.80 246.24
19	15.51~ 16.51	63.38 66.64	—— ——	63.38 66.64	30.18 30.18	284.62 316.12
20	16.51~ 17.51	71.28 74.77	—— ——	71.28 74.77	30.18 30.18	289.91 318.80
21	17.51~ 18.51	74.77 78.27	—— ——	74.77 78.27	30.18 30.18	318.80 347.69
22	18.51~ 19.51	70.61 73.76	—— ——	70.61 73.76	30.18 30.18	397.06 430.04
23	19.51~ 20.17	70.38 72.37	—— ——	70.38 72.37	30.18 30.18	457.03 480.17
24	20.17~ 25.01	-1733.79 -1691.83	110.74 128.17	110.74 128.17	30.18 30.18	2126.01 2160.85

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_a \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	3.08	0.00	0.00
2	4.08	1.00	2.66
3	5.08	2.00	3.77
4	5.49	2.41	4.13

$$p_{dw} = \pm\frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

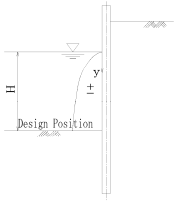
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

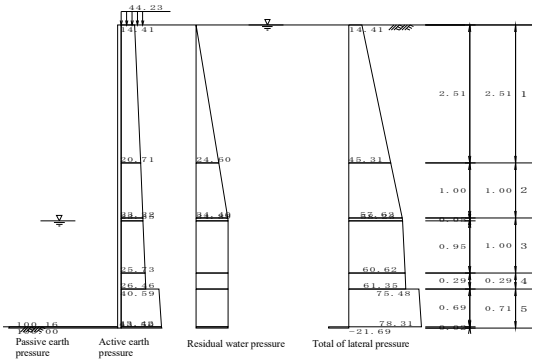
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition

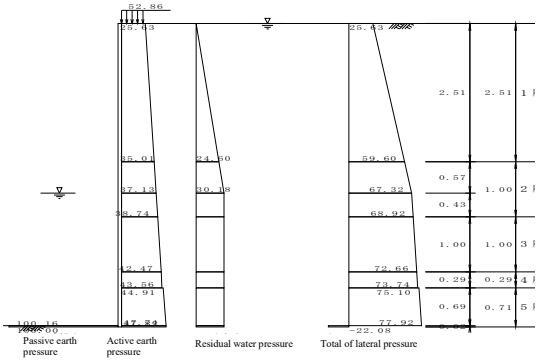


No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.51	14.41 20.71	0.00 24.60	——— ———	14.41 45.31
2	2.51~ 3.51	20.71 23.22	24.60 34.40	——— ———	45.31 57.62
3	3.51~ 3.56	23.22 23.35	34.40 34.89	——— ———	57.62 58.23
4	3.56~ 4.51	23.35 25.73	34.89 34.89	——— ———	58.23 60.62
5	4.51~ 4.80	25.73 26.46	34.89 34.89	——— ———	60.62 61.35
6	4.80~ 5.49	40.59 43.42	34.89 34.89	——— ———	75.48 78.31
7	5.49~ 5.51	43.42 43.50	34.89 34.89	100.00 100.16	-21.69 -21.77

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.49 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.51	25.63 35.01	0.00 24.60	——— ———	25.63 59.60
2	2.51~ 3.08	35.01 37.13	24.60 30.18	——— ———	59.60 67.32
3	3.08~ 3.51	37.13 38.74	30.18 30.18	——— ———	67.32 68.92
4	3.51~ 4.51	38.74 42.47	30.18 30.18	——— ———	68.92 72.66
5	4.51~ 4.80	42.47 43.56	30.18 30.18	——— ———	72.66 73.74
6	4.80~ 5.49	44.91 47.74	30.18 30.18	——— ———	75.10 77.92
7	5.49~ 5.51	47.74 47.82	30.18 30.18	100.00 100.16	-22.08 -22.16

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.49 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name		25 H _ H 1000 -250 -16 -22 -18	
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	892400 cm^4(original condition)
	I	=	776388 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 776388 \times 10^{-8} = 1.533 \times 10^6$

No	Depth m	N Value
1	2.01	2
2	3.01	2
3	4.01	4
4	5.01	5
5	6.01	5
6	7.01	7
7	8.01	12
8	9.01	13
9	10.01	19
10	11.01	14

No	Depth m	N Value
11	12.01	24
12	13.01	21
13	14.01	19
14	15.01	21
15	16.01	29
16	17.01	24
17	18.01	24
18	19.01	32
19	20.01	36
20	21.01	29

No	Depth m	N Value
21	22.01	37
22	23.01	50
23	24.01	50
24	25.01	50

5.2 Normal Condition

Assuming Kh = 7624 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.187 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 5.34 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.49 m) to 5.34 m depth (GL -10.83 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.49	0.52	5.0	5.0	2.60
2	6.01	1.00	5.0	7.0	6.00
3	7.01	1.00	7.0	12.0	9.50
4	8.01	1.00	12.0	13.0	12.50
5	9.01	1.00	13.0	19.0	16.00
6	10.01	0.82	19.0	14.9	13.94
	L = Σh = 5.34		ΣA =	60.54	

A: (upper N-value + lower N-value) × h/2

$$\text{Average N-value} \quad N' = \frac{\Sigma A}{L} = \frac{60.54}{5.34} = 11.33$$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 11.33 = 31728 \text{ kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 31728 = 105759 \text{ kN/m}^3 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 105759(10.00/0.3)^{-3/4} = 7624 \text{ kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 7624 kN/m3.

5.3 Seismic Condition

Assuming Kh = 14039 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.218 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 4.59 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.49 m) and 4.59 m depth (GL -10.08 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.49	0.52	5.0	5.0	2.60
2	6.01	1.00	5.0	7.0	6.00
3	7.01	1.00	7.0	12.0	9.50
4	8.01	1.00	12.0	13.0	12.50
5	9.01	1.00	13.0	19.0	16.00
6	10.01	0.07	19.0	18.7	1.25
	L = Σh = 4.59		ΣA =	47.85	

A: (upper N-value + lower N-value) × h/2

$$\text{Average N-value} \quad N' = \frac{\Sigma A}{L}$$

$$= \frac{47.85}{4.59}$$

$$= 10.43$$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 10.43 = 29213\ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 29213 = 194753\ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 194753(10.00/0.3)^{-3/4} = 14039\ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 14039 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.51	2.51	14.41 45.31	18.09 56.86	4.65 3.82	84.17 217.03
2	2.51~ 3.51	1.00	45.31 57.62	22.65 28.81	2.65 2.31	59.96 66.65
3	3.51~ 3.56	0.05	57.62 58.23	1.44 1.46	1.96 1.95	2.83 2.83
4	3.56~ 4.51	0.95	58.23 60.62	27.66 28.79	1.61 1.30	44.63 37.34
5	4.51~ 4.80	0.29	60.62 61.35	8.79 8.90	0.88 0.79	7.76 7.00
6	4.80~ 5.49	0.69	75.48 78.31	26.04 27.02	0.46 0.23	11.98 6.21
				ΣP = 256.51	ΣM = 548.38	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 23.4 kN/m
depth to acting position H_t = 0.0 m
moment M_m = 0.0 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 5.49 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 128.47\ kN \cdot m$

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	3.08~ 4.08	1.00	0.0 2.7	0.00 1.33	2.08 1.74	0.00 2.32
2	4.08~ 5.08	1.00	2.7 3.8	1.33 1.88	1.08 0.74	1.43 1.40
3	5.08~ 5.49	0.41	3.8 4.1	0.77 0.85	0.27 0.14	0.21 0.12
				ΣPdw = 6.16	Σ Mdw = 5.48	

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}}$$

$$= \frac{1121.17}{386.21} = 2.90\ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 386.21}{5.49} = 140.70\ kN/m$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name 25 H _ H 1000 -250 -16 -22 -18
Unit width B = 1.0000 m
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.87
Section efficiency μ = 1.00
Young's modulus E = 200000 N/mm^2
Inertia sectional moment I_0 = 892400 cm^4 (original condition)
I = 776388 cm^4 (after reduction by corrosion and section)

$EI = 200000 \times 10^3 \times 776388 \times 10^{-8} = 1.553 \times 10^6$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t}$$

$$= \frac{676.84}{279.91} = 2.42\ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 279.91}{5.49} = 101.97\ kN/m$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.51	2.51	25.63 59.60	32.17 74.80	4.65 3.82	149.70 285.50
2	2.51~ 3.08	0.57	59.60 67.32	16.99 19.19	2.79 2.60	47.39 49.88
3	3.08~ 3.51	0.43	67.32 68.92	14.47 14.82	2.27 2.12	32.81 31.46
4	3.51~ 4.51	1.00	68.92 72.66	34.46 36.33	1.65 1.31	56.75 47.71
5	4.51~ 4.80	0.29	72.66 73.74	10.54 10.69	0.88 0.79	9.31 8.41
6	4.80~ 5.49	0.69	75.10 77.92	25.91 26.88	0.46 0.23	11.92 6.18
				ΣP = 317.25	ΣM = 737.02	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 62.8 kN/m
depth to acting position H_t = 0.00 m
moment M_m = 33.9 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 5.49 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 378.67\ kN \cdot m$

6.2.1 Normal Condition

modulus of lateral subgrade reaction K_h = 7624 kN/m^3
calculated value β = 0.18717 m^{-1}
resultant earth force (lateral) P_0 = 279.91 kN/m
height of acting position of load h_0 = 2.42 m
moment M_0 = 676.84 kN・m/m

in consideration of ψ_m = 1.466,
maximum moment M_{max} = 992.21 kN・m/m
depth of generated position of M_{max} l_m = 2.582 m
depth of 1st fixed point l_i = 6.778 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction K_h = 14039 kN/m^3
calculated value β = 0.21804 m^{-1}
resultant earth force (lateral) P_0 = 386.21 kN/m
height of acting position of load h_0 = 2.90 m
moment M_0 = 1121.17 kN・m/m

in consideration of ψ_m = 1.291,
maximum moment M_{max} = 1447.61 kN・m/m
depth of generated position of M_{max} l_m = 1.906 m
depth of 1st fixed point l_i = 5.508 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name 25 H _ H 1000 -250 -16 -22 -18
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.88
Section efficiency μ = 1.00
Module of section Z_0 = 12240 cm^3 (original condition)
Z = 10771 cm^3 (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{992.21 \times 10^6}{10771 \times 10^3} = 92\ N/mm^2 \leqq \sigma_a = 180\ N/mm^2$$

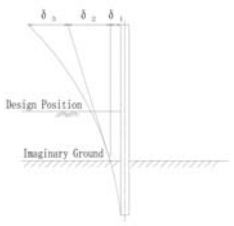
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1447.61 \times 10^6}{10771 \times 10^3} = 134\ N/mm^2 \leqq \sigma_a = 270\ N/mm^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation

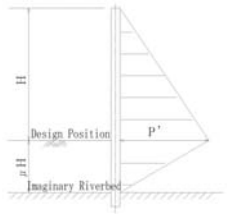


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.1872\times 2.42)\times 279.91}{2\times 2.00\times 10^8\times 776388\times 10^{-8}\times 0.1872^3} = 0.01997 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.1872\times 2.42)\times 279.91}{2\times 2.00\times 10^8\times 776388\times 10^{-8}\times 0.1872^2}\times(5.49+0.00) = 0.02691 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.49} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{101.97\times 5.49^4}{120\times 2.00\times 10^8\times 776388\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

$$= 0.00199 \text{ m}$$

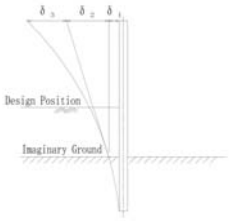
$$\delta = \delta 1+\delta 2+\delta 3$$
$$= 0.01997 + 0.02691 + 0.00199$$
$$= 0.04886 \text{ m}$$
Size = 48.86 ≦ δa = 50.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

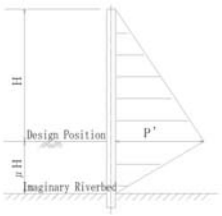


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2180\times 2.90)\times 386.21}{2\times 2.00\times 10^8\times 776388\times 10^{-8}\times 0.2180^3} = 0.01959 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.2180\times 2.90)\times 386.21}{2\times 2.00\times 10^8\times 776388\times 10^{-8}\times 0.2180^2}\times(5.49+0.00) = 0.03254 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.49} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{140.70\times 5.49^4}{120\times 2.00\times 10^8\times 776388\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

$$= 0.00274 \text{ m}$$

$$\delta = \delta 1+\delta 2+\delta 3$$
$$= 0.01959 + 0.03254 + 0.00274$$
$$= 0.05488 \text{ m}$$
Size = 54.88 ≦ δa = 75.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name		25 H _ H 1000 -250 -16 -22 -18
Unit width	B	= 1.0000 m
Corrosion rate	η	= 1.00
Section efficiency	μ	= 1.00
Young's modulus	E	= 200000 N/mm²
Inertia sectional moment	I_0	= 892400 cm⁴ (original condition)
	I	= 892400 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 892400 × 10⁻⁸		= 1.785 × 10⁶

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 7624 kN/m³
Calculated value β = 0.18077 m⁻¹

Penetration length of SSP $D = 0.00 + \frac{3}{0.181} = 16.60$ m
Whole length of SSP $L = 5.49 - 0.40 + 16.60 = 21.69$ m

7.1.1 Seismic Condition

Modules of lateral subgrade reaction K_h = 14039 kN/m³
Calculated value β = 0.21058 m⁻¹

Penetration length of SSP $D = 0.00 + \frac{3}{0.211} = 14.25$ m
Whole length of SSP $L = 5.49 - 0.40 + 14.25 = 19.34$ m

Therefore, the total length of the sheet pile is 22.00 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile 25 H _ H 1000 -250 -16 -22 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	892400		
Sectional Modulus	Z (cm3)	12240		
Maximum bending moment	Mmax (kN・m・m)		992.21	1447.61
Stress intensity	σ (N/mm2)		92 (180)	134 (270)
Lateral displacement	δ (mm)		48.86 (50.0)	54.88 (75.0)
Penetration depths	D (m)		16.60	14.25
Whole length of SSP	L (m)	22.00		

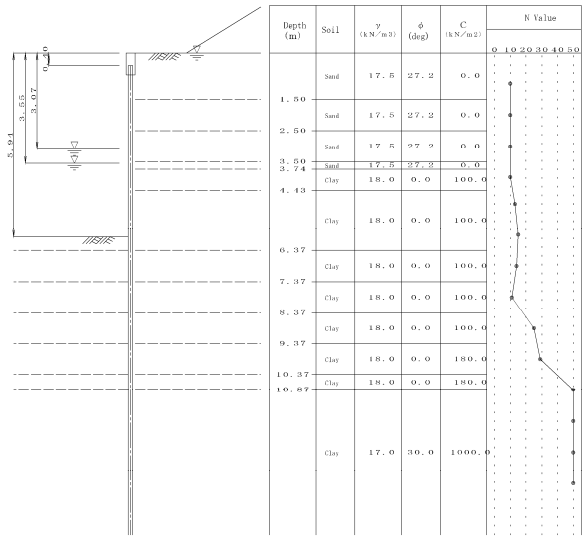
Block No. : L-9
Sta. : 8+120~8+300

Design Cross Section : Sta 8+120
Boring Name : DD-BH-L05

Specification : SSP SP-10H
(Combined) : H 900-250-14-25-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.94 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_R	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.55 m (Normal Condition)
	L_{wp}'	=	3.07 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress : Chang's formula

Penetration depths : $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water : γ_w = 9.8 kN/m³

Type of water pressure : trapezoidal water pressure

Lateral pressure : calculated in consideration of site conditions

Study case : - Normal Condition
- Seismic Condition

Design earthquake intensity : k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	23.4 kN/m	(Normal Condition)
		Pt'	=	62.8 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	Mm	=	0.0 kN･m/m	(Normal Condition)
		Mm'	=	33.9 kN･m/m	(Seismic Condition)
	Depth of acting point	Hm'	=	0.00 m	(Seismic Condition)
		Hm	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load : not considered

Minimum angle of rupture : ζ_0 = 10 degrees

Rear side angle of slope : not considered

Angle of rupture (clayey soil) : $\zeta = \tan^{-1}\sqrt{1-\frac{\sum \gamma h + 2Q}{2C}} \cdot \tan\theta$

Equilibrium factor of compression : K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m

E_0 = 2800N

Average N-value : calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value
1	1.00	10	11	10.87	50
2	2.00	10	12	11.87	50
3	3.00	10	13	12.87	50
4	4.00	10	14	13.87	50
5	4.87	13	15	14.87	50
6	5.87	15			
7	6.87	14			
8	7.87	11			
9	8.87	25			
10	9.87	29			

1.6 Vertical Load

Vertical load on landside : calculated in consideration of embankment shape on landside

Vertical load on riverside : not considered

1.7 Soil Modulus

Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	1.50	1.50
2	2.50	1.00
3	3.50	1.00
4	3.74	0.24
5	4.43	0.69
6	6.37	1.94
7	7.37	1.00
8	8.37	1.00
9	9.37	1.00
10	10.37	1.00
11	10.87	0.50
12	14.87	4.00

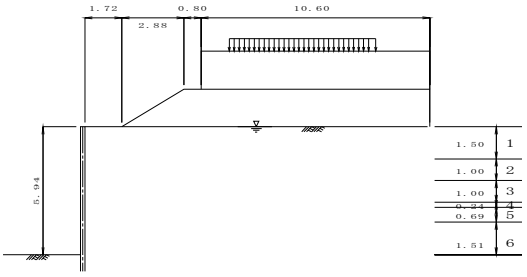
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	1.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
2	2.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
3	3.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
4	3.74	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
5	4.43	C	9.9	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
6	6.37	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
7	7.37	C	15.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
8	8.37	C	14.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
9	9.37	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
10	10.37	C	25.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
11	10.87	C	29.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
12	14.87	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate				Thickness	soil single weight γ		internal friction angle	stickiness	decay angle ζ	
		Bottom Left m	Top Left m	Top Right m	Bottom Right m	h m	Normal Condition kN/m3	Seismic Condition kN/m3	φ degree	C kN/m2	Normal Condition degree	Seismic Condition degree
1	Sand	1.72	4.60	16.00	16.00	1.75	19.0	19.0	30.0	0.0	Auto	Auto
2	Sand	5.40	5.40	16.00	16.00	1.76	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area		load strength	
	From m	End point m	Normal Condition kN/m2	Seismic Condition kN/m2
1	6.70	13.50	10.0	5.0

Angle of rapture in embankment calculated in consideration of embankment conditions

1	5.94 ~ 4.43	Clay	0.0	15.0	100.0	46.84	21.79	58.21	45.00
2	4.43 ~ 3.74	Clay	0.0	15.0	100.0	34.46	21.79	43.41	45.00
3	3.74 ~ 3.50	Sand	27.2	15.0	0.0	28.80	21.79	36.65	54.95
4	3.50 ~ 2.50	Sand	27.2	15.0	0.0	26.95	21.79	34.30	54.95
5	2.50 ~ 1.50	Sand	27.2	15.0	0.0	19.25	21.79	24.50	54.95
6	1.50 ~ 0.00	Sand	27.2	15.0	0.0	11.55	21.79	14.70	54.95
7		embankment	30.0	———	0.0	66.69	10.00	0.00	60.00
8		embankment	30.0	———	0.0	33.44	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45º since θ = 0º

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00º)
- φ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = $\tan^{-1}$k or θ = $\tan^{-1}$k'
- γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m^2)
- C : cohesive force of soil (kN/m^2)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.00	1.51	0.00	0.00	1.51	1.51
2	45.00	0.69	1.51	1.51	2.20	2.20
3	54.95	0.24	2.20	2.20	2.37	2.44
4	54.95	1.00	2.37	2.44	3.07	3.44
5	54.95	1.00	3.07	3.44	3.77	4.44
6	54.95	1.50	3.77	4.44	4.82	5.94
7	60.00	1.75	4.82	5.94	5.83	7.69
8	60.00	1.76	5.83	7.69	6.85	9.45

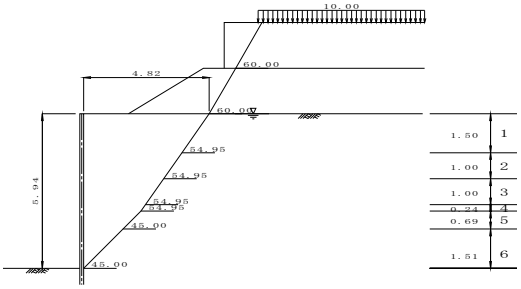
From the above table, the loading width (L) on the ground surface is 4.82 m.

1.9 Steel Sheet Pile (SSP)

Material name	10 H _ H 900 -250 -14 -25 -18		
Young's modulus	E =	200000 N/mm^2	
Inertia sectional moment	I_0 =	631400 cm^4	
Sectional factor	Z_0 =	10120 cm^3	
Corrosion margin	t_1 =	1.00 mm (riverside)	t_2 = 1.00 mm (landside)
Corrosion rate (to I_0)	η =	0.87	
Corrosion rate (to Z_0)	η =	0.88	
Section efficiency (to I_0)	μ =	1.00	
Section efficiency (to Z_0)	μ =	1.00	
Round unit of SSP length		0.50 m	
Allowable stress	σ_a =	180 N/mm (Normal)	
	σ_a' =	270 N/mm (Seismic)	
Allowable displacement	δ_a =	50.0 mm (Normal)	
	δ_a' =	75.0 mm (Seismic)	
Bending of cantilever beam		calculated as distributed load of each layer	
Reduction of material modulus		Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction Not reduced: I_0 applied to calculation of penetration depth Reduced: I_0 applied to calculation of section forces and displacement Reduced: Z_0 applied to calculation of stresses	

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	3.80	72.11
2	19.0	1.66	31.50
Σ			103.62

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	0.15	1.50
Σ			1.50

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

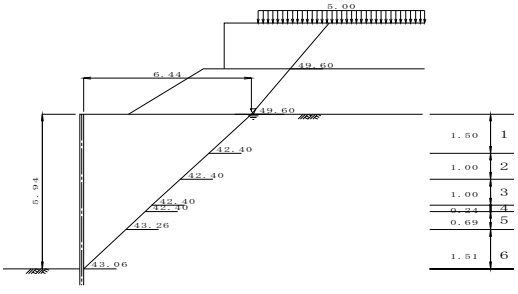
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times l)+\Sigma P}{L}$$

$$= \frac{103.62 + 1.50 + 0.00}{4.82}$$

$$= 21.79\ \mathrm{kN/m^2}$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.94 ~ 4.43	Clay	0.0	15.0	100.0	46.84	39.94	58.21	0.200	11.31	43.06
2	4.43 ~ 3.74	Clay	0.0	15.0	100.0	34.46	39.94	43.41	0.200	11.31	43.26
3	3.74 ~ 3.50	Sand	27.2	15.0	0.0	28.80	39.94	36.65	0.200	11.31	42.40
4	3.50 ~ 2.50	Sand	27.2	15.0	0.0	26.95	39.94	34.30	0.200	11.31	42.40
5	2.50 ~ 1.50	Sand	27.2	15.0	0.0	19.25	39.94	24.50	0.200	11.31	42.40
6	1.50 ~ 0.00	Sand	27.2	15.0	0.0	11.55	39.94	14.70	0.200	11.31	42.40
7		embankment	30.0	———	0.0	66.69	5.00	0.00	0.200	11.31	49.60
8		embankment	30.0	———	0.0	33.44	5.00	0.00	0.200	11.31	49.60

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	43.06	1.51	0.00	0.00	1.62	1.51
2	43.26	0.69	1.62	1.51	2.35	2.20
3	42.40	0.24	2.35	2.20	2.61	2.44
4	42.40	1.00	2.61	2.44	3.71	3.44
5	42.40	1.00	3.71	3.44	4.80	4.44
6	42.40	1.50	4.80	4.44	6.44	5.94
7	49.60	1.75	6.44	5.94	7.93	7.69
8	49.60	1.76	7.93	7.69	9.43	9.45

From the above table, the loading width (L) on the ground surface is 6.44 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	7.05	133.98
2	19.0	5.78	109.77
Σ			243.75

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	2.73	13.66
Σ			13.66

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

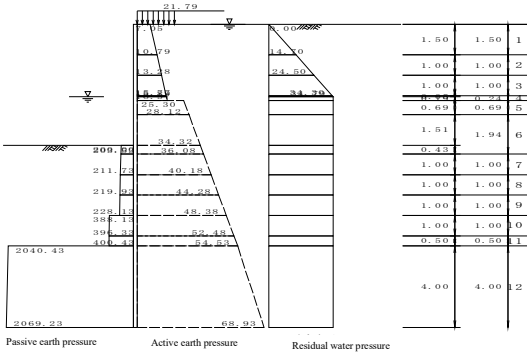
$$Q = \frac{\Sigma(\gamma \times A) + \Sigma(Q \times l) + \Sigma P}{L}$$

$$= \frac{243.75 + 13.66 + 0.00}{6.44}$$

$$= 39.94 \ kN/m^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qu kN/m2	Ka	Ka × cos δ
1	0.00~ 1.50	Sand	7.7	27.2	——— ———	21.793 33.343	0.33489 0.33489	0.32348 0.32348
2	1.50~ 2.50	Sand	7.7	27.2	——— ———	33.343 41.043	0.33489 0.33489	0.32348 0.32348
3	2.50~ 3.50	Sand	7.7	27.2	——— ———	41.043 48.743	0.33489 0.33489	0.32348 0.32348
4	3.50~ 3.55	Sand	7.7	27.2	——— ———	48.743 49.128	0.33489 0.33489	0.32348 0.32348
5	3.55~ 3.74	Sand	7.7	27.2	——— ———	49.128 50.591	0.33489 0.33489	0.32348 0.32348
6	3.74~ 4.43	Clay	8.2	———	100.0 100.0	50.591 56.249	——— ———	——— ———
7	4.43~ 5.94	Clay	8.2	———	100.0 100.0	56.249 68.631	——— ———	——— ———
8	5.94~ 6.37	Clay	8.2	———	100.0 100.0	68.631 72.157	——— ———	——— ———
9	6.37~ 7.37	Clay	8.2	———	100.0 100.0	72.157 80.357	——— ———	——— ———
10	7.37~ 8.37	Clay	8.2	———	100.0 100.0	80.357 88.557	——— ———	——— ———
11	8.37~ 9.37	Clay	8.2	———	100.0 100.0	88.557 96.757	——— ———	——— ———
12	9.37~ 10.37	Clay	8.2	———	180.0 180.0	96.757 104.957	——— ———	——— ———
13	10.37~ 10.87	Clay	8.2	———	180.0 180.0	104.957 109.057	——— ———	——— ———
14	10.87~ 14.87	Clay	7.2	———	1000.0 1000.0	109.057 137.857	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
8	5.94~ 6.37	Clay	8.2	0.0	100.0 100.0	0.000 3.526	——— ———	——— ———
9	6.37~ 7.37	Clay	8.2	0.0	100.0 100.0	3.526 11.726	——— ———	——— ———
10	7.37~ 8.37	Clay	8.2	0.0	100.0 100.0	11.726 19.926	——— ———	——— ———
11	8.37~ 9.37	Clay	8.2	0.0	100.0 100.0	19.926 28.126	——— ———	——— ———
12	9.37~ 10.37	Clay	8.2	0.0	180.0 180.0	28.126 36.326	——— ———	——— ———
13	10.37~ 10.87	Clay	8.2	0.0	180.0 180.0	36.326 40.426	——— ———	——— ———
14	10.87~ 14.87	Clay	7.2	30.0	1000.0 1000.0	40.426 69.226	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.50	7.05 10.79	——— ———	7.05 10.79	0.00 14.70	——— ———
2	1.50~ 2.50	10.79 13.28	——— ———	10.79 13.28	14.70 24.50	——— ———
3	2.50~ 3.50	13.28 15.77	——— ———	13.28 15.77	24.50 34.30	——— ———
4	3.50~ 3.55	15.77 15.89	——— ———	15.77 15.89	34.30 34.79	——— ———
5	3.55~ 3.74	15.89 16.37	——— ———	15.89 16.37	34.79 34.79	——— ———
6	3.74~ 4.43	-149.41 -143.75	25.30 28.12	25.30 28.12	34.79 34.79	——— ———
7	4.43~ 5.94	-143.75 -131.37	28.12 34.32	28.12 34.32	34.79 34.79	——— ———
8	5.94~ 6.37	-131.37 -127.84	34.32 36.08	34.32 36.08	34.79 34.79	200.00 203.53
9	6.37~ 7.37	-127.84 -119.64	36.08 40.18	36.08 40.18	34.79 34.79	203.53 211.73
10	7.37~ 8.37	-119.64 -111.44	40.18 44.28	40.18 44.28	34.79 34.79	211.73 219.93
11	8.37~ 9.37	-111.44 -103.24	44.28 48.38	44.28 48.38	34.79 34.79	219.93 228.13
12	9.37~ 10.37	-263.24 -255.04	48.38 52.48	48.38 52.48	34.79 34.79	388.13 396.33
13	10.37~ 10.87	-255.04 -250.94	52.48 54.53	52.48 54.53	34.79 34.79	396.33 400.43
14	10.87~ 14.87	-1890.94 -1862.14	54.53 68.93	54.53 68.93	34.79 34.79	2040.43 2069.23

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

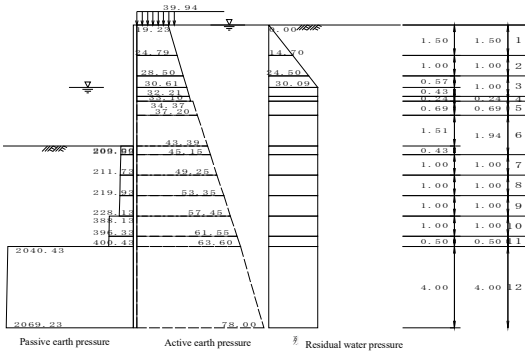
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 1.50	Sand	7.7	27.2	——— ———	39.94 51.49	0.00 14.70	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
2	1.50~ 2.50	Sand	7.7	27.2	——— ———	51.49 59.19	14.70 24.50	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
3	2.50~ 3.07	Sand	7.7	27.2	——— ———	59.19 63.58	24.50 30.09	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
4	3.07~ 3.50	Sand	7.7	27.2	——— ———	63.58 66.89	30.09 34.30	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
5	3.50~ 3.74	Sand	7.7	27.2	——— ———	66.89 68.74	34.30 36.65	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
6	3.74~ 4.43	Clay	8.2	———	100.0 100.0	68.74 74.40	36.65 43.41	0.200 0.200	11.31 11.31	——— ———	——— ———	43.35 43.26
7	4.43~ 5.94	Clay	8.2	———	100.0 100.0	74.40 86.78	43.41 58.21	0.200 0.200	11.31 11.31	——— ———	——— ———	43.26 43.06
8	5.94~ 6.37	Clay	8.2	———	100.0 100.0	86.78 90.31	58.21 62.43	0.200 0.200	11.31 11.31	——— ———	——— ———	43.06 43.00
9	6.37~ 7.37	Clay	8.2	———	100.0 100.0	90.31 98.51	62.43 72.23	0.200 0.200	11.31 11.31	——— ———	——— ———	43.00 42.87
10	7.37~ 8.37	Clay	8.2	———	100.0 100.0	98.51 106.71	72.23 82.03	0.200 0.200	11.31 11.31	——— ———	——— ———	42.87 42.73
11	8.37~ 9.37	Clay	8.2	———	100.0 100.0	106.71 114.91	82.03 91.83	0.200 0.200	11.31 11.31	——— ———	——— ———	42.73 42.59
12	9.37~ 10.37	Clay	8.2	———	180.0 180.0	114.91 123.11	91.83 101.63	0.200 0.200	11.31 11.31	——— ———	——— ———	43.71 43.64
13	10.37~ 10.87	Clay	8.2	———	180.0 180.0	123.11 127.21	101.63 106.53	0.200 0.200	11.31 11.31	——— ———	——— ———	43.64 43.60
14	10.87~ 14.87	Clay	7.2	———	1000.0 1000.0	127.21 156.01	106.53 145.73	0.200 0.200	11.31 11.31	——— ———	——— ———	44.76 44.72

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma \gamma h + 2Q}{2C}} \cdot \tan\theta$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
8	5.94~ 6.37	Clay	8.20	0.0	100.0 100.0	0.000 3.526	0.00 4.21	0.200 0.200	11.31 11.31	——— ———	——— ———
9	6.37~ 7.37	Clay	8.20	0.0	100.0 100.0	3.526 11.726	4.21 14.01	0.200 0.200	11.31 11.31	——— ———	——— ———
10	7.37~ 8.37	Clay	8.20	0.0	100.0 100.0	11.726 19.926	14.01 23.81	0.200 0.200	11.31 11.31	——— ———	——— ———
11	8.37~ 9.37	Clay	8.20	0.0	100.0 100.0	19.926 28.126	23.81 33.61	0.200 0.200	11.31 11.31	——— ———	——— ———
12	9.37~ 10.37	Clay	8.20	0.0	180.0 180.0	28.126 36.326	33.61 43.41	0.200 0.200	11.31 11.31	——— ———	——— ———
13	10.37~ 10.87	Clay	8.20	0.0	180.0 180.0	36.326 40.426	43.41 48.31	0.200 0.200	11.31 11.31	——— ———	——— ———
14	10.87~ 14.87	Clay	7.20	30.0	1000.0 1000.0	40.426 69.226	48.31 87.51	0.200 0.200	11.31 11.31	——— ———	——— ———

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.50	19.23 24.79	——— ———	19.23 24.79	0.00 14.70	——— ———
2	1.50~ 2.50	24.79 28.50	——— ———	24.79 28.50	14.70 24.50	——— ———
3	2.50~ 3.07	28.50 30.61	——— ———	28.50 30.61	24.50 30.09	——— ———
4	3.07~ 3.50	30.61 32.21	——— ———	30.61 32.21	30.09 30.09	——— ———
5	3.50~ 3.74	32.21 33.10	——— ———	32.21 33.10	30.09 30.09	——— ———
6	3.74~ 4.43	-117.03 -110.16	34.37 37.20	34.37 37.20	30.09 30.09	——— ———
7	4.43~ 5.94	-110.16 -95.11	37.20 43.39	37.20 43.39	30.09 30.09	——— ———
8	5.94~ 6.37	-95.11 -90.82	43.39 45.15	43.39 45.15	30.09 30.09	200.00 203.53
9	6.37~ 7.37	-90.82 -80.83	45.15 49.25	45.15 49.25	30.09 30.09	203.53 211.73
10	7.37~ 8.37	-80.83 -70.82	49.25 53.35	49.25 53.35	30.09 30.09	211.73 219.93
11	8.37~ 9.37	-70.82 -60.81	53.35 57.45	53.35 57.45	30.09 30.09	219.93 228.13
12	9.37~ 10.37	-221.42 -211.48	57.45 61.55	57.45 61.55	30.09 30.09	388.13 396.33
13	10.37~ 10.87	-211.48 -206.51	61.55 63.60	61.55 63.60	30.09 30.09	396.33 400.43
14	10.87~ 14.87	-1847.21 -1812.58	63.60 78.00	63.60 78.00	30.09 30.09	2040.43 2069.23

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma \gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	3.07	0.00	0.00
2	4.07	1.00	2.91
3	5.07	2.00	4.11
4	5.94	2.87	4.92

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

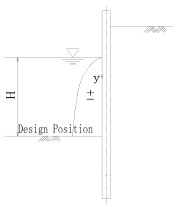
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

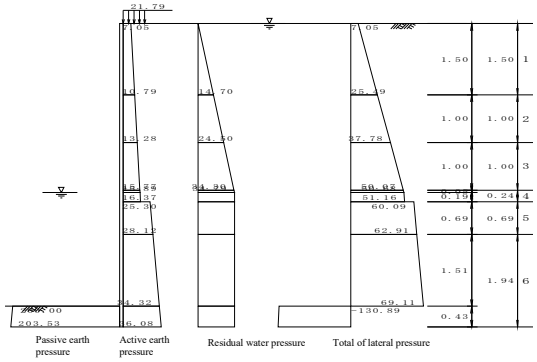
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition

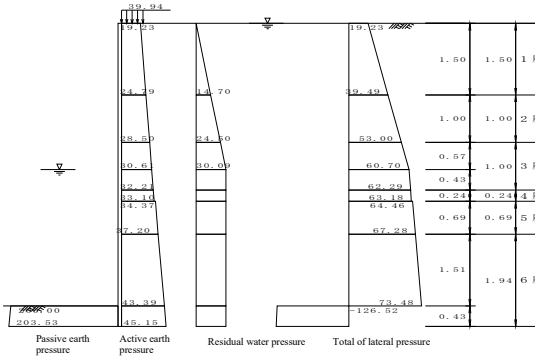


No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	7.05 10.79	0.00 14.70	——— ———	7.05 25.49
2	1.50~ 2.50	10.79 13.28	14.70 24.50	——— ———	25.49 37.78
3	2.50~ 3.50	13.28 15.77	24.50 34.30	——— ———	37.78 50.07
4	3.50~ 3.55	15.77 15.89	34.30 34.79	——— ———	50.07 50.68
5	3.55~ 3.74	15.89 16.37	34.79 34.79	——— ———	50.68 51.16
6	3.74~ 4.43	25.30 28.12	34.79 34.79	——— ———	60.09 62.91
7	4.43~ 5.94	28.12 34.32	34.79 34.79	——— ———	62.91 69.11
8	5.94~ 6.37	34.32 36.08	34.79 34.79	200.00 203.53	-130.89 -132.66

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.94 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	19.23 24.79	0.00 14.70	——— ———	19.23 39.49
2	1.50~ 2.50	24.79 28.50	14.70 24.50	——— ———	39.49 53.00
3	2.50~ 3.07	28.50 30.61	24.50 30.09	——— ———	53.00 60.70
4	3.07~ 3.50	30.61 32.21	30.09 30.09	——— ———	60.70 62.29
5	3.50~ 3.74	32.21 33.10	30.09 30.09	——— ———	62.29 63.18
6	3.74~ 4.43	34.37 37.20	30.09 30.09	——— ———	64.46 67.28
7	4.43~ 5.94	37.20 43.39	30.09 30.09	——— ———	67.28 73.48
8	5.94~ 6.37	43.39 45.15	30.09 30.09	200.00 203.53	-126.52 -128.29

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.94 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_{II}}{0.3}\right)^{-3/4} \qquad (B_{II} = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name	10 H _ H 900 -250 -14 -25 -18				
Unit width	B	=	1.0000 m		
Corrosion margin	t_1	=	1.00 mm (active side)	t_2 =	1.00 mm (passive side)
Corrosion rate	η	=	0.87		
Section efficiency	μ	=	1.00		
Young's modulus	E	=	200000 N/mm^2		
Inertia sectional moment	I_0	=	631400 cm^4(original condition)		
	I	=	549318 cm^4(after reduction by corrosion and section)		
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 549318 \times 10^{-8} = 1.099 \times 10^6$		

No	Depth m	N Value
1	1.00	10
2	2.00	10
3	3.00	10
4	4.00	10
5	4.87	13
6	5.87	15
7	6.87	14
8	7.87	11
9	8.87	25
10	9.87	29

No	Depth m	N Value
11	10.87	50
12	11.87	50
13	12.87	50
14	13.87	50
15	14.87	50

5.2 Normal Condition

Assuming Kh = 12977 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.233\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 4.29\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.94 m) to 4.29 m depth (GL -10.23 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.94	0.93	14.9	14.0	13.45
2	6.87	1.00	14.0	11.0	12.50
3	7.87	1.00	11.0	25.0	18.00
4	8.87	1.00	25.0	29.0	27.00
5	9.87	0.36	29.0	36.6	11.79
		L = Σh = 4.29		ΣA =	82.74

A: (upper N-value + lower N-value) × h/2

$$\text{Average N-value} \quad N' = \frac{\Sigma A}{L} = \frac{82.74}{4.29} = 19.29$$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 19.29 = 54008\ \text{kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 54008 = 180027\ \text{kN/m}^3 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_{II}/0.3)^{-3/4} = 180027(10.00/0.3)^{-3/4} = 12977\ \text{kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 12977 kN/m3.

5.3 Seismic Condition

Assuming Kh = 23420 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.270\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 3.70\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL 5.94 m) and 3.70 m depth (GL -9.64 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.94	0.93	14.9	14.0	13.45
2	6.87	1.00	14.0	11.0	12.50
3	7.87	1.00	11.0	25.0	18.00
4	8.87	0.77	25.0	28.1	20.47
		L = Σh = 3.70		ΣA =	64.42

A: (upper N-value + lower N-value) × h/2

$$\text{Average N-value} \quad N' = \frac{\Sigma A}{L}$$

$$= \frac{64.42}{3.70}$$

$$= 17.41$$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 17.41 = 48736 \ kN/m^2$$
$$K_{h0} = \frac{1}{0.3} \times \alpha \times 48736 = 324903 \ kN/m^3 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$
$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 324903(10.00/0.3)^{-3/4} = 23420 \ kN/m^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 23420 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	7.05 25.49	5.29 19.11	5.44 4.94	28.76 94.42
2	1.50~ 2.50	1.00	25.49 37.78	12.74 18.89	4.11 3.77	52.33 71.27
3	2.50~ 3.50	1.00	37.78 50.07	18.89 25.03	3.11 2.77	58.68 69.43
4	3.50~ 3.55	0.05	50.07 50.68	1.25 1.27	2.42 2.41	3.03 3.05
5	3.55~ 3.74	0.19	50.68 51.16	4.81 4.86	2.33 2.26	11.20 11.00
6	3.74~ 4.43	0.69	60.09 62.91	20.73 21.71	1.97 1.74	40.84 37.77
7	4.43~ 5.94	1.51	62.91 69.11	47.50 52.17	1.01 0.50	47.82 26.26
				ΣP = 254.26	ΣM = 555.86	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	23.4 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.94 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	3.07~ 4.07	1.00	0.0 2.9	0.00 1.45	2.54 2.20	0.00 3.20
2	4.07~ 5.07	1.00	2.9 4.1	1.45 2.05	1.54 1.20	2.23 2.47
3	5.07~ 5.94	0.87	4.1 4.9	1.79 2.14	0.58 0.29	1.04 0.62
				ΣPdw = 8.89	Σ Mdw = 9.56	

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}}$$
$$= \frac{1192.78}{387.61} = 3.08 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 387.61}{5.94} = 130.51 \ kN/m$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name			10 H _ H 900 -250 -14 -25 -18
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	631400 cm⁴ (original condition)
	I	=	549318 cm⁴ (after reduction by corrosion and section)

$EI = 200000 \times 10^3 \times 549318 \times 10^{-8} = 1.099 \times 10^6$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp(-\tan^{-1}\frac{1}{1+2\beta h_0})$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 139.00$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t}$$
$$= \frac{694.86}{277.66} = 2.50 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 277.66}{5.94} = 93.49 \ kN/m$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	19.23 39.49	14.42 29.62	5.44 4.94	78.47 146.32
2	1.50~ 2.50	1.00	39.49 53.00	19.75 26.50	4.11 3.77	81.09 100.00
3	2.50~ 3.07	0.57	53.00 60.70	15.11 17.30	3.25 3.06	49.09 52.94
4	3.07~ 3.50	0.43	60.70 62.29	13.05 13.39	2.73 2.58	35.58 34.60
5	3.50~ 3.74	0.24	62.29 63.18	7.48 7.58	2.36 2.28	17.64 17.29
6	3.74~ 4.43	0.69	64.46 67.28	22.24 23.21	1.97 1.74	43.81 40.39
7	4.43~ 5.94	1.51	67.28 73.48	50.80 55.47	1.01 0.50	51.14 27.92
				ΣP = 315.92	ΣM = 776.28	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	62.8 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	33.9 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.94 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 406.93$ kN・m

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	12977 kN/m³
calculated value	β	=	0.23311 m⁻¹
resultant earth force (lateral)	P_0	=	277.66 kN/m
height of acting position of load	h_0	=	2.50 m
moment	M_0	=	667.86 kN・m/m
in consideration of ψ_m = 1.327, maximum moment	M_{max}	=	922.29 kN・m/m
depth of generated position of M_{max}	l_m	=	1.855 m
depth of 1st fixed point	l_i	=	5.224 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	23420 kN/m³
calculated value	β	=	0.27019 m⁻¹
resultant earth force (lateral)	P_0	=	387.61 kN/m
height of acting position of load	h_0	=	3.08 m
moment	M_0	=	1192.78 kN・m/m
in consideration of ψ_m = 1.194, maximum moment	M_{max}	=	1424.56 kN・m/m
depth of generated position of M_{max}	l_m	=	1.330 m
depth of 1st fixed point	l_i	=	4.23 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name			10 H _ H 900 -250 -14 -25 -18
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.88
Section efficiency	μ	=	1.00
Module of section	Z_0	=	10120 cm³ (original condition)
	Z	=	8906 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{922.29 \times 10^6}{8906 \times 10^3} = 104 \ N/mm^2 \leqq \sigma_a = 180 \ N/mm^2$$

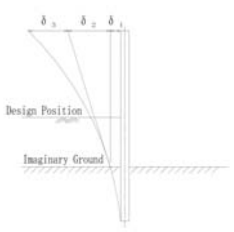
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1424.56 \times 10^6}{8906 \times 10^3} = 160 \ N/mm^2 \leqq \sigma_a = 270 \ N/mm^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation

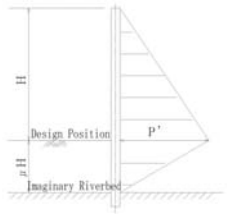


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2331\times 2.50)\times 277.66}{2\times 2.00\times 10^8\times 549318\times 10^{-8}\times 0.2331^3} = 0.01579 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.2331\times 2.50)\times 277.66}{2\times 2.00\times 10^8\times 549318\times 10^{-8}\times 0.2331^2}\times(5.94+0.00) = 0.02993 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.94} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{93.49\times 5.94^4}{120\times 2.00\times 10^8\times 549318\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

$$= 0.00353 \text{ m}$$

$$\mu = \frac{L_k}{H} = \frac{0.00}{5.94} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{130.51\times 5.94^4}{120\times 2.00\times 10^8\times 549318\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

$$= 0.00493 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.01638 + 0.03822 + 0.00493
= 0.05953 m
Size = 59.53 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name		10 H _ H 900 -250 -14 -25 -18
Unit width	B	= 1.0000 m
Corrosion rate	η	= 1.00
Section efficiency	μ	= 1.00
Young's modulus	E	= 200000 N/mm²
Inertia sectional moment	I_0	= 631400 cm⁴ (original condition)
	I	= 631400 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 631400 × 10⁻⁸		= 1.236 × 10⁶

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 12977 kN/m³
Calculated value β = 0.22514 m⁻¹

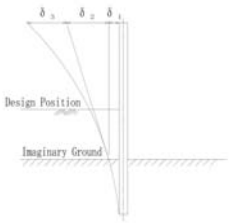
Penetration length of SSP D = 0.00 + 3 / 0.225 = 13.33 m
Whole length of SSP L = 5.94 − 0.40 + 13.33 = 18.87 m

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.01579 + 0.02993 + 0.00353
= 0.04925 m
Size = 49.25 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

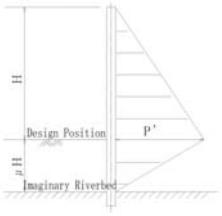


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2702\times 3.08)\times 387.61}{2\times 2.00\times 10^8\times 549318\times 10^{-8}\times 0.2702^3} = 0.01638 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.2702\times 3.08)\times 387.61}{2\times 2.00\times 10^8\times 549318\times 10^{-8}\times 0.2702^2}\times(5.94+0.00) = 0.03822 \text{ m}$$



7.1.1 Seismic Condition

Modules of lateral subgrade reaction K_h = 23420 kN/m³
Calculated value β = 0.26095 m⁻¹

Penetration length of SSP D = 0.00 + 3 / 0.261 = 11.50 m
Whole length of SSP L = 5.94 − 0.40 + 11.50 = 17.04 m

Therefore, the total length of the sheet pile is 19.00 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile 10 H _ H 900 -250 -14 -25 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	631400		
Sectional Modulus	Z (cm3)	10120		
Maximum bending moment	Mmax (kN・m・m)		922.29	1424.56
Stress intensity	σ (N/mm2)		104 (180)	160 (270)
Lateral displacement	δ (mm)		49.25 (50.0)	59.53 (75.0)
Penetration depths	D (m)		13.33	11.50
Whole length of SSP	L (m)	19.00		

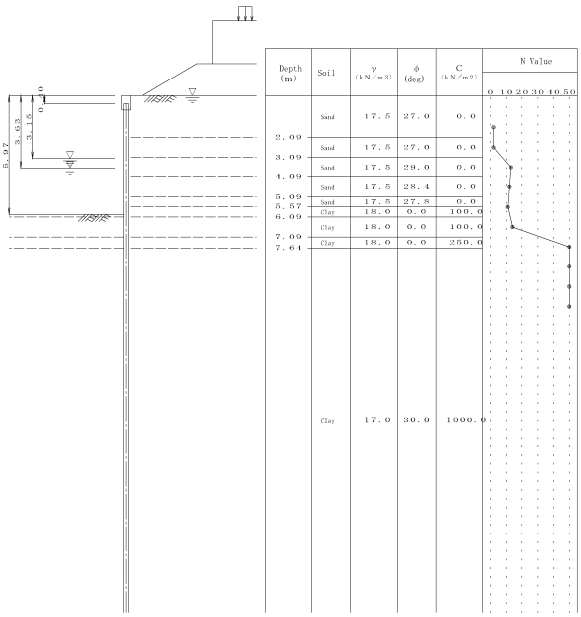
Block No. : L-10
Sta. : 8+300~8+600

Design Cross Section : Sta 8+400
Boring Name : DD-BH-L07

Specification : SSP SP-10H
(Combined) : H 800-250-14-22-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.79 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_R	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.63 m (Normal Condition)
	L_{wp}'	=	3.15 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress : Chang's formula

Penetration depths : $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water : γ_w = 9.8 kN/m³

Type of water pressure : trapezoidal water pressure

Lateral pressure : calculated in consideration of site conditions

Study case : - Normal Condition
- Seismic Condition

Design earthquake intensity : k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	23.4 kN/m	(Normal Condition)
		Pt'	=	62.8 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	Mm	=	0.0 kN･m/m	(Normal Condition)
		Mm'	=	33.9 kN･m/m	(Seismic Condition)
	Depth of acting point	Hm'	=	0.00 m	(Seismic Condition)
		Hm	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load : not considered

Minimum angle of rupture : ζ_0 = 10 degrees

Rear side angle of slope : not considered

Angle of rupture (clayey soil) : $\zeta = \tan^{-1}\sqrt{1-\frac{\sum \gamma h + 2Q}{2C}\cdot\tan\theta}$

Equilibrium factor of compression : K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m
E_0 = 2800N

Average N-value : calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value
1	1.59	2			
2	2.59	2			
3	3.59	13			
4	4.59	12			
5	5.59	11			
6	6.59	14			
7	7.59	50			
8	8.59	50			
9	9.59	50			
10	10.59	50			

1.6 Vertical Load

Vertical load on landside : calculated in consideration of embankment shape on landside

Vertical load on riverside : not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	2.09	2.09
2	3.09	1.00
3	4.09	1.00
4	5.09	1.00
5	5.57	0.48
6	6.09	0.52
7	7.09	1.00
8	7.64	0.55
9	24.90	17.26

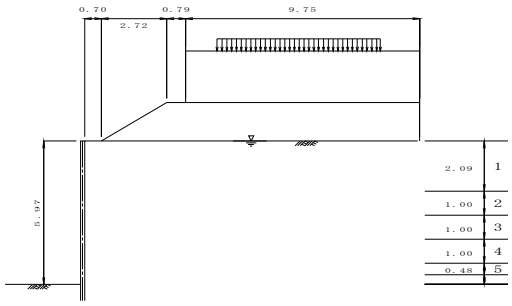
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	2.09	S	2.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
2	3.09	S	2.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
3	4.09	S	13.0	17.50	7.70	29.0	0.0	0.0	0.200	Auto	Auto
4	5.09	S	12.0	17.50	7.70	28.4	0.0	0.0	0.200	Auto	Auto
5	5.57	S	11.0	17.50	7.70	27.8	0.0	0.0	0.200	Auto	Auto
6	6.09	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
7	7.09	C	14.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
8	7.64	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
9	24.90	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate				Thickness	soil single weight γ		internal friction angle	stickiness	decay angle ζ	
		Bottom Left m	Top Left m	Top Right m	Bottom Right m	h m	Normal Condition kN/m3	Seismic Condition kN/m3	φ degree	C kN/m2	Normal Condition degree	Seismic Condition degree
1	Sand	0.70	3.42	13.96	13.96	1.60	19.0	19.0	30.0	0.0	Auto	Auto
2	Sand	4.21	4.21	13.96	13.96	2.15	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area		load strength	
	From m	End point m	Normal Condition kN/m2	Seismic Condition kN/m2
1	5.52	12.32	10.0	5.0

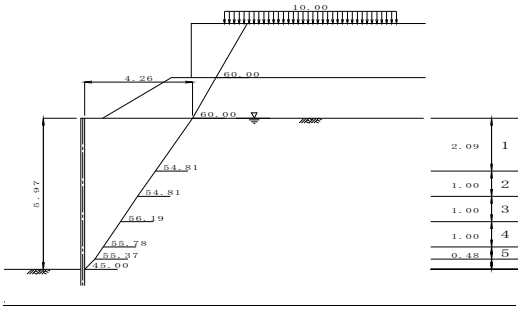
Angle of rapture in embankment calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name	10 H _ H 800 -250 -14 -22 -18				
Young's modulus	E	=	200000 N/mm^2		
Inertia sectional moment	I_0	=	471700 cm^4		
Sectional factor	Z_0	=	8240 cm^3		
Corrosion margin	t_1	=	1.00 mm (riverside)	t_2 =	1.00 mm (landside)
Corrosion rate (to I_0)	η	=	0.86		
Corrosion rate (to Z_0)	η	=	0.88		
Section efficiency (to I_0)	μ	=	1.00		
Section efficiency (to Z_0)	μ	=	1.00		
Round unit of SSP length			0.50 m		
Allowable stress	σ_a	=	180 N/mm (Normal)		
	σ_a'	=	270 N/mm (Seismic)		
Allowable displacement	δ_a	=	50.0 mm (Normal)		
	δ_a'	=	75.0 mm (Seismic)		
Bending of cantilever beam			calculated as distributed load of each layer		
Reduction of material modulus			Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction Not reduced: I_0 applied to calculation of penetration depth Reduced: I_0 applied to calculation of section forces and displacement Reduced: Z_0 applied to calculation of stresses		

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	5.97 ~ 5.57	Clay	0.0	15.0	100.0	46.17	36.41	58.51	45.00
2	5.57 ~ 5.09	Sand	27.8	15.0	0.0	42.89	36.41	54.59	55.37
3	5.09 ~ 4.09	Sand	28.4	15.0	0.0	39.19	36.41	49.88	55.78
4	4.09 ~ 3.09	Sand	29.0	15.0	0.0	31.49	36.41	40.08	56.19
5	3.09 ~ 2.09	Sand	27.0	15.0	0.0	23.79	36.41	30.28	54.81
6	2.09 ~ 0.00	Sand	27.0	15.0	0.0	16.09	36.41	20.48	54.81
7		embankment	30.0	——	0.0	71.25	10.00	0.00	60.00
8		embankment	30.0	——	0.0	40.85	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- φ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan^{-1}k or θ = tan^{-1}k'
- γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m^2)
- C : cohesive force of soil (kN/m^2)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.00	0.40	0.00	0.00	0.40	0.40
2	55.37	0.48	0.40	0.40	0.73	0.88
3	55.78	1.00	0.73	0.88	1.41	1.88
4	56.19	1.00	1.41	1.88	2.08	2.88
5	54.81	1.00	2.08	2.88	2.79	3.88
6	54.81	2.09	2.79	3.88	4.26	5.97
7	60.00	1.60	4.26	5.97	5.18	7.57
8	60.00	2.15	5.18	7.57	6.43	9.72

From the above table, the loading width (L) on the ground surface is 4.26 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	4.26	80.93
2	19.0	3.43	65.15
Σ			146.08

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	0.91	9.05
Σ			9.05

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

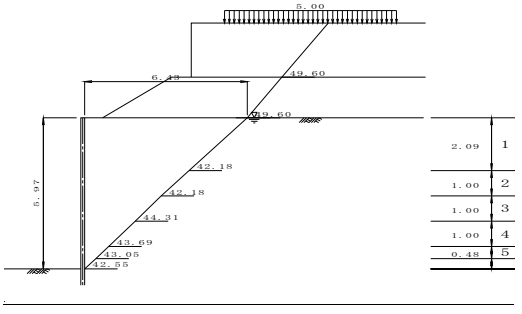
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{146.08 + 9.05 + 0.00}{4.26}$$

$$= 36.41 \text{ kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.97 ~ 5.57	Clay	0.0	15.0	100.0	46.17	55.64	58.51	0.200	11.31	42.55
2	5.57 ~ 5.09	Sand	27.8	15.0	0.0	42.89	55.64	54.59	0.200	11.31	43.05
3	5.09 ~ 4.09	Sand	28.4	15.0	0.0	39.19	55.64	49.88	0.200	11.31	43.69
4	4.09 ~ 3.09	Sand	29.0	15.0	0.0	31.49	55.64	40.08	0.200	11.31	44.31
5	3.09 ~ 2.09	Sand	27.0	15.0	0.0	23.79	55.64	30.28	0.200	11.31	42.18
6	2.09 ~ 0.00	Sand	27.0	15.0	0.0	16.09	55.64	20.48	0.200	11.31	42.18
7		embankment	30.0	———	0.0	71.25	5.00	0.00	0.200	11.31	49.60
8		embankment	30.0	———	0.0	40.85	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- φ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C : cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	42.55	0.40	0.00	0.00	0.44	0.40
2	43.05	0.48	0.44	0.40	0.95	0.88
3	43.69	1.00	0.95	0.88	2.00	1.88
4	44.31	1.00	2.00	1.88	3.02	2.88
5	42.18	1.00	3.02	2.88	4.12	3.88
6	42.18	2.09	4.12	3.88	6.43	5.97
7	49.60	1.60	6.43	5.97	7.79	7.57
8	49.60	2.15	7.79	7.57	9.62	9.72

From the above table, the loading width (L) on the ground surface is 6.43 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	8.08	153.57
2	19.0	9.67	183.71
Σ			337.28

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	4.10	20.51
Σ			20.51

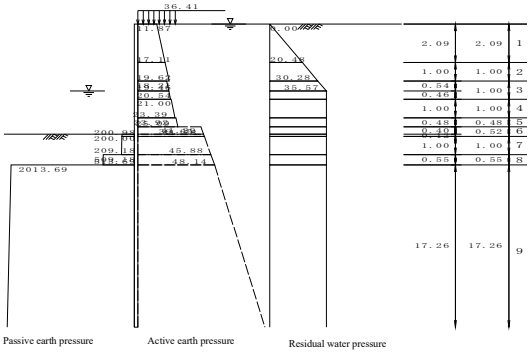
Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times l)+\Sigma P}{L} = \frac{337.28 + 20.51 + 0.00}{6.43} = 55.64\ \text{kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



Passive earth pressure Active earth pressure Residual water pressure

3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 2.09	Sand	7.7	27.0	———	36.414	0.33738	0.32589
					———	52.507	0.33738	0.32589
2	2.09~ 3.09	Sand	7.7	27.0	———	52.507	0.33738	0.32589
					———	60.207	0.33738	0.32589
3	3.09~ 3.63	Sand	7.7	29.0	———	60.207	0.31307	0.30240
					———	64.365	0.31307	0.30240
4	3.63~ 4.09	Sand	7.7	29.0	———	64.365	0.31307	0.30240
					———	67.907	0.31307	0.30240
5	4.09~ 5.09	Sand	7.7	28.4	———	67.907	0.32022	0.30931
					———	75.607	0.32022	0.30931
6	5.09~ 5.57	Sand	7.7	27.8	———	75.607	0.32749	0.31633
					———	79.303	0.32749	0.31633
7	5.57~ 5.97	Clay	8.2	———	100.0	79.303	———	———
					100.0	82.583	———	———
8	5.97~ 6.09	Clay	8.2	———	100.0	82.583	———	———
					100.0	83.567	———	———
9	6.09~ 7.09	Clay	8.2	———	100.0	83.567	———	———
					100.0	91.767	———	———
10	7.09~ 7.64	Clay	8.2	———	250.0	91.767	———	———
					250.0	96.277	———	———
11	7.64~ 24.90	Clay	7.2	———	1000.0	96.277	———	———
					1000.0	220.549	———	———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ = 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
8	5.97~ 6.09	Clay	8.2	0.0	100.0	0.000	———	———
					100.0	0.984	———	———
9	6.09~ 7.09	Clay	8.2	0.0	100.0	0.984	———	———
					100.0	9.184	———	———
10	7.09~ 7.64	Clay	8.2	0.0	250.0	9.184	———	———
					250.0	13.694	———	———
11	7.64~ 24.90	Clay	7.2	30.0	1000.0	13.694	———	———
					1000.0	137.966	———	———

Coefficient of passive earth pressure of sandy soil Kp is calculated by the formula below;

δ = -15.00、β = 0.00、θ = 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\dfrac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 2.09	11.87	———	11.87	0.00	———
		17.11	———	17.11	20.48	———
2	2.09~ 3.09	17.11	———	17.11	20.48	———
		19.62	———	19.62	30.28	———
3	3.09~ 3.63	18.21	———	18.21	30.28	———
		19.46	———	19.46	35.57	———
4	3.63~ 4.09	19.46	———	19.46	35.57	———
		20.54	———	20.54	35.57	———
5	4.09~ 5.09	21.00	———	21.00	35.57	———
		23.39	———	23.39	35.57	———
6	5.09~ 5.57	23.92	———	23.92	35.57	———
		25.09	———	25.09	35.57	———
7	5.57~ 5.97	-120.70	39.65	39.65	35.57	———
		-117.42	41.29	41.29	35.57	———
8	5.97~ 6.09	-117.42	41.29	41.29	35.57	200.00
		-116.43	41.78	41.78	35.57	200.98
9	6.09~ 7.09	-116.43	41.78	41.78	35.57	200.98
		-108.23	45.88	45.88	35.57	209.18
10	7.09~ 7.64	-408.23	45.88	45.88	35.57	509.18
		-403.72	48.14	48.14	35.57	513.69
11	7.64~ 24.90	-1903.72	48.14	48.14	35.57	2013.69
		-1779.45	110.27	110.27	35.57	2137.97

- Formula for active earth pressure

Sand $P_{a1}=K_a\cdot[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}]\cdot\cos\delta$

Clay $P_{a1}=\Sigma\gamma h+Q-2C$
$P_{a2}=K_c\cdot(\Sigma\gamma h+Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1}=[K_a(\Sigma\gamma h+Q)-2C\sqrt{K_a}]\cdot\cos\delta$

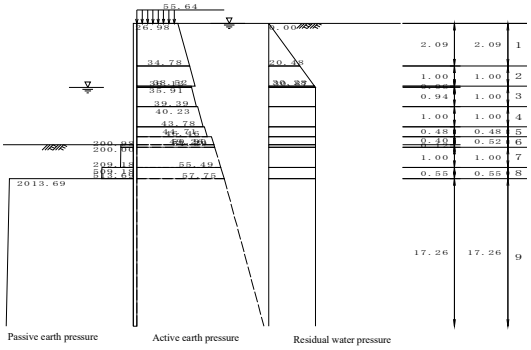
- Formula for passive earth pressure

Sand $P_p=K_p\cdot[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}]\cdot\cos\delta$

Clay $P_p=\Sigma\gamma h+Q+2C$

Mixed soil $P_p=[K_p(\Sigma\gamma h+Q)+2C\sqrt{K_p}]\cdot\cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 2.09	Sand	7.7	27.0	——— ———	55.64 71.73	0.00 20.48	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
2	2.09~ 3.09	Sand	7.7	27.0	——— ———	71.73 79.43	20.48 30.28	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
3	3.09~ 3.15	Sand	7.7	29.0	——— ———	79.43 79.89	30.28 30.87	0.200 0.200	11.31 11.31	0.46809 0.46809	0.45214 0.45214	——— ———
4	3.15~ 4.09	Sand	7.7	29.0	——— ———	79.89 87.13	30.87 40.08	0.200 0.200	11.31 11.31	0.46809 0.46809	0.45214 0.45214	——— ———
5	4.09~ 5.09	Sand	7.7	28.4	——— ———	87.13 94.83	40.08 49.88	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	——— ———
6	5.09~ 5.57	Sand	7.7	27.8	——— ———	94.83 98.53	49.88 54.59	0.200 0.200	11.31 11.31	0.48814 0.48814	0.47151 0.47151	——— ———
7	5.57~ 5.97	Clay	8.2	———	100.0 100.0	98.53 101.81	54.59 58.51	0.200 0.200	11.31 11.31	——— ———	——— ———	42.60 42.55
8	5.97~ 6.09	Clay	8.2	———	100.0 100.0	101.81 102.79	58.51 59.68	0.200 0.200	11.31 11.31	——— ———	——— ———	42.55 42.53
9	6.09~ 7.09	Clay	8.2	———	100.0 100.0	102.79 110.99	59.68 69.48	0.200 0.200	11.31 11.31	——— ———	——— ———	42.53 42.39
10	7.09~ 7.64	Clay	8.2	———	250.0 250.0	110.99 115.50	69.48 74.87	0.200 0.200	11.31 11.31	——— ———	——— ———	44.01 43.98
11	7.64~ 24.90	Clay	7.2	———	1000.0 1000.0	115.50 239.77	74.87 244.02	0.200 0.200	11.31 11.31	——— ———	——— ———	44.75 44.57

4	3.15~ 4.09	36.12 39.39	——— ———	36.12 39.39	30.87 30.87	——— ———
5	4.09~ 5.09	40.23 43.78	——— ———	40.23 43.78	30.87 30.87	——— ———
6	5.09~ 5.57	44.71 46.46	——— ———	44.71 46.46	30.87 30.87	——— ———
7	5.57~ 5.97	-80.75 -76.75	49.26 50.90	49.26 50.90	30.87 30.87	——— ———
8	5.97~ 6.09	-76.75 -75.55	50.90 51.39	50.90 51.39	30.87 30.87	200.00 200.98
9	6.09~ 7.09	-75.55 -65.53	51.39 55.49	51.39 55.49	30.87 30.87	200.98 209.18
10	7.09~ 7.64	-366.33 -360.88	55.49 57.75	55.49 57.75	30.87 30.87	509.18 513.69
11	7.64~ 24.90	-1861.28 -1711.78	57.75 119.89	57.75 119.89	30.87 30.87	2013.69 2137.97

- Formula for active earth pressure

Sand $P_{a1}=K_a\cdot[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}]\cdot\cos\delta$

Clay $P_{a1}=\Sigma\gamma h+Q-2C$
$P_{a2}=K_c\cdot(\Sigma\gamma h+Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1}=[K_a(\Sigma\gamma h+Q)-2C\sqrt{K_a}]\cdot\cos\delta$

- Formula for passive earth pressure

Sand $P_p=K_p\cdot[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}]\cdot\cos\delta$

Clay $P_p=\Sigma\gamma h+Q+2C$

Mixed soil $P_p=[K_p(\Sigma\gamma h+Q)+2C\sqrt{K_p}]\cdot\cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	3.15	0.00	0.00
2	4.15	1.00	2.88
3	5.15	2.00	4.07
4	5.97	2.82	4.84

$$p_{dw}=\pm\frac{7}{8}k_{hs}\cdot\gamma_w\cdot\sqrt{H\cdot y}$$

Where,

k_{hs}: design seismic coefficient
γ_w : unit weight of water
H : water depth of riverside
y : depth from water surface to the point where active water pressure is calculated

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a=\frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta=\tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}}\cdot\tan\theta$$

3.2.2 Soil Modulus of Passive Side

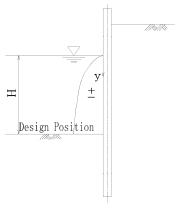
No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
8	5.97~ 6.09	Clay	8.20	0.0	100.0 100.0	0.000 0.984	0.00 1.18	0.200 0.200	11.31 11.31	——— ———	——— ———
9	6.09~ 7.09	Clay	8.20	0.0	100.0 100.0	0.984 9.184	1.18 10.98	0.200 0.200	11.31 11.31	——— ———	——— ———
10	7.09~ 7.64	Clay	8.20	0.0	250.0 250.0	9.184 13.694	10.98 16.37	0.200 0.200	11.31 11.31	——— ———	——— ———
11	7.64~ 24.90	Clay	7.20	30.0	1000.0 1000.0	13.694 137.966	16.37 185.51	0.200 0.200	11.31 11.31	——— ———	——— ———

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.
δ = 0.00 degrees, β = 0.00 degrees
Seismic composite angle θ = tan -1 k

$$K_p=\frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

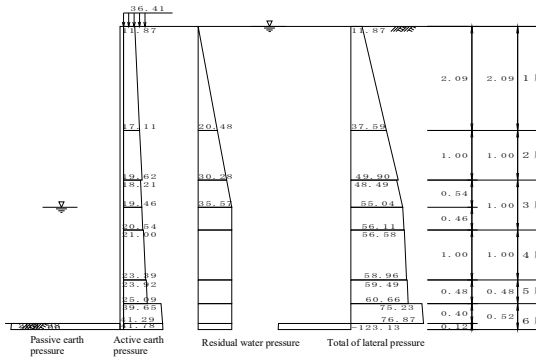
No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 2.09	26.98 34.78	——— ———	26.98 34.78	0.00 20.48	——— ———
2	2.09~ 3.09	34.78 38.52	——— ———	34.78 38.52	20.48 30.28	——— ———
3	3.09~ 3.15	35.91 36.12	——— ———	35.91 36.12	30.28 30.87	——— ———



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



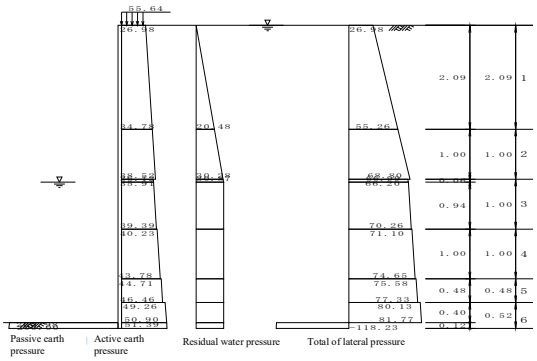
No	Depth. m	Ps kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.09	11.87 17.11	0.00 20.48	——— ———	11.87 37.59
2	2.09~ 3.09	17.11 19.62	20.48 30.28	——— ———	37.59 49.90
3	3.09~ 3.63	18.21 19.46	30.28 35.57	——— ———	48.49 55.04

4	3.63~ 4.09	19.46 20.54	35.57 35.57	——— ———	55.04 56.11
5	4.09~ 5.09	21.00 23.39	35.57 35.57	——— ———	56.58 58.96
6	5.09~ 5.57	23.92 25.09	35.57 35.57	——— ———	59.49 60.66
7	5.57~ 5.97	39.65 41.29	35.57 35.57	——— ———	75.23 76.87
8	5.97~ 6.09	41.29 41.78	35.57 35.57	200.00 200.98	-123.13 -123.63

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.97 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.09	26.98 34.78	0.00 20.48	——— ———	26.98 55.26
2	2.09~ 3.09	34.78 38.52	20.48 30.28	——— ———	55.26 68.80
3	3.09~ 3.15	35.91 36.12	30.28 30.87	——— ———	66.20 66.99
4	3.15~ 4.09	36.12 39.39	30.87 30.87	——— ———	66.99 70.26
5	4.09~ 5.09	40.23 43.78	30.87 30.87	——— ———	71.10 74.65
6	5.09~ 5.57	44.71 46.46	30.87 30.87	——— ———	75.58 77.33
7	5.57~ 5.97	49.26 50.90	30.87 30.87	——— ———	80.13 81.77
8	5.97~ 6.09	50.90 51.39	30.87 30.87	200.00 200.98	-118.23 -118.72

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.97 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name		10 H _ H 800 -250 -14 -22 -18	
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.86
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	471700 cm^4(original condition)
	I	=	405662 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 405662 \times 10^{-8} = 8.133 \times 10^8$

No	Depth m	N Value
1	1.59	2
2	2.59	2
3	3.59	13
4	4.59	12
5	5.59	11
6	6.59	14
7	7.59	50
8	8.59	50
9	9.59	50
10	10.59	50

5.2 Normal Condition

Assuming Kh = 25452 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.298\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 3.36\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.97 m) to 3.36 m depth (GL -9.33 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.97	0.62	12.1	14.0	8.10
2	6.59	1.00	14.0	50.0	32.00
3	7.59	1.00	50.0	50.0	50.00
4	8.59	0.74	50.0	50.0	37.02
		L = Σh = 3.36		ΣA =	127.12

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{127.12}{3.36} = 37.83$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 37.83 = 105924\ \text{kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 105924 = 353080\ \text{kN/m}^3 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 353080(10.00/0.3)^{-3/4} = 25452\ \text{kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 25452 kN/m3.

5.3 Seismic Condition

Assuming Kh = 48080 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.349\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 2.87\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.97 m) and 2.87 m depth (GL -8.84 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.97	0.62	12.1	14.0	8.10
2	6.59	1.00	14.0	50.0	32.00
3	7.59	1.00	50.0	50.0	50.00
4	8.59	0.25	50.0	50.0	12.32
		L = Σh = 2.87		ΣA =	102.42

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L}$

$$= \frac{102.42}{2.87}$$

$$= 35.73$$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 35.73 = 100049\ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 100049 = 666995\ kN/m^3$ (α:Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 666995(10.00/0.3)^{-3/4} = 48080\ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 48080 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.09	2.09	11.87 37.59	12.40 39.29	5.27 4.58	65.39 179.79
2	2.09~ 3.09	1.00	37.59 49.90	18.80 24.95	3.55 3.21	66.67 80.18
3	3.09~ 3.63	0.54	48.49 55.04	13.09 14.86	2.70 2.52	35.35 37.45
4	3.63~ 4.09	0.46	55.04 56.11	12.66 12.91	2.19 2.03	27.68 26.24
5	4.09~ 5.09	1.00	56.58 58.96	28.29 29.48	1.55 1.21	43.75 35.77
6	5.09~ 5.57	0.48	59.49 60.66	14.28 14.56	0.72 0.56	10.28 8.15
7	5.57~ 5.97	0.40	75.23 76.87	15.05 15.37	0.27 0.13	4.01 2.05
				ΣP= 265.97	ΣM= 622.77	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load		P_t	=	23.4 kN/m
	depth to acting position	H_t	=	0.0 m
	moment	M_m	=	0.0 kN・m/m
	depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping		H	=	5.97 m
Depth of Imaginary riverbed from riverbed		L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 139.70\ kN \cdot m$
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{762.46}{289.37} = 2.63\ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 289.37}{5.97} = 96.94\ kN/m$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.09	2.09	26.98 55.26	28.19 57.75	5.27 4.58	148.67 264.31
2	2.09~ 3.09	1.00	55.26 68.80	27.63 34.40	3.55 3.21	98.00 110.53
3	3.09~ 3.15	0.06	66.20 66.99	1.99 2.01	2.86 2.84	5.68 5.71
4	3.15~ 4.09	0.94	66.99 70.26	31.49 33.02	2.51 2.19	78.93 72.43
5	4.09~ 5.09	1.00	71.10 74.65	35.55 37.33	1.55 1.21	54.98 45.29
6	5.09~ 5.57	0.48	75.58 77.33	18.14 18.56	0.72 0.56	13.06 10.39
7	5.57~ 5.97	0.40	80.13 81.77	16.03 16.35	0.27 0.13	4.27 2.18
				ΣP= 358.44	ΣM= 914.44	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load		P_t	=	62.8 kN/m
	depth to acting position	H_t	=	0.00 m
	moment	M_m	=	33.9 kN・m/m
	depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping		H	=	5.97 m
Depth of Imaginary riverbed from riverbed		L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 408.82\ kN \cdot m$

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	3.15~ 4.15	1.00	0.0 2.9	0.00 1.44	2.49 2.15	0.00 3.10
2	4.15~ 5.15	1.00	2.9 4.1	1.44 2.04	1.49 1.15	2.14 2.35
3	5.15~ 5.97	0.82	4.1 4.8	1.67 1.98	0.55 0.27	0.91 0.54
				ΣPdw= 8.57	Σ Mdw= 9.05	

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1332.30}{429.80} = 3.10\ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 429.80}{5.97} = 143.99\ kN/m$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name		10 H _ H 800 -250 -14 -22 -18		
Unit width	B	=	1.0000 m	
Corrosion margin	t_1	=	1.00 mm (active side)	t_2= 1.00 mm (passive side)
Corrosion rate	η	=	0.86	
Section efficiency	μ	=	1.00	
Young's modulus	E	=	200000 N/mm^2	
Inertia sectional moment	I_0	=	471700 cm^4 (original condition)	
	I	=	4005662 cm^4 (after reduction by corrosion and section)	

$EI = 200000 \times 10^3 \times 4005622 \times 10^{-8} = 8.113 \times 10^5$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	25452	kN/m^3
calculated value	β	=	0.29759	m^{-1}
resultant earth force (lateral)	P_0	=	289.37	kN/m
height of acting position of load	h_0	=	2.63	m
Moment	M_0	=	762.46	kN・m/m
in consideration of ψ_m = 1.212, maximum moment	M_{max}	=	924.35	kN・m/m
depth of generated position of M_{max}	l_m	=	1.248	m
depth of 1st fixed point	l_i	=	3.887	m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	48080	kN/m^3
calculated value	β	=	0.34888	m^{-1}
resultant earth force (lateral)	P_0	=	429.80	kN/m
height of acting position of load	h_0	=	3.10	m
moment	M_0	=	1332.30	kN・m/m
in consideration of ψ_m = 1.129, maximum moment	M_{max}	=	1504.35	kN・m/m
depth of generated position of M_{max}	l_m	=	0.878	m
depth of 1st fixed point	l_i	=	3.129	m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 800 -250 -14 -22 -18		
Corrosion margin	t_1	=	1.00 mm (active side) t_2= 1.00 mm (passive side)
Corrosion rate	η	=	0.88
Section efficiency	μ	=	1.00
Module of section	Z_0	=	8240 cm^3 (original condition)
	Z	=	7251 cm^3 (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{924.35 \times 10^6}{7251 \times 10^3} = 127\ N/mm^2 \leqq \sigma_a = 180\ N/mm^2$$

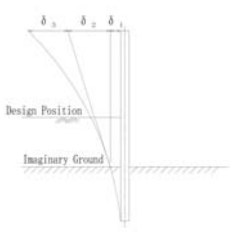
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1504.35 \times 10^6}{7251 \times 10^3} = 207\ N/mm^2 \leqq \sigma_a = 270\ N/mm^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation

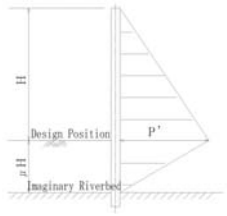


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2976\times 2.63)\times 289.37}{2\times 2.00\times 10^8\times 405662\times 10^{-8}\times 0.2976^3} = 0.01207 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.2976\times 2.63)\times 289.37}{2\times 2.00\times 10^8\times 405662\times 10^{-8}\times 0.2976^2}\times(5.97+0.00) = 0.03088 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.97} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{96.94\times 5.97^4}{120\times 2.00\times 10^8\times 405662\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

$$= 0.00506 \text{ m}$$

$$\mu = \frac{L_k}{H} = \frac{0.00}{5.97} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{143.99\times 5.97^4}{120\times 2.00\times 10^8\times 405662\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

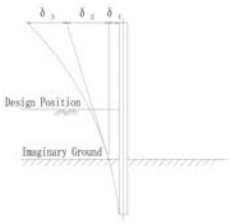
$$= 0.00751 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.01207 + 0.03088 + 0.00506
= 0.04801 m
Size = 48.01 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

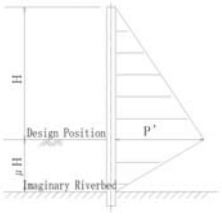


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.3489\times 3.10)\times 429.80}{2\times 2.00\times 10^8\times 405662\times 10^{-8}\times 0.3489^3} = 0.01298 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.3489\times 3.10)\times 429.80}{2\times 2.00\times 10^8\times 405662\times 10^{-8}\times 0.3489^2}\times(5.97+0.00) = 0.04109 \text{ m}$$



7.1.1 Seismic Condition

Modules of lateral subgrade reaction $K_h = 48080$ kN/m³
Calculated value $\beta = 0.33597$ m⁻¹

Penetration length of SSP $D = 0.00 + \frac{3}{0.336} = 8.93$ m
Whole length of SSP $L = 5.97 - 0.40 + 8.93 = 14.50$ m

Therefore, the total length of the sheet pile is 16.50 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile 10 H _ H 800 -250 -14 -22 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	471700		
Sectional Modulus	Z (cm3)	8240		
Maximum bending moment	Mmax (kN・m・m)		924.35	1504.35
Stress intensity	σ (N/mm2)		127 (180)	207 (270)
Lateral displacement	δ (mm)		48.01 (50.0)	61.59 (75.0)
Penetration depths	D (m)		10.47	8.93
Whole length of SSP	L (m)	16.50		

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name			10 H _ H 800 -250 -14 -22 -18
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	471700 cm⁴ (original condition)
	I	=	471700 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 471700 × 10⁻⁸		=	6.434 × 10⁵

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction $K_h = 25452$ kN/m³
Calculated value $\beta = 0.28658$ m⁻¹

Penetration length of SSP $D = 0.00 + \frac{3}{0.287} = 10.47$ m
Whole length of SSP $L = 5.97 - 0.40 + 10.47 = 16.04$ m

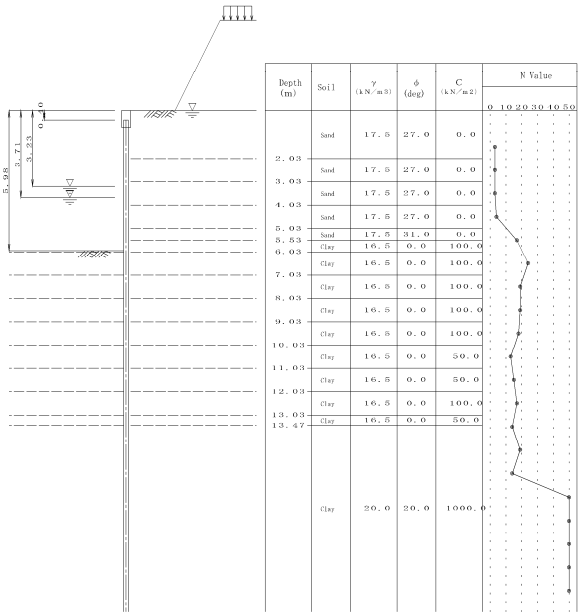
Block No. : L-11
Sta. : 8+600~8+835

Design Cross Section : Sta 8+780
Boring Name : DD-BH-L08

Specification : SSP SP-10H
（Combined） : H 1000-250-16-28-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.98 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_R	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.71 m (Normal Condition)
	L_{wp}'	=	3.23 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress : Chang's formula

Penetration depths : $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water : γ_w = 9.8 kN/m³

Type of water pressure : trapezoidal water pressure

Lateral pressure : calculated in consideration of site conditions

Study case : - Normal Condition
- Seismic Condition

Design earthquake intensity : k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	23.4 kN/m	(Normal Condition)
		Pt'	=	62.8 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	Mm	=	0.0 kN･m/m	(Normal Condition)
		Mm'	=	33.9 kN･m/m	(Seismic Condition)
	Depth of acting point	Hm'	=	0.00 m	(Seismic Condition)
		Hm	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load : not considered

Minimum angle of rupture : ζ_0 = 10 degrees

Rear side angle of slope : not considered

Angle of rupture (clayey soil) : $\zeta = \tan^{-1}\sqrt{1-\frac{\sum \gamma h + 2Q}{2C}\cdot\tan\theta}$

Equilibrium factor of compression : K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_u}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_u = 10.00 m

E_0 = 2800N

Average N-value : calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value
1	1.53	3	11	11.53	15
2	2.53	3	12	12.53	17
3	3.53	3	13	13.53	14
4	4.53	4	14	14.53	19
5	5.53	17	15	15.53	14
6	6.53	24	16	16.53	50
7	7.53	19	17	17.53	50
8	8.53	19	18	18.53	50
9	9.53	18	19	19.53	50
10	10.53	13	20	20.53	50

1.6 Vertical Load

Vertical load on landside : calculated in consideration of embankment shape on landside

Vertical load on riverside : not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	2.03	2.03
2	3.03	1.00
3	4.03	1.00
4	5.03	1.00
5	5.53	0.50
6	6.03	0.50
7	7.03	1.00
8	8.03	1.00
9	9.03	1.00
10	10.03	1.00
11	11.03	1.00
12	12.03	1.00
13	13.03	1.00
14	13.47	0.44
15	20.53	7.06

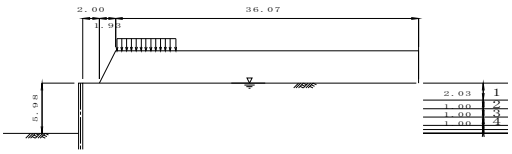
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	2.03	S	3.0	17.50	7.50	27.0	0.0	0.0	0.200	Auto	Auto
2	3.03	S	3.0	17.50	7.50	27.0	0.0	0.0	0.200	Auto	Auto
3	4.03	S	3.0	17.50	7.50	27.0	0.0	0.0	0.200	Auto	Auto
4	5.03	S	4.0	17.50	7.50	27.0	0.0	0.0	0.200	Auto	Auto
5	5.53	S	17.0	17.50	7.50	31.0	0.0	0.0	0.200	Auto	Auto
6	6.03	C	17.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
7	7.03	C	24.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
8	8.03	C	19.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
9	9.03	C	19.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
10	10.03	C	18.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
11	11.03	C	13.0	16.50	6.50	0.0	50.0	0.0	0.200	Auto	Auto
12	12.03	C	15.0	16.50	6.50	0.0	50.0	0.0	0.200	Auto	Auto
13	13.03	C	17.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
14	13.47	C	14.0	16.50	6.50	0.0	50.0	0.0	0.200	Auto	Auto
15	20.53	C	44.4	20.00	10.00	20.0	1000.0	0.0	0.200	Auto	Auto

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate				Thickness	soil single weight γ		internal friction angle	stickiness	decay angle ζ	
		Bottom Left m	Top Left m	Top Right m	Bottom Right m	h m	Normal Condition kN/m3	Seismic Condition kN/m3	φ degree	C kN/m2	Normal Condition degree	Seismic Condition degree
1	Sand	2.00	3.93	40.00	40.00	3.86	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area		load strength	
	From m	End point m	Normal Condition kN/m2	Seismic Condition kN/m2
1	4.08	11.08	10.0	5.0

Angle of rapture in embankment calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name 10 H _ H 1000 -250 -16 -28 -18
Young's modulus E = 200000 N/mm²
Inertia sectional moment I_0 = 845700 cm⁴
Sectional factor Z_0 = 12670 cm³

Corrosion margin t_1 = 1.00 mm (riverside) t_2 = 1.00 mm (landside)

Corrosion rate (to I_0) η = 0.87
Corrosion rate (to Z_0) η = 0.89
Section efficiency (to I_0) μ = 1.00
Section efficiency (to Z_0) μ = 1.00

Round unit of SSP length 0.50 m

Allowable stress σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

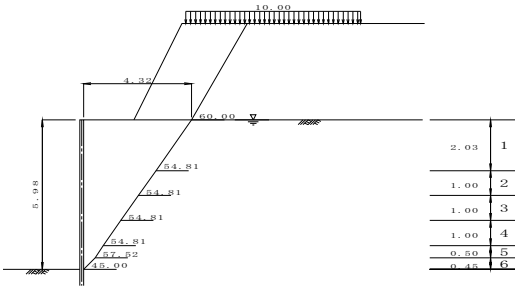
Allowable displacement δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam calculated as distributed load of each layer

Reduction of material modulus Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	5.98 ~ 5.53	Clay	0.0	15.0	100.0	44.40	47.60	58.60	45.00
2	5.53 ~ 5.03	Sand	31.0	15.0	0.0	41.47	47.60	54.19	57.52
3	5.03 ~ 4.03	Sand	27.0	15.0	0.0	37.72	47.60	49.29	54.81
4	4.03 ~ 3.03	Sand	27.0	15.0	0.0	30.23	47.60	39.49	54.81
5	3.03 ~ 2.03	Sand	27.0	15.0	0.0	22.72	47.60	29.69	54.81
6	2.03 ~ 0.00	Sand	27.0	15.0	0.0	15.22	47.60	19.89	54.81
7		embankment	30.0	——	0.0	73.34	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°
Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = $\tan^{-1}$k or θ = $\tan^{-1}$k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.00	0.45	0.00	0.00	0.45	0.45
2	57.52	0.50	0.45	0.45	0.77	0.95
3	54.81	1.00	0.77	0.95	1.47	1.95
4	54.81	1.00	1.47	1.95	2.18	2.95
5	54.81	1.00	2.18	2.95	2.88	3.95
6	54.81	2.03	2.88	3.95	4.32	5.98
7	60.00	3.86	4.32	5.98	6.54	9.84

From the above table, the loading width (L) on the ground surface is 4.32 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	9.51	180.75
Σ			180.75

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	2.46	24.64
Σ			24.64

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

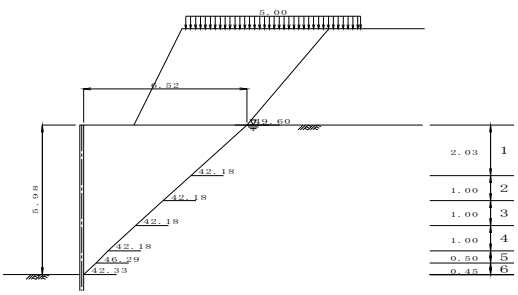
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times l)+\Sigma P}{L}$$

$$= \frac{180.75 + 24.64 + 0.00}{4.32}$$

$$= 47.60 \text{ kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.98 ~ 5.53	Clay	0.0	15.0	100.0	44.40	62.86	58.60	0.200	11.31	42.33
2	5.53 ~ 5.03	Sand	31.0	15.0	0.0	41.47	62.86	54.19	0.200	11.31	46.29
3	5.03 ~ 4.03	Sand	27.0	15.0	0.0	37.72	62.86	49.29	0.200	11.31	42.18
4	4.03 ~ 3.03	Sand	27.0	15.0	0.0	30.23	62.86	39.49	0.200	11.31	42.18
5	3.03 ~ 2.03	Sand	27.0	15.0	0.0	22.72	62.86	29.69	0.200	11.31	42.18
6	2.03 ~ 0.00	Sand	27.0	15.0	0.0	15.22	62.86	19.89	0.200	11.31	42.18
7		embankment	30.0	———	0.0	73.34	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h + Q}$$

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C : cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	42.33	0.45	0.00	0.00	0.49	0.45
2	46.29	0.50	0.49	0.45	0.97	0.95
3	42.18	1.00	0.97	0.95	2.08	1.95
4	42.18	1.00	2.08	1.95	3.18	2.95
5	42.18	1.00	3.18	2.95	4.28	3.95
6	42.18	2.03	4.28	3.95	6.52	5.98
7	49.60	3.86	6.52	5.98	9.81	9.84

From the above table, the loading width (L) on the ground surface is 6.52 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	20.07	381.41
Σ			381.41

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	5.73	28.64
Σ			28.64

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

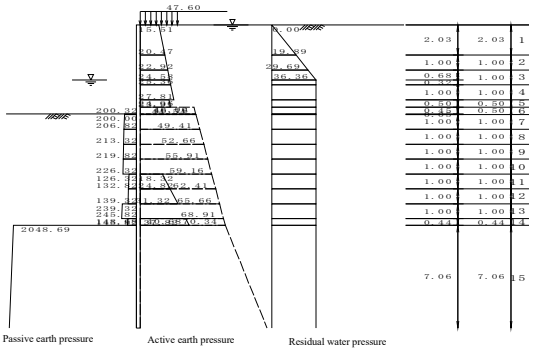
$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{381.41 + 28.64 + 0.00}{6.52}$$

$$= 62.86\ \mathrm{kN/m^2}$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh + Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 2.03	Sand	7.5	27.0	——— ———	47.596 62.821	0.33738 0.33738	0.32589 0.32589
2	2.03~ 3.03	Sand	7.5	27.0	——— ———	62.821 70.321	0.33738 0.33738	0.32589 0.32589
3	3.03~ 3.71	Sand	7.5	27.0	——— ———	70.321 75.421	0.33738 0.33738	0.32589 0.32589
4	3.71~ 4.03	Sand	7.5	27.0	——— ———	75.421 77.821	0.33738 0.33738	0.32589 0.32589
5	4.03~ 5.03	Sand	7.5	27.0	——— ———	77.821 85.321	0.33738 0.33738	0.32589 0.32589
6	5.03~ 5.53	Sand	7.5	31.0	——— ———	85.321 89.071	0.29008 0.29008	0.28020 0.28020
7	5.53~ 5.98	Clay	6.5	———	100.0 100.0	89.071 91.996	——— ———	——— ———
8	5.98~ 6.03	Clay	6.5	———	100.0 100.0	91.996 92.321	——— ———	——— ———
9	6.03~ 7.03	Clay	6.5	———	100.0 100.0	92.321 98.821	——— ———	——— ———
10	7.03~ 8.03	Clay	6.5	———	100.0 100.0	98.821 105.321	——— ———	——— ———
11	8.03~ 9.03	Clay	6.5	———	100.0 100.0	105.321 111.821	——— ———	——— ———
12	9.03~ 10.03	Clay	6.5	———	100.0 100.0	111.821 118.321	——— ———	——— ———
13	10.03~ 11.03	Clay	6.5	———	50.0 50.0	118.321 124.821	——— ———	——— ———
14	11.03~ 12.03	Clay	6.5	———	50.0 50.0	124.821 131.321	——— ———	——— ———
15	12.03~ 13.03	Clay	6.5	———	100.0 100.0	131.321 137.821	——— ———	——— ———
16	13.03~ 13.47	Clay	6.5	———	50.0 50.0	137.821 140.681	——— ———	——— ———
17	13.47~ 20.53	Clay	10.0	———	1000.0 1000.0	140.681 211.281	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh + Qp kN/m2	Kp	Kp × cos δ
8	5.98~ 6.03	Clay	6.5	0.0	100.0 100.0	0.000 0.325	——— ———	——— ———
9	6.03~ 7.03	Clay	6.5	0.0	100.0 100.0	0.325 6.825	——— ———	——— ———
10	7.03~ 8.03	Clay	6.5	0.0	100.0 100.0	6.825 13.325	——— ———	——— ———
11	8.03~ 9.03	Clay	6.5	0.0	100.0 100.0	13.325 19.825	——— ———	——— ———
12	9.03~ 10.03	Clay	6.5	0.0	100.0 100.0	19.825 26.325	——— ———	——— ———
13	10.03~ 11.03	Clay	6.5	0.0	50.0 50.0	26.325 32.825	——— ———	——— ———
14	11.03~ 12.03	Clay	6.5	0.0	50.0 50.0	32.825 39.325	——— ———	——— ———
15	12.03~ 13.03	Clay	6.5	0.0	100.0 100.0	39.325 45.825	——— ———	——— ———
16	13.03~ 13.47	Clay	6.5	0.0	50.0 50.0	45.825 48.685	——— ———	——— ———
17	13.47~ 20.53	Clay	10.0	20.0	1000.0 1000.0	48.685 119.285	——— ———	——— ———

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= -15.00、β = 0.00、θ = 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 2.03	15.51 20.47	——— ———	15.51 20.47	0.00 19.89	——— ———
2	2.03~ 3.03	20.47 22.92	——— ———	20.47 22.92	19.89 29.69	——— ———
3	3.03~ 3.71	22.92 24.58	——— ———	22.92 24.58	29.69 36.36	——— ———
4	3.71~ 4.03	24.58 25.36	——— ———	24.58 25.36	36.36 36.36	——— ———
5	4.03~ 5.03	25.36 27.81	——— ———	25.36 27.81	36.36 36.36	——— ———
6	5.03~ 5.53	23.91 24.96	——— ———	23.91 24.96	36.36 36.36	——— ———
7	5.53~ 5.98	-110.93 -108.00	44.54 46.00	44.54 46.00	36.36 36.36	——— ———
8	5.98~ 6.03	-108.00 -107.68	46.00 46.16	46.00 46.16	36.36 36.36	200.00 200.32
9	6.03~ 7.03	-107.68 -101.18	46.16 49.41	46.16 49.41	36.36 36.36	200.32 206.82
10	7.03~ 8.03	-101.18 -94.68	49.41 52.66	49.41 52.66	36.36 36.36	206.82 213.32
11	8.03~ 9.03	-94.68 -88.18	52.66 55.91	52.66 55.91	36.36 36.36	213.32 219.82
12	9.03~ 10.03	-88.18 -81.68	55.91 59.16	55.91 59.16	36.36 36.36	219.82 226.32
13	10.03~ 11.03	18.32 24.82	59.16 62.41	59.16 62.41	36.36 36.36	126.32 132.82

14	11.03~ 12.03	24.82 31.32	62.41 65.66	62.41 65.66	36.36 36.36	132.82 139.32
15	12.03~ 13.03	-68.68 -62.18	65.66 68.91	65.66 68.91	36.36 36.36	239.32 245.82
16	13.03~ 13.47	37.82 40.68	68.91 70.34	68.91 70.34	36.36 36.36	145.82 148.68
17	13.47~ 20.53	-1859.32 -1788.72	70.34 105.64	70.34 105.64	36.36 36.36	2048.69 2119.28

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma \gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

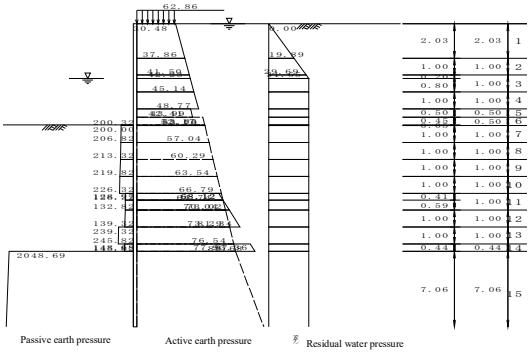
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 2.03	Sand	7.5	27.0	—— ——	62.86 78.09	0.00 19.89	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
2	2.03~ 3.03	Sand	7.5	27.0	—— ——	78.09 85.59	19.89 29.69	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
3	3.03~ 3.23	Sand	7.5	27.0	—— ——	85.59 87.09	29.69 31.65	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
4	3.23~ 4.03	Sand	7.5	27.0	—— ——	87.09 93.09	31.65 39.49	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
5	4.03~ 5.03	Sand	7.5	27.0	—— ——	93.09 100.59	39.49 49.29	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
6	5.03~ 5.53	Sand	7.5	31.0	—— ——	100.59 104.34	49.29 54.19	0.200 0.200	11.31 11.31	0.43652 0.43652	0.42164 0.42164	—— ——
7	5.53~ 5.98	Clay	6.5	——	100.0 100.0	104.34 107.26	54.19 58.60	0.200 0.200	11.31 11.31	—— ——	—— ——	42.38 42.33
8	5.98~ 6.03	Clay	6.5	——	100.0 100.0	107.26 107.59	58.60 59.09	0.200 0.200	11.31 11.31	—— ——	—— ——	42.33 42.33
9	6.03~ 7.03	Clay	6.5	——	100.0 100.0	107.59 114.09	59.09 68.89	0.200 0.200	11.31 11.31	—— ——	—— ——	42.33 42.22
10	7.03~ 8.03	Clay	6.5	——	100.0 100.0	114.09 120.59	68.89 78.69	0.200 0.200	11.31 11.31	—— ——	—— ——	42.22 42.10
11	8.03~ 9.03	Clay	6.5	——	100.0 100.0	120.59 127.09	78.69 88.49	0.200 0.200	11.31 11.31	—— ——	—— ——	42.10 41.99
12	9.03~ 10.03	Clay	6.5	——	100.0 100.0	127.09 133.59	88.49 98.29	0.200 0.200	11.31 11.31	—— ——	—— ——	41.99 41.87
13	10.03~ 10.44	Clay	6.5	——	50.0 50.0	133.59 136.23	98.29 ——	0.200 ——	11.31 ——	—— ——	—— ——	37.92 ——
14	10.44~ 11.03	Clay	6.5	——	50.0 50.0	136.23 140.09	—— 108.09	—— 0.200	—— 11.31	—— ——	—— ——	—— 37.62
15	11.03~ 12.03	Clay	6.5	——	50.0 50.0	140.09 146.59	108.09 117.89	0.200 0.200	11.31 11.31	—— ——	—— ——	37.62 37.32
16	12.03~ 13.03	Clay	6.5	——	100.0 100.0	146.59 153.09	117.89 127.69	0.200 0.200	11.31 11.31	—— ——	—— ——	41.64 41.52
17	13.03~ 13.47	Clay	6.5	——	50.0 50.0	153.09 155.95	127.69 132.01	0.200 0.200	11.31 11.31	—— ——	—— ——	37.01 36.87
18	13.47~ 20.53	Clay	10.0	——	1000.0 1000.0	155.95 226.55	132.01 201.19	0.200 0.200	11.31 11.31	—— ——	—— ——	44.68 44.58

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}} \cdot \tan\theta$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
8	5.98~ 6.03	Clay	6.50	0.0	100.0 100.0	0.000 0.325	0.00 0.49	0.200 0.200	11.31 11.31	—— ——	—— ——
9	6.03~ 7.03	Clay	6.50	0.0	100.0 100.0	0.325 6.825	0.49 10.29	0.200 0.200	11.31 11.31	—— ——	—— ——
10	7.03~ 8.03	Clay	6.50	0.0	100.0 100.0	6.825 13.325	10.29 20.09	0.200 0.200	11.31 11.31	—— ——	—— ——
11	8.03~ 9.03	Clay	6.50	0.0	100.0 100.0	13.325 19.825	20.09 29.89	0.200 0.200	11.31 11.31	—— ——	—— ——
12	9.03~ 10.03	Clay	6.50	0.0	100.0 100.0	19.825 26.325	29.89 39.69	0.200 0.200	11.31 11.31	—— ——	—— ——
13	10.03~ 10.44	Clay	6.50	0.0	50.0 50.0	26.325 28.971	39.69 ——	0.200 ——	11.31 ——	—— ——	—— ——
14	10.44~ 11.03	Clay	6.50	0.0	50.0 50.0	28.971 32.825	—— 49.49	—— 0.200	—— 11.31	—— ——	—— ——
15	11.03~ 12.03	Clay	6.50	0.0	50.0 50.0	32.825 39.325	49.49 59.29	0.200 0.200	11.31 11.31	—— ——	—— ——
16	12.03~ 13.03	Clay	6.50	0.0	100.0 100.0	39.325 45.825	59.29 69.09	0.200 0.200	11.31 11.31	—— ——	—— ——
17	13.03~ 13.47	Clay	6.50	0.0	50.0 50.0	45.825 48.685	69.09 73.40	0.200 0.200	11.31 11.31	—— ——	—— ——
18	13.47~ 20.53	Clay	10.00	20.0	1000.0 1000.0	48.685 119.285	73.40 142.59	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.
δ = 0.00 degrees, β = 0.00 degrees
Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 2.03	30.48 37.86	—— ——	30.48 37.86	0.00 19.89	—— ——
2	2.03~ 3.03	37.86 41.50	—— ——	37.86 41.50	19.89 29.69	—— ——
3	3.03~ 3.23	41.50 42.23	—— ——	41.50 42.23	29.69 31.65	—— ——
4	3.23~ 4.03	42.23 45.14	—— ——	42.23 45.14	31.65 31.65	—— ——
5	4.03~ 5.03	45.14 48.77	—— ——	45.14 48.77	31.65 31.65	—— ——
6	5.03~ 5.53	42.41 43.99	—— ——	42.41 43.99	31.65 31.65	—— ——
7	5.53~ 5.98	-73.64 -70.06	52.17 53.63	52.17 53.63	31.65 31.65	—— ——
8	5.98~ 6.03	-70.06 -69.66	53.63 53.79	53.63 53.79	31.65 31.65	200.00 200.32
9	6.03~ 7.03	-69.66 -61.71	53.79 57.04	53.79 57.04	31.65 31.65	200.32 206.82
10	7.03~ 8.03	-61.71 -53.75	57.04 60.29	57.04 60.29	31.65 31.65	206.82 213.32
11	8.03~ 9.03	-53.75 -45.79	60.29 63.54	60.29 63.54	31.65 31.65	213.32 219.82
12	9.03~ 10.03	-45.79 -37.81	63.54 66.79	63.54 66.79	31.65 31.65	219.82 226.32
13	10.03~ 10.44	64.74 68.12	66.79 68.12	66.79 68.12	31.65 31.65	126.32 128.97
14	10.44~ 11.03	68.12 73.02	68.12 70.04	68.12 73.02	31.65 31.65	128.97 132.82
15	11.03~ 12.03	73.02 81.34	70.04 73.29	73.02 81.34	31.65 31.65	132.82 139.32
16	12.03~ 13.03	-21.83 -13.82	73.29 76.54	73.29 76.54	31.65 31.65	239.32 245.82
17	13.03~ 13.47	89.68 93.36	76.54 77.97	89.68 93.36	31.65 31.65	145.82 148.68
18	13.47~ 20.53	-1812.64 -1727.69	77.97 113.27	77.97 113.27	31.65 31.65	2048.69 2119.28

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma \gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

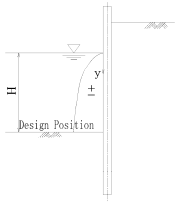
3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	3.23	0.00	0.00
2	4.23	1.00	2.84
3	5.23	2.00	4.02
4	5.98	2.75	4.72

$$p_{dr} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

Where,

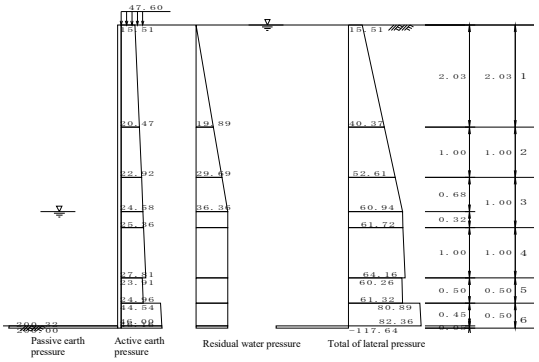
k_{hs}: design seismic coefficient
γ_w : unit weight of water
H : water depth of riverside
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.03	30.48 37.86	0.00 19.89	——— ———	30.48 57.76
2	2.03~ 3.03	37.86 41.50	19.89 29.69	——— ———	57.76 71.19
3	3.03~ 3.23	41.50 42.23	29.69 31.65	——— ———	71.19 73.88
4	3.23~ 4.03	42.23 45.14	31.65 31.65	——— ———	73.88 76.79
5	4.03~ 5.03	45.14 48.77	31.65 31.65	——— ———	76.79 80.43
6	5.03~ 5.53	42.41 43.99	31.65 31.65	——— ———	74.06 75.65
7	5.53~ 5.98	52.17 53.63	31.65 31.65	——— ———	83.82 85.28
8	5.98~ 6.03	53.63 53.79	31.65 31.65	200.00 200.32	-114.72 -114.88

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.98 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

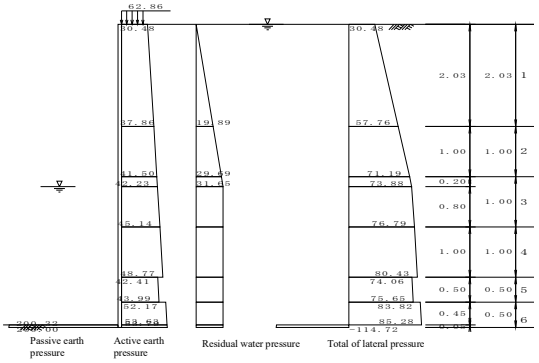
Material Name		10 H _ H 1000 -250 -16 -28 -18	
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	845700 cm^4(original condition)
	I	=	735759 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 735759 \times 10^{-8} = 1.472 \times 10^6$

No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.03	15.51 20.47	0.00 19.89	——— ———	15.51 40.37
2	2.03~ 3.03	20.47 22.92	19.89 29.69	——— ———	40.37 52.61
3	3.03~ 3.71	22.92 24.58	29.69 36.36	——— ———	52.61 60.94
4	3.71~ 4.03	24.58 25.36	36.36 36.36	——— ———	60.94 61.72
5	4.03~ 5.03	25.36 27.81	36.36 36.36	——— ———	61.72 64.16
6	5.03~ 5.53	23.91 24.96	36.36 36.36	——— ———	60.26 61.32
7	5.53~ 5.98	44.54 46.00	36.36 36.36	——— ———	80.89 82.36
8	5.98~ 6.03	46.00 46.16	36.36 36.36	200.00 200.32	-117.64 -117.81

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.98 m)

4.2 Seismic Condition



No	Depth m	N Value
1	1.53	3
2	2.53	3
3	3.53	3
4	4.53	4
5	5.53	17
6	6.53	24
7	7.53	19
8	8.53	19
9	9.53	18
10	10.53	13

No	Depth m	N Value
11	11.53	15
12	12.53	17
13	13.53	14
14	14.53	19
15	15.53	14
16	16.53	50
17	17.53	50
18	18.53	50
19	19.53	50
20	20.53	50

5.2 Normal Condition

Assuming Kh = 12736 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.216 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 4.64 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.98 m) to 4.64 m depth (GL -10.62 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.98	0.55	20.1	24.0	12.14
2	6.53	1.00	24.0	19.0	21.50
3	7.53	1.00	19.0	19.0	19.00
4	8.53	1.00	19.0	18.0	18.50
5	9.53	1.00	18.0	13.0	15.50
6	10.53	0.09	13.0	13.2	1.13
	L = Σh = 4.64		ΣA =	87.77	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{87.77}{4.64} = 18.93$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 18.93 = 53006 \text{ kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 53006 = 176688 \text{ kN/m}^3 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 176688(10.00/0.3)^{-3/4} = 12736 \text{ kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 12736 kN/m3.

5.3 Seismic Condition

Assuming Kh = 26667 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}} = 0.259 \ m^{-1}$$

$$L = \frac{1}{\beta} = 3.85 \ m$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.98 m) and 3.85 m depth (GL -9.83 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.98	0.55	20.1	24.0	12.14
2	6.53	1.00	24.0	19.0	21.50
3	7.53	1.00	19.0	19.0	19.00
4	8.53	1.00	19.0	18.0	18.50
5	9.53	0.30	18.0	16.5	5.25
	L = Σh = 3.85		Σ A =	76.39	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{76.39}{3.85} = 19.82$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 19.82 = 55491 \ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 55491 = 369943 \ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 369943(10.00/0.3)^{-3/4} = 26667 \ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 26667 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.03	2.03	15.51 40.37	15.74 40.97	5.30 4.63	83.49 189.56
2	2.03~ 3.03	1.00	40.37 52.61	20.18 26.31	3.62 3.28	73.00 86.37
3	3.03~ 3.71	0.68	52.61 60.94	17.89 20.72	2.72 2.50	48.71 51.73
4	3.71~ 4.03	0.32	60.94 61.72	9.75 9.88	2.16 2.06	21.09 20.31
5	4.03~ 5.03	1.00	61.72 64.16	30.86 32.08	1.62 1.28	49.89 41.17
6	5.03~ 5.53	0.50	60.26 61.32	15.07 15.33	0.78 0.62	11.80 9.45
7	5.53~ 5.98	0.45	80.89 82.36	18.20 18.53	0.30 0.15	5.46 2.78
				Σ P = 291.50	Σ M =	694.82

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	23.4 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.98 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 139.93 \ kN \cdot m$
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{834.75}{314.90} = 2.65 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 314.90}{5.98} = 105.32 \ kN/m$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.03	2.03	30.48 57.76	30.94 58.62	5.30 4.63	164.08 271.23
2	2.03~ 3.03	1.00	57.76 71.19	28.88 35.60	3.62 3.28	104.44 116.88
3	3.03~ 3.23	0.20	71.19 73.88	7.12 7.39	2.88 2.82	20.53 20.81
4	3.23~ 4.03	0.80	73.88 76.79	29.55 30.72	2.48 2.22	73.39 68.09
5	4.03~ 5.03	1.00	76.79 80.43	38.40 40.21	1.62 1.28	62.07 51.61
6	5.03~ 5.53	0.50	74.06 75.65	18.52 18.91	0.78 0.62	14.50 11.66
7	5.53~ 5.98	0.45	83.82 85.28	18.86 19.19	0.30 0.15	5.66 2.88
				Σ P = 382.90	Σ M =	987.83

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	62.8 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	33.9 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.98 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 409.44 \ kN \cdot m$

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y' m	Moment Mdw kN・m
1	3.23~ 4.23	1.00	0.0 2.8	0.00 1.42	2.42 2.08	0.00 2.96
2	4.23~ 5.23	1.00	2.8 4.0	1.42 2.01	1.42 1.08	2.01 2.18
3	5.23~ 5.98	0.75	4.0 4.7	1.51 1.77	0.50 0.25	0.75 0.44
				Σ Pdw = 8.13	Σ Mdw =	8.35

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1405.63}{453.83} = 3.10 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 453.83}{5.98} = 151.78 \ kN/m$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name	10 H _ H 1000 -250 -16 -28 -18		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	845700 cm^4 (original condition)
	I	=	735759 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 735759 × 10^{-8}		=	1.472 × 10^6

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	12763 kN/m^3
calculated value	β	=	0.21568 m^{-1}
resultant earth force (lateral)	P_0	=	314.90 kN/m
height of acting position of load	h_0	=	2.65 m
moment	M_0	=	834.75 kN・m/m
in consideration of ψ_m = 1.337,			
maximum moment	M_{max}	=	1115.93 kN・m/m
depth of generated position of M_{max}	l_m	=	2.024 m
depth of 1st fixed point	l_i	=	5.665 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	26667	kN/m³
calculated value	β	=	0.25944	m⁻¹
resultant earth force (lateral)	P_0	=	453.83	kN/m
height of acting position of load	h_0	=	3.10	m
moment	M_0	=	1405.63	kN·m/m

in consideration of ψ_m = 1.205,

maximum moment	M_{max}	=	1693.26	kN·m/m
depth of generated position of M_{max}	l_m	=	1.412	m
depth of 1st fixed point	l_i	=	4.439	m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 1000 -250 -16 -28 -18		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.89
Section efficiency	μ	=	1.00
Module of section	Z_0	=	12670 cm³ (original condition)
	Z	=	11276 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1115.93\times10^6}{11276\times10^3} = 99\ N/mm^2 \leqq \sigma_a = 180\ N/mm^2$$

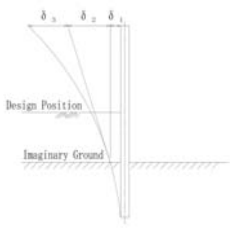
6.3.2 Seismic Condition

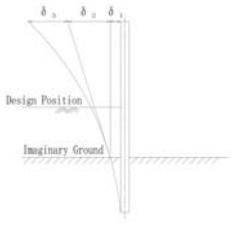
$$\sigma = \frac{M_{max}}{Z} = \frac{1693.26\times10^6}{11276\times10^3} = 150\ N/mm^2 \leqq \sigma_a = 270\ N/mm^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

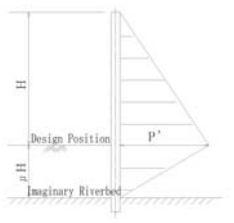
Displacement Calculation





$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.2594\times3.10)\times453.83}{2\times2.00\times10^8\times735759\times10^{-8}\times0.2594^3} = 0.01593\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.2594\times3.10)\times453.83}{2\times2.00\times10^8\times735759\times10^{-8}\times0.2594^2}\times(5.98+0.00) = 0.03572\ m$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.98} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{151.78\times5.98^4}{120\times2.00\times10^8\times735759\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4)$$

$$= 0.00440\ m$$

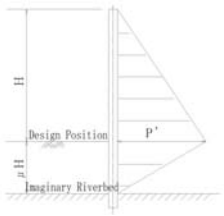
$\delta = \delta1 + \delta2 + \delta3$
= 0.01593 + 0.03572 + 0.00440
= 0.05604 m
Size = 56.04 ≦ δa = 75.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.2157\times2.65)\times314.90}{2\times2.00\times10^8\times735759\times10^{-8}\times0.2157^3} = 0.01676\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.2157\times2.65)\times314.90}{2\times2.00\times10^8\times735759\times10^{-8}\times0.2157^2}\times(5.98+0.00) = 0.02948\ m$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.98} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{105.32\times5.98^4}{120\times2.00\times10^8\times735759\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4)$$

$$= 0.00305\ m$$

$\delta = \delta1 + \delta2 + \delta3$
= 0.01676 + 0.02948 + 0.00305
= 0.04930 m
Size = 49.30 ≦ δa = 50.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name	10 H _ H 1000 -250 -16 -28 -18		
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	845700 cm⁴ (original condition)
	I	=	845700 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 845700 × 10⁻⁸		=	1.691 × 10⁶

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction	K_h	=	12736 kN/m²
Calculated value	β	=	0.20830 m⁻¹
Penetration length of SSP	D	=	$0.00 + \frac{3}{0.208}$ = 14.40 m
Whole length of SSP	L	=	5.98 − 0.40 + 14.40 = 19.98 m

7.1.1 Seismic Condition

Modules of lateral subgrade reaction	K_h	=	26667 kN/m³
Calculated value	β	=	0.25056 m⁻¹
Penetration length of SSP	D	=	$0.00 + \frac{3}{0.251}$ = 11.97 m
Whole length of SSP	L	=	5.98 − 0.40 + 11.97 = 17.55 m

Therefore, the total length of the sheet pile is 20.00 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile　　10 H _ H 1000 -250 -16 -28 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	845700		
Sectional Modulus	Z (cm3)	12670		
Maximum bending moment	Mmax (kN・m・m)		1115.93	1693.26
Stress intensity	σ (N/mm2)		99 (180)	150 (270)
Lateral displacement	δ (mm)		49.30 (50.0)	56.04 (75.0)
Penetration depths	D (m)		14.40	11.97
Whole length of SSP	L (m)	20.00		

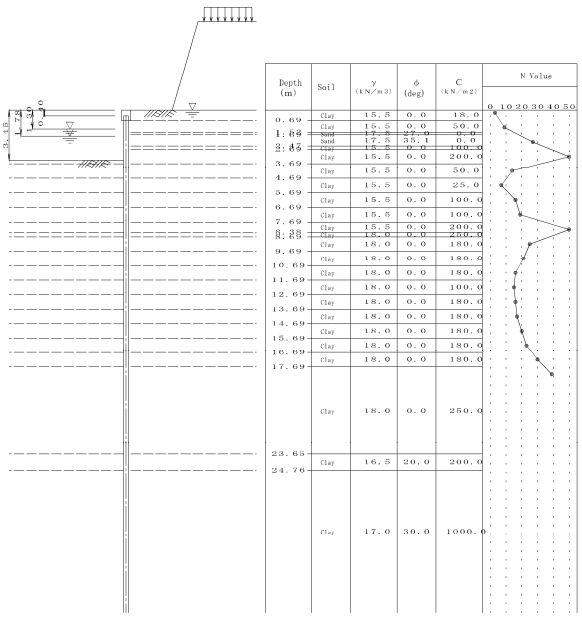
Block No. : L-12
Sta. : 9+205~9+320

Design Cross Section : Sta 9+300
Boring Name : BMLL-26

Specification : SSP SP-10H
（Combined） : H 700-200-12-19-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	3.45 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_h	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	1.78 m (Normal Condition)
	L_{wp}'	=	1.30 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress　　Chang's formula
Penetration depths　　$L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water　　γ_w = 9.8 kN/m^3

Type of water pressure　　trapezoidal water pressure

Lateral pressure　　calculated in consideration of site conditions

Study case　　- Normal Condition
- Seismic Condition

Design earthquake intensity　　k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	= 61.1 kN/m	(Normal Condition)
		Pt'	= 147.5 kN/m	(Seismic Condition)
	Depth of acting point	Ht	= 0.0 m	(Normal Condition)
		Ht'	= 0.0 m	(Seismic Condition)
	Moment	M_m	= 39.00 kN・m/m	(Normal Condition)
		M_m'	= 234.9kN・m/m	(Seismic Condition)
	Depth of acting point	H_m'	= 0.00 m	(Seismic Condition)
		H_m	= 0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load　　not considered

Minimum angle of rupture　　ζ_0 = 10 degrees

Rear side angle of slope　　not considered

Angle of rupture (clayey soil)　　$\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C} \cdot \tan\theta}$

Equilibrium factor of compression　　K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m
E_0 = 2800N

Average N-value　　calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value
1	0.19	3	11	10.19	21
2	1.19	9	12	11.19	16
3	2.19	27	13	12.19	15
4	3.19	50	14	13.19	16
5	4.19	14	15	14.19	17
6	5.19	7	16	15.19	20
7	6.19	16	17	16.19	23
8	7.19	19	18	17.19	30
9	8.19	50	19	18.19	39
10	9.19	25			

1.6 Vertical Load

Vertical load on landside　　calculated in consideration of embankment shape on landside

Vertical load on riverside　　not considered

1.7 Soil Modulus

Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	0.69	0.69
2	1.52	0.83
3	1.69	0.17
4	2.47	0.78
5	2.69	0.22
6	3.69	1.00
7	4.69	1.00
8	5.69	1.00
9	6.69	1.00
10	7.69	1.00
11	8.38	0.69
12	8.69	0.31
13	9.69	1.00
14	10.69	1.00
15	11.69	1.00
16	12.69	1.00
17	13.69	1.00
18	14.69	1.00
19	15.69	1.00
20	16.69	1.00
21	17.69	1.00
22	23.65	5.96
23	24.76	1.11
24	33.10	8.34

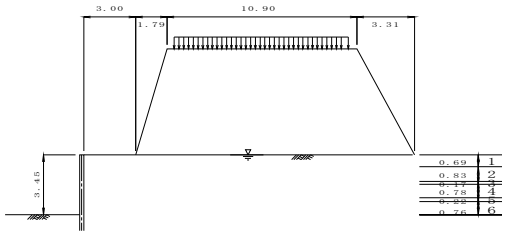
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	0.69	C	3.0	15.50	5.70	0.0	18.0	0.0	0.200	Auto	Auto
2	1.52	C	9.0	15.50	5.70	0.0	50.0	0.0	0.200	Auto	Auto
3	1.69	S	9.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
4	2.47	S	27.0	17.50	7.70	35.1	0.0	0.0	0.200	Auto	Auto
5	2.69	C	27.0	15.50	5.70	0.0	100.0	0.0	0.200	Auto	Auto
6	3.69	C	50.0	15.50	5.70	0.0	200.0	0.0	0.200	Auto	Auto
7	4.69	C	14.0	15.50	5.70	0.0	50.0	0.0	0.200	Auto	Auto
8	5.69	C	7.0	15.50	5.70	0.0	25.0	0.0	0.200	Auto	Auto
9	6.69	C	16.0	15.50	5.70	0.0	100.0	0.0	0.200	Auto	Auto
10	7.69	C	19.0	15.50	5.70	0.0	100.0	0.0	0.200	Auto	Auto
11	8.38	C	50.0	15.50	5.70	0.0	200.0	0.0	0.200	Auto	Auto
12	8.69	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
13	9.69	C	25.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
14	10.69	C	21.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
15	11.69	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
16	12.69	C	15.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
17	13.69	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
18	14.69	C	17.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
19	15.69	C	20.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
20	16.69	C	23.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
21	17.69	C	30.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
22	23.65	C	39.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
23	24.76	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto
24	33.10	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note) depth : from top of coping to bottom of the layer　　C_o : soil adhesion
soil : sandy(S), clayey(C), mixed (M)　　a : slope of soil adhesion
N-value : average N-value in the layer　　k' : design seismic coefficient (underwater)
γ : wet unit weight of soil　　ζ : angle of active rupture
γ' : saturated unit weight of soil　　kh : modulus of subgrade reaction
φ : internal friction angle of soil

Angle of wall friction

Angle of wall friction	Normal Condition	Seisimic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate	Thickness	soil single weight γ	internal friction angle	stickiness	decay angle ζ

		Bottom Left m	Top Left m	Top Right m	Bottom Right m	h m	Normal Condition kN/m3	Seismic Condition kN/m3	φ degree	C kN/m2	Normal Condition degree	Seismic Condition degree
1	Sand	3.00	4.79	15.69	19.00	6.09	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area		load strength	
	From m	End point m	Normal Condition kN/m2	Seismic Condition kN/m2
1	5.20	15.20	10.0	5.0

Angle of rapture in embankment　　calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name　　10 H _ H 700 -200 - 12-19-18
Young's modulus　　E = 200000 N/mm^2
Inertia sectional moment　　I_0 = 299700 cm^4
Sectional factor　　Z_0 = 5540 cm^3

Corrosion margin　　t_1 = 1.00 mm (riverside)　　t_2 = 1.00 mm (landside)

Corrosion rate (to I_0)　　η = 0.84
Corrosion rate (to Z_0)　　η = 0.86
Section efficiency (to I_0)　　μ = 1.00
Section efficiency (to Z_0)　　μ = 1.00

Round unit of SSP length　　0.50 m

Allowable stress　　σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

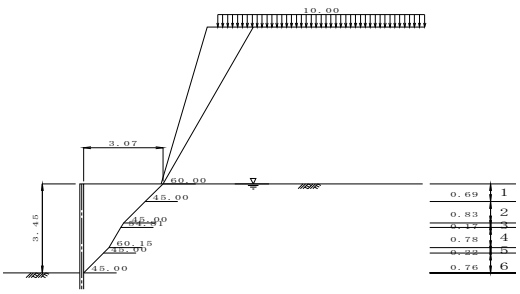
Allowable displacement　　δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam　　calculated as distributed load of each layer

Reduction of material modulus　　Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	3.45 ~ 2.69	Clay	0.0	15.0	200.0	21.57	39.61	33.81	45.00
2	2.69 ~ 2.47	Clay	0.0	15.0	100.0	17.23	39.61	26.36	45.00
3	2.47 ~ 1.69	Sand	35.1	15.0	0.0	15.98	39.61	24.21	60.15
4	1.69 ~ 1.52	Sand	27.0	15.0	0.0	9.97	39.61	16.56	54.81
5	1.52 ~ 0.69	Clay	0.0	15.0	50.0	8.66	39.61	14.90	45.00
6	0.69 ~ 0.00	Clay	0.0	15.0	18.0	3.93	39.61	6.76	45.00
7		embankment	30.0	——	0.0	115.71	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°
Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan^{-1}k or θ = tan^{-1}k'

γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m^2)
C cohesive force of soil (kN/m^2)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.00	0.76	0.00	0.00	0.76	0.76
2	45.00	0.22	0.76	0.76	0.98	0.98
3	60.15	0.78	0.98	0.98	1.43	1.76
4	54.81	0.17	1.43	1.76	1.55	1.93
5	45.00	0.83	1.55	1.93	2.38	2.76
6	45.00	0.69	2.38	2.76	3.07	3.45
7	60.00	6.09	3.07	3.45	6.58	9.54

From the above table, the loading width (L) on the ground surface is 3.07 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	5.67	107.66
Σ			107.66

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	1.38	13.83
Σ			13.83

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

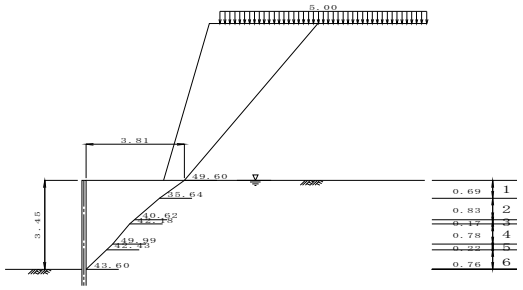
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{107.66 + 13.83 + 0.00}{3.07}$$

$$= 39.61 \text{ kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	3.45 ~ 2.69	Clay	0.0	15.0	200.0	21.57	81.10	33.81	0.200	11.31	43.60
2	2.69 ~ 2.47	Clay	0.0	15.0	100.0	17.23	81.10	26.36	0.200	11.31	42.43
3	2.47 ~ 1.69	Sand	35.1	15.0	0.0	15.98	81.10	24.21	0.200	11.31	49.99
4	1.69 ~ 1.52	Sand	27.0	15.0	0.0	9.97	81.10	16.56	0.200	11.31	42.18
5	1.52 ~ 0.69	Clay	0.0	15.0	50.0	8.66	81.10	14.90	0.200	11.31	40.62
6	0.69 ~ 0.00	Clay	0.0	15.0	18.0	3.93	81.10	6.76	0.200	11.31	35.64
7		embankment	30.0	———	0.0	115.71	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h + Q}$$

Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)

θ = tan^{-1}k or θ = tan^{-1}k'
γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m^2)
C cohesive force of soil (kN/m^2)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	43.60	0.76	0.00	0.00	0.80	0.76
2	42.43	0.22	0.80	0.76	1.04	0.98
3	49.99	0.78	1.04	0.98	1.69	1.76
4	42.18	0.17	1.69	1.76	1.88	1.93
5	40.62	0.83	1.88	1.93	2.85	2.76
6	35.64	0.69	2.85	2.76	3.81	3.45
7	49.60	6.09	3.81	3.45	8.99	9.54

From the above table, the loading width (L) on the ground surface is 3.81 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	15.27	290.10
Σ			290.10

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.79	18.97
Σ			18.97

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

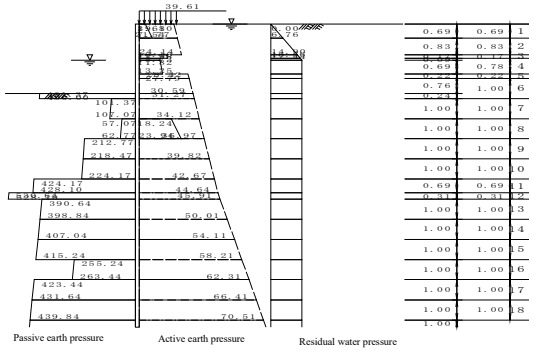
$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{290.10 + 18.97 + 0.00}{3.81}$$

$$= 81.10 \text{ kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 0.69	Clay	5.7	———	18.0 18.0	39.609 43.542	——— ———	——— ———
2	0.69~ 1.52	Clay	5.7	———	50.0 50.0	43.542 48.273	——— ———	——— ———
3	1.52~ 1.69	Sand	7.7	27.0	——— ———	48.273 49.582	0.33738 0.33738	0.32589 0.32589
4	1.69~ 1.78	Sand	7.7	35.1	——— ———	49.582 50.275	0.24677 0.24677	0.23836 0.23836
5	1.78~ 2.47	Sand	7.7	35.1	——— ———	50.275 55.588	0.24677 0.24677	0.23836 0.23836
6	2.47~ 2.69	Clay	5.7	———	100.0 100.0	55.588 56.842	——— ———	——— ———
7	2.69~ 3.45	Clay	5.7	———	200.0 200.0	56.842 61.174	——— ———	——— ———
8	3.45~ 3.69	Clay	5.7	———	200.0 200.0	61.174 62.542	——— ———	——— ———
9	3.69~ 4.69	Clay	5.7	———	50.0 50.0	62.542 68.242	——— ———	——— ———
10	4.69~ 5.69	Clay	5.7	———	25.0 25.0	68.242 73.942	——— ———	——— ———
11	5.69~ 6.69	Clay	5.7	———	100.0 100.0	73.942 79.642	——— ———	——— ———
12	6.69~ 7.69	Clay	5.7	———	100.0 100.0	79.642 85.342	——— ———	——— ———

13	7.69~ 8.38	Clay	5.7	——	200.0 200.0	85.342 89.275	——	——
14	8.38~ 8.69	Clay	8.2	——	250.0 250.0	89.275 91.817	——	——
15	8.69~ 9.69	Clay	8.2	——	180.0 180.0	91.817 100.017	——	——
16	9.69~ 10.69	Clay	8.2	——	180.0 180.0	100.017 108.217	——	——
17	10.69~ 11.69	Clay	8.2	——	180.0 180.0	108.217 116.417	——	——
18	11.69~ 12.69	Clay	8.2	——	100.0 100.0	116.417 124.617	——	——
19	12.69~ 13.69	Clay	8.2	——	180.0 180.0	124.617 132.817	——	——
20	13.69~ 14.69	Clay	8.2	——	180.0 180.0	132.817 141.017	——	——
21	14.69~ 15.69	Clay	8.2	——	180.0 180.0	141.017 149.217	——	——
22	15.69~ 16.69	Clay	8.2	——	180.0 180.0	149.217 157.417	——	——
23	16.69~ 17.69	Clay	8.2	——	180.0 180.0	157.417 165.617	——	——
24	17.69~ 23.65	Clay	8.2	——	250.0 250.0	165.617 214.489	——	——
25	23.65~ 24.76	Clay	6.7	——	200.0 200.0	214.489 221.926	——	——
26	24.76~ 33.10	Clay	7.2	——	1000.0 1000.0	221.926 281.974	——	——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

$\delta = 15.00$、$\beta = 0.00$、$\theta = 0.00$

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cosδ
8	3.45~ 3.69	Clay	5.7	0.0	200.0 200.0	0.000 1.368	——	——
9	3.69~ 4.69	Clay	5.7	0.0	50.0 50.0	1.368 7.068	——	——
10	4.69~ 5.69	Clay	5.7	0.0	25.0 25.0	7.068 12.768	——	——
11	5.69~ 6.69	Clay	5.7	0.0	100.0 100.0	12.768 18.468	——	——
12	6.69~ 7.69	Clay	5.7	0.0	100.0 100.0	18.468 24.168	——	——
13	7.69~ 8.38	Clay	5.7	0.0	200.0 200.0	24.168 28.101	——	——
14	8.38~ 8.69	Clay	8.2	0.0	250.0 250.0	28.101 30.643	——	——
15	8.69~ 9.69	Clay	8.2	0.0	180.0 180.0	30.643 38.843	——	——
16	9.69~ 10.69	Clay	8.2	0.0	180.0 180.0	38.843 47.043	——	——
17	10.69~ 11.69	Clay	8.2	0.0	180.0 180.0	47.043 55.243	——	——
18	11.69~ 12.69	Clay	8.2	0.0	100.0 100.0	55.243 63.443	——	——
19	12.69~ 13.69	Clay	8.2	0.0	180.0 180.0	63.443 71.643	——	——
20	13.69~ 14.69	Clay	8.2	0.0	180.0 180.0	71.643 79.843	——	——
21	14.69~ 15.69	Clay	8.2	0.0	180.0 180.0	79.843 88.043	——	——
22	15.69~ 16.69	Clay	8.2	0.0	180.0 180.0	88.043 96.243	——	——
23	16.69~ 17.69	Clay	8.2	0.0	180.0 180.0	96.243 104.443	——	——
24	17.69~ 23.65	Clay	8.2	0.0	250.0 250.0	104.443 153.315	——	——
25	23.65~ 24.76	Clay	6.7	20.0	200.0 200.0	153.315 160.752	——	——
26	24.76~ 33.10	Clay	7.2	30.0	1000.0 1000.0	160.752 220.800	——	——

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;

$\delta = -15.00$、$\beta = 0.00$、$\theta = 0.00$

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.69	3.61 7.54	19.80 21.77	19.80 21.77	0.00 6.76	——
2	0.69~ 1.52	-56.46 -51.73	21.77 24.14	21.77 24.14	6.76 14.90	——
3	1.52~ 1.69	15.73 16.16	——	15.73 16.16	14.90 16.56	——
4	1.69~ 1.78	11.82 11.98	——	11.82 11.98	16.56 17.44	——
5	1.78~ 2.47	11.98 13.25	——	11.98 13.25	17.44 17.44	——
6	2.47~ 2.69	-144.41 -143.16	27.79 28.42	27.79 28.42	17.44 17.44	——
7	2.69~ 3.45	-343.16 -338.83	28.42 30.59	28.42 30.59	17.44 17.44	——
8	3.45~ 3.69	-338.83 -337.46	30.59 31.27	30.59 31.27	17.44 17.44	400.00 401.37
9	3.69~ 4.69	-37.46 -31.76	31.27 34.12	31.27 34.12	17.44 17.44	101.37 107.07
10	4.69~ 5.69	18.24 23.94	34.12 36.97	34.12 36.97	17.44 17.44	57.07 62.77
11	5.69~ 6.69	-126.06 -120.36	36.97 39.82	36.97 39.82	17.44 17.44	212.77 218.47
12	6.69~ 7.69	-120.36 -114.66	39.82 42.67	39.82 42.67	17.44 17.44	218.47 224.17
13	7.69~ 8.38	-314.66 -310.72	42.67 44.64	42.67 44.64	17.44 17.44	424.17 428.10
14	8.38~ 8.69	-410.72 -408.18	44.64 45.91	44.64 45.91	17.44 17.44	528.10 530.64
15	8.69~ 9.69	-268.18 -259.98	45.91 50.01	45.91 50.01	17.44 17.44	390.64 398.84
16	9.69~ 10.69	-259.98 -251.78	50.01 54.11	50.01 54.11	17.44 17.44	398.84 407.04
17	10.69~ 11.69	-251.78 -243.58	54.11 58.21	54.11 58.21	17.44 17.44	407.04 415.24
18	11.69~ 12.69	-83.58 -75.38	58.21 62.31	58.21 62.31	17.44 17.44	255.24 263.44
19	12.69~ 13.69	-235.38 -227.18	62.31 66.41	62.31 66.41	17.44 17.44	423.44 431.64
20	13.69~ 14.69	-227.18 -218.98	66.41 70.51	66.41 70.51	17.44 17.44	431.64 439.84
21	14.69~ 15.69	-218.98 -210.78	70.51 74.61	70.51 74.61	17.44 17.44	439.84 448.04
22	15.69~ 16.69	-210.78 -202.58	74.61 78.71	74.61 78.71	17.44 17.44	448.04 456.24
23	16.69~ 17.69	-202.58 -194.38	78.71 82.81	78.71 82.81	17.44 17.44	456.24 464.44
24	17.69~ 23.65	-334.38 -285.51	82.81 107.24	82.81 107.24	17.44 17.44	604.44 653.32
25	23.65~ 24.76	-185.51 -178.07	107.24 110.96	107.24 110.96	17.44 17.44	553.32 560.75
26	24.76~ 33.10	-1778.07 -1718.03	110.96 140.99	110.96 140.99	17.44 17.44	2160.75 2220.80

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_a \cdot (\Sigma\gamma h + Q)$

K_a : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

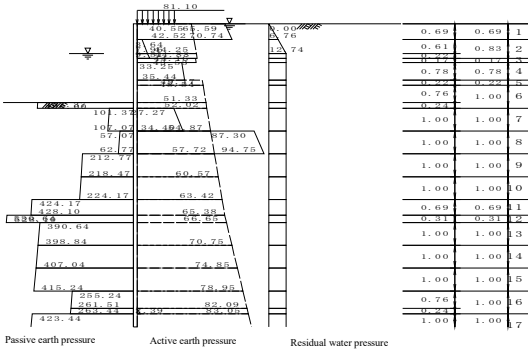
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 0.69	Clay	5.7	——	18.0 18.0	81.10 85.03	0.00 6.76	0.200 0.200	11.31 11.31	——	——	35.95 35.64
2	0.69~ 1.30	Clay	5.7	——	50.0 50.0	85.03 88.51	6.76 12.74	0.200 0.200	11.31 11.31	——	——	40.82 40.68
3	1.30~ 1.52	Clay	5.7	——	50.0 50.0	88.51 89.76	12.74 14.90	0.200 0.200	11.31 11.31	——	——	40.68 40.62
4	1.52~ 1.69	Sand	7.7	27.0	——	89.76 91.07	14.90 16.56	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
5	1.69~ 2.47	Sand	7.7	35.1	——	91.07 97.08	16.56 24.21	0.200 0.200	11.31 11.31	0.37794 0.37794	0.36506 0.36506	——
6	2.47~ 2.69	Clay	5.7	——	100.0 100.0	97.08 98.33	24.21 26.36	0.200 0.200	11.31 11.31	——	——	42.46 42.43
7	2.69~ 3.45	Clay	5.7	——	200.0 200.0	98.33 102.66	26.36 33.81	0.200 0.200	11.31 11.31	——	——	43.66 43.60
8	3.45~ 3.69	Clay	5.7	——	200.0 200.0	102.66 104.03	33.81 36.16	0.200 0.200	11.31 11.31	——	——	43.60 43.58
9	3.69~ 4.69	Clay	5.7	——	50.0 50.0	104.03 109.73	36.16 45.96	0.200 0.200	11.31 11.31	——	——	40.04 39.82
10	4.69~ 5.69	Clay	5.7	——	25.0 25.0	109.73 115.43	45.96 55.76	0.200 0.200	11.31 11.31	——	——	36.12 35.79
11	5.69~ 6.69	Clay	5.7	——	100.0 100.0	115.43 121.13	55.76 65.56	0.200 0.200	11.31 11.31	——	——	42.03 41.90

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
12	6.69~ 7.69	Clay	5.7	——	100.0 100.0	121.13 126.83	65.56 75.36	0.200 0.200	11.31 11.31	——	——	41.90 41.77

13	7.69~ 8.38	Clay	5.7	——	200.0 200.0	126.83 130.76	75.36 82.12	0.200 0.200	11.31 11.31	—— ——	—— ——	43.29 43.24
14	8.38~ 8.69	Clay	8.2	——	250.0 250.0	130.76 133.31	82.12 85.16	0.200 0.200	11.31 11.31	—— ——	—— ——	43.58 43.55
15	8.69~ 9.69	Clay	8.2	——	180.0 180.0	133.31 141.51	85.16 94.96	0.200 0.200	11.31 11.31	—— ——	—— ——	43.02 42.91
16	9.69~ 10.69	Clay	8.2	——	180.0 180.0	141.51 149.71	94.96 104.76	0.200 0.200	11.31 11.31	—— ——	—— ——	42.91 42.80
17	10.69~ 11.69	Clay	8.2	——	180.0 180.0	149.71 157.91	104.76 114.56	0.200 0.200	11.31 11.31	—— ——	—— ——	42.80 42.69
18	11.69~ 12.45	Clay	8.2	——	100.0 100.0	157.91 164.17	114.56 ——	0.200 ——	11.31 ——	—— ——	—— ——	41.08 ——
19	12.45~ 12.69	Clay	8.2	——	100.0 100.0	164.17 166.11	—— 124.36	—— 0.200	—— 11.31	—— ——	—— ——	—— 40.91
20	12.69~ 13.69	Clay	8.2	——	180.0 180.0	166.11 174.31	124.36 134.16	0.200 0.200	11.31 11.31	—— ——	—— ——	42.58 42.47
21	13.69~ 14.69	Clay	8.2	——	180.0 180.0	174.31 182.51	134.16 143.96	0.200 0.200	11.31 11.31	—— ——	—— ——	42.47 42.36
22	14.69~ 15.69	Clay	8.2	——	180.0 180.0	182.51 190.71	143.96 153.76	0.200 0.200	11.31 11.31	—— ——	—— ——	42.36 42.25
23	15.69~ 16.69	Clay	8.2	——	180.0 180.0	190.71 198.91	153.76 163.56	0.200 0.200	11.31 11.31	—— ——	—— ——	42.25 42.14
24	16.69~ 17.69	Clay	8.2	——	180.0 180.0	198.91 207.11	163.56 173.36	0.200 0.200	11.31 11.31	—— ——	—— ——	42.14 42.04
25	17.69~ 23.65	Clay	8.2	——	250.0 250.0	207.11 255.98	173.36 231.77	0.200 0.200	11.31 11.31	—— ——	—— ——	42.81 42.34
26	23.65~ 24.76	Clay	6.7	——	200.0 200.0	255.98 263.42	231.77 242.65	0.200 0.200	11.31 11.31	—— ——	—— ——	41.74 41.66
27	24.76~ 33.10	Clay	7.2	——	1000.0 1000.0	263.42 323.46	242.65 324.38	0.200 0.200	11.31 11.31	—— ——	—— ——	44.26 44.10

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β= 0.00、θ= 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}}\cdot\tan\theta$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cos δ
8	3.45~ 3.69	Clay	5.70	0.0	200.0 200.0	0.000 1.368	0.00 2.35	0.200 0.200	11.31 11.31	—— ——	—— ——
9	3.69~ 4.69	Clay	5.70	0.0	50.0 50.0	1.368 7.068	2.35 12.15	0.200 0.200	11.31 11.31	—— ——	—— ——
10	4.69~ 5.69	Clay	5.70	0.0	25.0 25.0	7.068 12.768	12.15 21.95	0.200 0.200	11.31 11.31	—— ——	—— ——
11	5.69~ 6.69	Clay	5.70	0.0	100.0 100.0	12.768 18.468	21.95 31.75	0.200 0.200	11.31 11.31	—— ——	—— ——

12	6.69~ 7.69	Clay	5.70	0.0	100.0 100.0	18.468 24.168	31.75 41.55	0.200 0.200	11.31 11.31	—— ——	—— ——	
13	7.69~ 8.38	Clay	5.70	0.0	200.0 200.0	24.168 28.101	41.55 48.31	0.200 0.200	11.31 11.31	—— ——	—— ——	
14	8.38~ 8.69	Clay	8.20	0.0	250.0 250.0	28.101 30.643	48.31 51.35	0.200 0.200	11.31 11.31	—— ——	—— ——	
15	8.69~ 9.69	Clay	8.20	0.0	180.0 180.0	30.643 38.843	51.35 61.15	0.200 0.200	11.31 11.31	—— ——	—— ——	
16	9.69~ 10.69	Clay	8.20	0.0	180.0 180.0	38.843 47.043	61.15 70.95	0.200 0.200	11.31 11.31	—— ——	—— ——	
17	10.69~ 11.69	Clay	8.20	0.0	180.0 180.0	47.043 55.243	70.95 80.75	0.200 0.200	11.31 11.31	—— ——	—— ——	
18	11.69~ 12.45	Clay	8.20	0.0	100.0 100.0	55.243 61.511	80.75 ——	0.200 ——	11.31 ——	—— ——	—— ——	
19	12.45~ 12.69	Clay	8.20	0.0	100.0 100.0	61.511 63.443	—— 90.55	—— 0.200	—— 11.31	—— ——	—— ——	
20	12.69~ 13.69	Clay	8.20	0.0	180.0 180.0	63.443 71.643	90.55 100.35	0.200 0.200	11.31 11.31	—— ——	—— ——	
21	13.69~ 14.69	Clay	8.20	0.0	180.0 180.0	71.643 79.843	100.35 110.15	0.200 0.200	11.31 11.31	—— ——	—— ——	
22	14.69~ 15.69	Clay	8.20	0.0	180.0 180.0	79.843 88.043	110.15 119.95	0.200 0.200	11.31 11.31	—— ——	—— ——	
23	15.69~ 16.69	Clay	8.20	0.0	180.0 180.0	88.043 96.243	119.95 129.75	0.200 0.200	11.31 11.31	—— ——	—— ——	
24	16.69~ 17.69	Clay	8.20	0.0	180.0 180.0	96.243 104.443	129.75 139.55	0.200 0.200	11.31 11.31	—— ——	—— ——	
25	17.69~ 23.65	Clay	8.20	0.0	250.0 250.0	104.443 153.315	139.55 197.96	0.200 0.200	11.31 11.31	—— ——	—— ——	
26	23.65~ 24.76	Clay	6.70	20.0	200.0 200.0	153.315 160.752	197.96 208.84	0.200 0.200	11.31 11.31	—— ——	—— ——	
27	24.76~ 33.10	Clay	7.20	30.0	1000.0 1000.0	160.752 220.800	208.84 290.57	0.200 0.200	11.31 11.31	—— ——	—— ——	

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.69	65.59 70.74	40.55 42.52	65.59 70.74	0.00 6.76	——
2	0.69~ 1.30	3.64 7.96	42.52 44.25	42.52 44.25	6.76 12.74	——
3	1.30~ 1.52	7.96 9.51	44.25 44.88	44.25 44.88	12.74 12.74	——

4	1.52~ 1.69	43.53 44.16	——	——	43.53 44.16	12.74 12.74	——					
5	1.69~ 2.47	33.25 35.44	——	——	33.25 35.44	12.74 12.74	——					
6	2.47~ 2.69	-82.49 -80.96	48.54 49.17	48.54 49.17	48.54 49.17	12.74 12.74	——					
7	2.69~ 3.45	-281.50 -276.25	49.17 51.33	49.17 51.33	49.17 51.33	12.74 12.74	——					
8	3.45~ 3.69	-276.25 -274.60	51.33 52.02	51.33 52.02	51.33 52.02	12.74 12.74	400.00 401.37					
9	3.69~ 4.69	27.27 34.40	52.02 54.87	52.02 54.87	52.02 54.87	12.74 12.74	101.37 107.07					
10	4.69~ 5.69	87.30 94.75	54.87 57.72	87.30 94.75	87.30 94.75	12.74 12.74	57.07 62.77					
11	5.69~ 6.69	-60.04 -53.04	57.72 60.57	57.72 60.57	57.72 60.57	12.74 12.74	212.77 218.47					
12	6.69~ 7.69	-53.04 -46.05	60.57 63.42	60.57 63.42	60.57 63.42	12.74 12.74	218.47 224.17					
13	7.69~ 8.38	-246.96 -242.18	63.42 65.38	63.42 65.38	63.42 65.38	12.74 12.74	424.17 428.10					
14	8.38~ 8.69	-342.37 -339.29	65.38 66.65	65.38 66.65	65.38 66.65	12.74 12.74	528.10 530.64					
15	8.69~ 9.69	-198.99 -189.01	66.65 70.75	66.65 70.75	66.65 70.75	12.74 12.74	390.64 398.84					
16	9.69~ 10.69	-189.01 -179.02	70.75 74.85	70.75 74.85	70.75 74.85	12.74 12.74	398.84 407.04					
17	10.69~ 11.69	-179.02 -169.03	74.85 78.95	74.85 78.95	74.85 78.95	12.74 12.74	407.04 415.24					
18	11.69~ 12.45	-7.75 0.00	78.95 82.09	78.95 82.09	78.95 82.09	12.74 12.74	255.24 261.51					
19	12.45~ 12.69	0.00 2.39	82.09 83.05	82.09 83.05	82.09 83.05	12.74 12.74	261.51 263.44					
20	12.69~ 13.69	-159.03 -149.02	83.05 87.15	83.05 87.15	83.05 87.15	12.74 12.74	423.44 431.64					
21	13.69~ 14.69	-149.02 -139.00	87.15 91.25	87.15 91.25	87.15 91.25	12.74 12.74	431.64 439.84					
22	14.69~ 15.69	-139.00 -128.97	91.25 95.35	91.25 95.35	91.25 95.35	12.74 12.74	439.84 448.04					
23	15.69~ 16.69	-128.97 -118.93	95.35 99.45	95.35 99.45	95.35 99.45	12.74 12.74	448.04 456.24					
24	16.69~ 17.69	-118.93 -108.89	99.45 103.55	99.45 103.55	99.45 103.55	12.74 12.74	456.24 464.44					
25	17.69~ 23.65	-249.64 -190.00	103.55 127.99	103.55 127.99	103.55 127.99	12.74 12.74	604.44 653.32					
26	23.65~ 24.76	-89.25 -80.10	127.99 131.71	127.99 131.71	127.99 131.71	12.74 12.74	553.32 560.75					
27	24.76~ 33.10	-1683.19 -1610.77	131.71 161.73	131.71 161.73	131.71 161.73	12.74 12.74	2160.75 2220.80					

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.30	0.00	0.00
2	2.30	1.00	2.51
3	3.30	2.00	3.56
4	3.45	2.15	3.69

$$p_{dw} = \pm\frac{7}{8}\, k_{hs}\cdot\gamma_w\cdot\sqrt{H\cdot y}$$

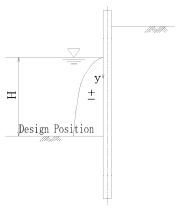
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

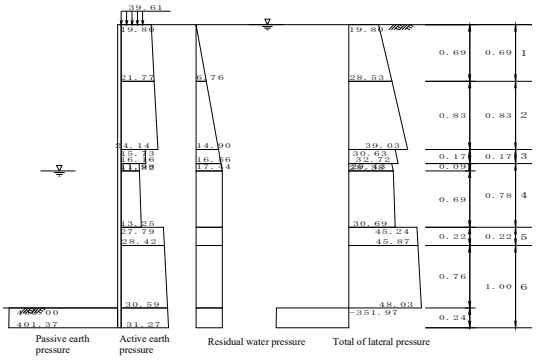
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition

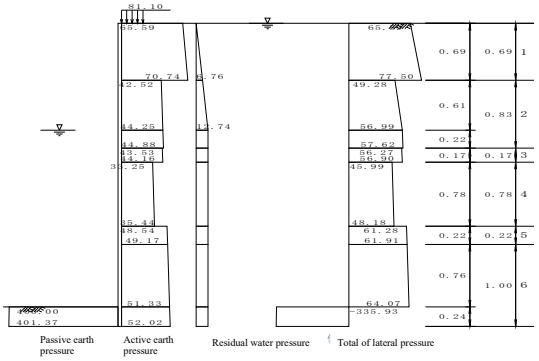


No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.69	19.80 21.77	0.00 6.76	——— ———	19.80 28.53
2	0.69~ 1.52	21.77 24.14	6.76 14.90	——— ———	28.53 39.03
3	1.52~ 1.69	15.73 16.16	14.90 16.56	——— ———	30.63 32.72
4	1.69~ 1.78	11.82 11.98	16.56 17.44	——— ———	28.38 29.43
5	1.78~ 2.47	11.98 13.25	17.44 17.44	——— ———	29.43 30.69
6	2.47~ 2.69	27.79 28.42	17.44 17.44	——— ———	45.24 45.87
7	2.69~ 3.45	28.42 30.59	17.44 17.44	——— ———	45.87 48.03
8	3.45~ 3.69	30.59 31.27	17.44 17.44	400.00 401.37	-351.97 -352.65

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -3.45 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.69	65.59 70.74	0.00 6.76	——— ———	65.59 77.50
2	0.69~ 1.30	42.52 44.25	6.76 12.74	——— ———	49.28 56.99
3	1.30~ 1.52	44.25 44.88	12.74 12.74	——— ———	56.99 57.62
4	1.52~ 1.69	43.53 44.16	12.74 12.74	——— ———	56.27 56.90
5	1.69~ 2.47	33.25 35.44	12.74 12.74	——— ———	45.99 48.18
6	2.47~ 2.69	48.54 49.17	12.74 12.74	——— ———	61.28 61.91
7	2.69~ 3.45	49.17 51.33	12.74 12.74	——— ———	61.91 64.07
8	3.45~ 3.69	51.33 52.02	12.74 12.74	400.00 401.37	-335.93 -336.61

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -3.45 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Calculation formula of lateral ground reaction coefficient

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_{II}}{0.3}\right)^{-3/4} \qquad (B_{II}=10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name	10 H _ H 700 -200 - 12-19-18			
Unit width	B	=	1.0000 m	
Corrosion margin	t_1	=	1.00 mm (active side)	t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.84	
Section efficiency	μ	=	1.00	
Young's modulus	E	=	200000 N/mm^2	
Inertia sectional moment	I_0	=	299700 cm^4(original condition)	
	I	=	251748 cm^4(after reduction by corrosion and section)	
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 251748 \times 10^{-8} = 5.035 \times 10^5$	

No	Depth m	N Value
1	0.19	3
2	1.19	9
3	2.19	27
4	3.19	50
5	4.19	14
6	5.19	7
7	6.19	16
8	7.19	19
9	8.19	50
10	9.19	25

No	Depth m	N Value
11	10.19	21
12	11.19	16
13	12.19	15
14	13.19	16
15	14.19	17
16	15.19	20
17	16.19	23
18	17.19	30
19	18.19	39

5.2 Normal Condition

Assuming Kh = 10722 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.270 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 3.70 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -3.45 m) to 3.70 m depth (GL -7.15 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	3.45	0.74	40.6	14.0	20.22
2	4.19	1.00	14.0	7.0	10.50
3	5.19	1.00	7.0	16.0	11.50
4	6.19	0.96	16.0	18.9	16.78
L = Σh = 3.70			ΣA = 59.00		

A: (upper N-value + lower N-value) × h/2

$$\text{Average N-value} \quad N' = \frac{\Sigma A}{L} = \frac{59.00}{3.70} = 15.94$$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 15.94 = 44622 \text{ kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 44622 = 148742 \text{ kN/m}^3 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_{II}/0.3)^{-3/4} = 148742(10.00/0.3)^{-3/4} = 10722 \text{ kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 10722 kN/m3.

5.3 Seismic Condition

Assuming Kh = 20931 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.319 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 3.13 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -3.45 m) and 3.13 m depth (GL -6.58 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	3.45	0.74	40.6	14.0	20.22
2	4.19	1.00	14.0	7.0	10.50
3	5.19	1.00	7.0	16.0	11.50
4	6.19	0.39	16.0	17.2	6.50
L = Σh = 3.13			ΣA = 48.72		

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{48.72}{3.13} = 15.56$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 15.56 = 43555\ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 43555 = 290364\ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_h/0.3)^{-3/4} = 290364(10.00/0.3)^{-3/4} = 20931\ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 20931 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.69	0.69	19.80 28.53	6.83 9.84	3.22 2.99	22.00 29.43
2	0.69~ 1.52	0.83	28.53 39.03	11.84 16.20	2.48 2.21	29.41 35.74
3	1.52~ 1.69	0.17	30.63 32.72	2.60 2.78	1.87 1.82	4.88 5.05
4	1.69~ 1.78	0.09	28.38 29.43	1.28 1.32	1.73 1.70	2.21 2.25
5	1.78~ 2.47	0.69	29.43 30.69	10.15 10.59	1.44 1.21	14.62 12.81
6	2.47~ 2.69	0.22	45.24 45.87	4.98 5.05	0.91 0.83	4.51 4.20
7	2.69~ 3.45	0.76	45.87 48.03	17.43 18.25	0.51 0.25	8.83 4.62
				ΣP= 119.15	ΣM= 180.58	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 61.1 kN/m
depth to acting position H_t = 0.0 m
moment M_m = 39.2 kN・m/m
depth to acting position H_m = 0.00 m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	1.30~ 2.30	1.00	0.0 2.5	0.00 1.26	1.82 1.48	0.00 1.87
2	2.30~ 3.30	1.00	2.5 3.6	1.26 1.78	0.82 0.48	1.03 0.86
3	3.30~ 3.45	0.15	3.6 3.7	0.27 0.28	0.10 0.05	0.03 0.01
			ΣPdw= 4.84		Σ Mdw= 3.79	

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1103.25}{354.49} = 3.11\ m$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 354.49}{3.45} = 205.50\ kN/m$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name 10 H _ H 700 -200 - 12-19-18
Unit width B = 1.0000 m
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.84
Section efficiency μ = 1.00
Young's modulus E = 200000 N/mm2
Inertia sectional moment I_0 = 299700 cm4 (original condition)
I = 251748 cm4 (after reduction by corrosion and section)
$EI = 200000 \times 10^3 \times 251748 \times 10^{-8} = 5.035 \times 10^5$

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$

$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp(-\tan^{-1}\frac{1}{1+2\beta h_0})$

$M_{max} = M_0 \cdot \phi_m$

$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$

$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$

$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x}(\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$

Height from riverbed to top of coping H = 3.45 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 250.00$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{430.57}{180.25} = 2.39\ m$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 180.25}{3.45} = 104.49\ kN/m$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.69	0.69	65.59 77.50	22.63 26.74	3.22 2.99	72.86 79.95
2	0.69~ 1.30	0.61	49.28 56.99	15.03 17.38	2.56 2.35	38.43 40.91
3	1.30~ 1.52	0.22	56.99 57.62	6.27 6.34	2.08 2.00	13.02 12.70
4	1.52~ 1.69	0.17	56.27 56.90	4.78 4.84	1.87 1.82	8.96 8.79
5	1.69~ 2.47	0.78	45.99 48.18	17.93 18.79	1.50 1.24	26.90 23.30
6	2.47~ 2.69	0.22	61.28 61.91	6.74 6.81	0.91 0.83	6.11 5.67
7	2.69~ 3.45	0.76	61.91 64.07	23.52 24.35	0.51 0.25	11.92 6.17
				ΣP= 202.15	ΣM= 355.68	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 147.5 kN/m
depth to acting position H_t = 0.00 m
moment M_m = 234.9 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 3.45 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 743.77$ kN・m

6.2.1 Normal Condition

modulus of lateral subgrade reaction K_h = 10722 kN/m3
calculated value β = 0.27012 m-1
resultant earth force (lateral) P_0 = 180.25 kN/m
height of acting position of load h_0 = 2.39 m
moment M_0 = 430.57 kN・m/m

in consideration of ψ_{hm} = 1.283,
maximum moment M_{max} = 552.49 kN・m/m
depth of generated position of M_{max} l_m = 1.524 m
depth of 1st fixed point l_i = 4.432 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction K_h = 20931 kN/m3
calculated value β = 0.31929 m-1
resultant earth force (lateral) P_0 = 354.49 kN/m
height of acting position of load h_0 = 3.11 m
moment M_0 = 1103.25 kN・m/m

in consideration of ψ_{hm} = 1.148,
maximum moment M_{max} = 1266.07 kN・m/m
depth of generated position of M_{max} l_m = 1.012 m
depth of 1st fixed point l_i = 3.472 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name 10 H _ H 700 -200 - 12-19-18
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.86
Section efficiency μ = 1.00
Module of section Z_0 = 5540 cm3 (original condition)
Z = 4764 cm3 (after reduction by corrosion and section)

6.3.1 Normal Condition

$\sigma = \frac{M_{max}}{Z} = \frac{552.49 \times 10^6}{4764 \times 10^3} = 116\ N/mm^2 \leqq \sigma_a = 180\ N/mm^2$

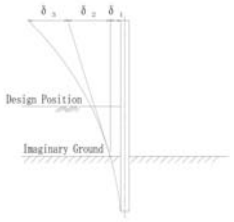
6.3.2 Seismic Condition

$\sigma = \frac{M_{max}}{Z} = \frac{1266.07 \times 10^6}{4764 \times 10^3} = 266\ N/mm^2 \leqq \sigma_a = 270\ N/mm^2$

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation

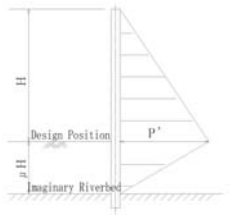


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2701\times 2.39)\times 180.25}{2\times 2.00\times 10^8\times 251748\times 10^{-8}\times 0.2701^3} = 0.01494\ \text{m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.2701\times 2.39)\times 180.25}{2\times 2.00\times 10^8\times 251748\times 10^{-8}\times 0.2701^2}\times(3.45+0.00) = 0.01939\ \text{m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{3.45} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{104.49\times 3.45^4}{120\times 2.00\times 10^8\times 251748\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

$$= 0.00098\ \text{m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.01494 + 0.01939 + 0.00098
= 0.03531 m
Size = 35.31 ≦ δa = 50.00 mm

where:
δ1: amount of displacement at the virtual ground surface

$$\mu = \frac{L_k}{H} = \frac{0.00}{3.45} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{205.50\times 3.45^4}{120\times 2.00\times 10^8\times 251748\times 10^{-8}}(4+20\times 0.000+40\times 0.000^2+35\times 0.000^3+11\times 0.000^4)$$

$$= 0.00193\ \text{m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.02156 + 0.03559 + 0.00193
= 0.05908 m
Size = 59.08 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name			10 H _ H 700 -200 - 12-19-18
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	299700 cm⁴ (original condition)
	I	=	299700 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 299700 × 10⁻⁸		=	5.994 × 10⁵

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

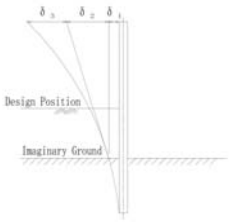
7.1.1 Normal Condition

Modules of lateral subgrade reaction	K_h	=	10722 kN/m³
Calculated value	β	=	0.25860 m⁻¹
Penetration length of SSP	D	=	$0.00 + \frac{3}{0.259}$ = 11.60 m
Whole length of SSP	L	=	3.45 − 0.40 + 11.60 = 14.65 m

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

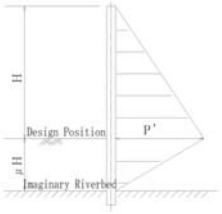


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.3193\times 3.11)\times 354.49}{2\times 2.00\times 10^8\times 251748\times 10^{-8}\times 0.3193^3} = 0.02156\ \text{m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.3193\times 3.11)\times 354.49}{2\times 2.00\times 10^8\times 251748\times 10^{-8}\times 0.3193^2}\times(3.45+0.00) = 0.03559\ \text{m}$$



7.1.1 Seismic Condition

Modules of lateral subgrade reaction	K_h	=	20931 kN/m³
Calculated value	β	=	0.30567 m⁻¹
Penetration length of SSP	D	=	$0.00 + \frac{3}{0.306}$ = 9.81 m
Whole length of SSP	L	=	3.45 − 0.40 + 9.81 = 12.86 m

Therefore, the total length of the sheet pile is 15.00 m from the rounded length value of 0.50 m.

8 Calculation Result

front sheet pile 10 H _ H 700 -200 - 12-19-18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	299700		
Sectional Modulus	Z (cm3)	5540		
Maximum bending moment	Mmax (kN・m・m)		552.49	1266.07
Stress intensity	σ (N/mm2)		116 (180)	266 (270)
Lateral displacement	δ (mm)		35.31 (50.0)	59.08 (75.0)
Penetration depths	D (m)		11.60	9.81
Whole length of SSP	L (m)	15.00		

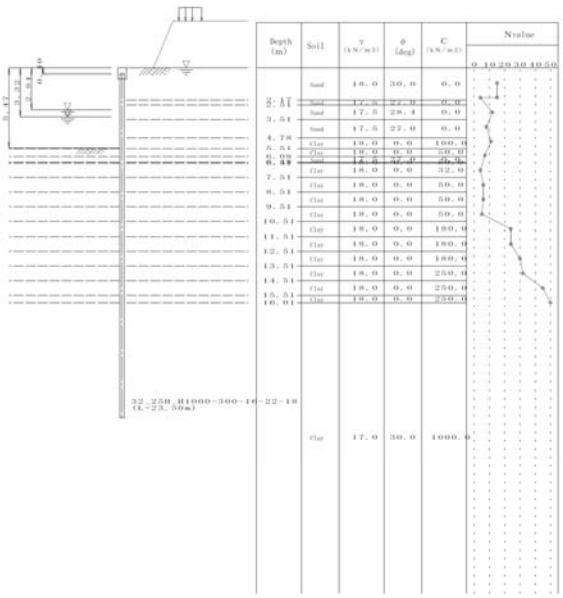
Block No. : R-8
Sta. : 6+420~6+920

Design Cross Section : Sta 6+820
Boring Name : BMRL-23

Specification : SSP SP-25H
（Combined） : H 1000-300-16-22-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.47 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_{ft}	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.32 m (Normal Condition)
	L_{wp}'	=	2.84 m (Seismic Condition)

N-value distribution

No	Depth m	N Value	No	Depth m	N Value
1	1.00	15	11	10.01	5
2	2.00	15	12	11.01	24
3	2.01	4	13	12.01	24
4	3.01	12	14	13.01	30
5	4.01	8	15	14.01	32
6	5.01	11	16	15.01	45
7	6.01	7	17	16.01	50
8	7.01	4			
9	8.01	6			
10	9.01	6			

1.3 Applied Formula

Formula for generated stress : Chang's formula

Penetration depths : $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water : γ_w = 9.8 kN/m^3

Type of water pressure : trapezoidal water pressure

Lateral pressure : calculated in consideration of site conditions

Study case : - Normal Condition
- Seismic Condition

Design earthquake intensity : k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	23.4 kN/m	(Normal Condition)
		Pt'	=	62.8 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	Mm	=	0.0 kN･m/m	(Normal Condition)
		Mm'	=	33.9 kN･m/m	(Seismic Condition)
	Depth of acting point	Hm'	=	0.00 m	(Seismic Condition)
		Hm	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load : not considered

Minimum angle of rupture : ζ_0 = 10 degrees

Rear side angle of slope : not considered

Angle of rupture (clayey soil) : $\zeta = \tan^{-1}\sqrt{1 - \frac{\sum \gamma h + 2Q}{2C}} \cdot \tan\theta$

Equilibrium factor of compression : K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula :

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\ \alpha\ E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m
E_0 = 2800N

Average N-value : calculated from average N-value between imaginary riverbed and depth as 1/β

1.6 Vertical Load

Vertical load on landside : calculated in consideration of embankment shape on landside

Vertical load on riverside : not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	2.17	2.17
2	2.51	0.34
3	3.51	1.00
4	4.78	1.27
5	5.51	0.73
6	6.08	0.57
7	6.48	0.40
8	6.51	0.03
9	7.51	1.00
10	8.51	1.00
11	9.51	1.00
12	10.51	1.00
13	11.51	1.00
14	12.51	1.00
15	13.51	1.00
16	14.51	1.00
17	15.51	1.00
18	16.01	0.50
19	34.50	18.49

No	Depth m	earth Soil	N Value	γ kN/m3	γ ' kN/m3	φ degree	C kN/m2	a	k '	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	2.17	S	15.0	18.00	8.20	30.0	0.0	0.0	0.200	Auto	Auto
2	2.51	S	4.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
3	3.51	S	12.0	17.50	7.70	28.4	0.0	0.0	0.200	Auto	Auto
4	4.78	S	8.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
5	5.51	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
6	6.08	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
7	6.48	S	7.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
8	6.51	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
9	7.51	C	4.0	18.00	8.20	0.0	32.0	0.0	0.200	Auto	Auto
10	8.51	C	6.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
11	9.51	C	6.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto

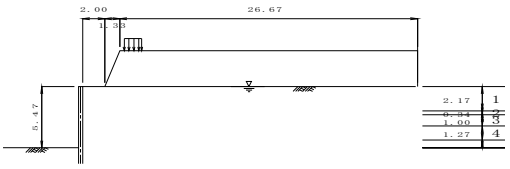
No	Depth m	earth Soil	N Value	γ kN/m3	γ ' kN/m3	ϕ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
12	10.51	C	5.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
13	11.51	C	24.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
14	12.51	C	24.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
15	13.51	C	30.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
16	14.51	C	32.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
17	15.51	C	45.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
18	16.01	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
19	34.50	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ ' : saturated unit weight of soil
ϕ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle ϕ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	2.00	3.33	30.00	30.00	3.21	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	End point m	load strength Normal Condition kN/m2	Seismic Condition kN/m2
1	3.73	5.29	5.0	0.0

Angle of rapture in embankment calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name 25 H _ H 1000 -300 -16 -22 -18
Young's modulus E = 200000 N/mm²
Inertia sectional moment I_0 = 962300 cm⁴
Sectional factor Z_0 = 13420 cm³

Corrosion margin t_1 = 1.00 mm (riverside) t_2 = 1.00 mm (landside)

Corrosion rate (to I_0) η = 0.87
Corrosion rate (to Z_0) η = 0.89
Section efficiency (to I_0) μ = 1.00
Section efficiency (to Z_0) μ = 1.00

Round unit of SSP length 0.50 m

Allowable stress σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

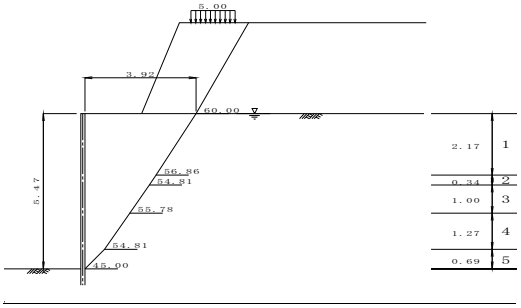
Allowable displacement δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam calculated as distributed load of each layer

Reduction of material modulus Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σ γ h kN/m2	Q kN/m2	γ wh w kN/m2	Angle of Rupture ζ degree
1	5.47 ~ 4.78	Clay	0.0	15.0	100.0	43.55	35.95	53.61	45.00
2	4.78 ~ 3.51	Sand	27.0	15.0	0.0	37.89	35.95	46.84	54.81
3	3.51 ~ 2.51	Sand	28.4	15.0	0.0	28.11	35.95	34.40	55.78
4	2.51 ~ 2.17	Sand	27.0	15.0	0.0	20.41	35.95	24.60	54.81
5	2.17 ~ 0.00	Sand	30.0	15.0	0.0	17.79	35.95	21.27	56.86
6		embankment	30.0	——	0.0	60.99	5.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}}\cdot\tan\theta$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°
Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = $\tan^{-1}$k or θ = $\tan^{-1}$k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	45.00	0.69	0.00	0.00	0.69	0.69
2	54.81	1.27	0.69	0.69	1.59	1.96
3	55.78	1.00	1.59	1.96	2.27	2.96
4	54.81	0.34	2.27	2.96	2.51	3.30
5	56.86	2.17	2.51	3.30	3.92	5.47
6	60.00	3.21	3.92	5.47	5.78	8.68

From the above table, the loading width (L) on the ground surface is 3.92 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	7.01	133.20
Σ			133.20

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	1.56	7.80
Σ			7.80

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

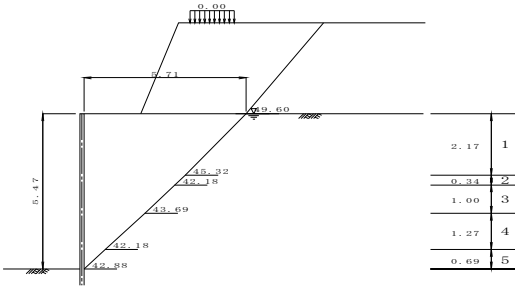
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{133.20 + 7.80 + 0.00}{3.92}$$

$$= 35.95\ \text{kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σ γ h kN/m2	Q kN/m2	γ wh w kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.47 ~ 4.78	Clay	0.0	15.0	100.0	43.55	47.12	53.61	0.200	11.31	42.88
2	4.78 ~ 3.51	Sand	27.0	15.0	0.0	37.89	47.12	46.84	0.200	11.31	42.18
3	3.51 ~ 2.51	Sand	28.4	15.0	0.0	28.11	47.12	34.40	0.200	11.31	43.69
4	2.51 ~ 2.17	Sand	27.0	15.0	0.0	20.41	47.12	24.60	0.200	11.31	42.18
5	2.17 ~ 0.00	Sand	30.0	15.0	0.0	17.79	47.12	21.27	0.200	11.31	45.32
6		embankment	30.0	——	0.0	60.99	0.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,

- ζ : angle of active rupture (degree, $\zeta \geq 10.00^{o}$)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  $\theta = \tan^{-1}k$ or $\theta = \tan^{-1}k'$
- γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m^2)
- C : cohesive force of soil (kN/m^2)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	42.88	0.69	0.00	0.00	0.74	0.69
2	42.18	1.27	0.74	0.69	2.14	1.96
3	43.69	1.00	2.14	1.96	3.19	2.96
4	42.18	0.34	3.19	2.96	3.57	3.30
5	45.32	2.17	3.57	3.30	5.71	5.47
6	49.60	3.21	5.71	5.47	8.44	8.68

From the above table, the loading width (L) on the ground surface is 5.71 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	14.17	269.19
Σ			269.19

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	0.0	1.56	0.00
Σ			0.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

8	5.51~ 6.08	Clay	8.2	——	50.0 50.0	79.825 84.499	—— ——	—— ——
9	6.08~ 6.48	Sand	7.7	27.0	—— ——	84.499 87.579	0.33738 0.33738	0.32589 0.32589
10	6.48~ 6.51	Clay	8.2	——	50.0 50.0	87.579 87.825	—— ——	—— ——
11	6.51~ 7.51	Clay	8.2	——	32.0 32.0	87.825 96.025	—— ——	—— ——
12	7.51~ 7.99	Clay	8.2	——	50.0 50.0	96.025 100.000	—— ——	—— ——
13	7.99~ 8.51	Clay	8.2	——	50.0 50.0	100.000 104.225	—— ——	—— ——
14	8.51~ 9.51	Clay	8.2	——	50.0 50.0	104.225 112.425	—— ——	—— ——
15	9.51~ 10.51	Clay	8.2	——	50.0 50.0	112.425 120.625	—— ——	—— ——
16	10.51~ 11.51	Clay	8.2	——	180.0 180.0	120.625 128.825	—— ——	—— ——
17	11.51~ 12.51	Clay	8.2	——	180.0 180.0	128.825 137.025	—— ——	—— ——
18	12.51~ 13.51	Clay	8.2	——	180.0 180.0	137.025 145.225	—— ——	—— ——
19	13.51~ 14.51	Clay	8.2	——	250.0 250.0	145.225 153.425	—— ——	—— ——
20	14.51~ 15.51	Clay	8.2	——	250.0 250.0	153.425 161.625	—— ——	—— ——
21	15.51~ 16.01	Clay	8.2	——	250.0 250.0	161.625 165.725	—— ——	—— ——
22	16.01~ 34.50	Clay	7.2	——	1000.0 1000.0	165.725 298.853	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
7	5.47~ 5.51	Clay	8.2	0.0	100.0 100.0	0.000 0.328	—— ——	—— ——
8	5.51~ 6.08	Clay	8.2	0.0	50.0 50.0	0.328 5.002	—— ——	—— ——
9	6.08~ 6.48	Sand	7.7	27.0	—— ——	5.002 8.082	4.26080 4.26080	4.11561 4.11561
10	6.48~ 6.51	Clay	8.2	0.0	50.0 50.0	8.082 8.328	—— ——	—— ——
11	6.51~ 7.51	Clay	8.2	0.0	32.0 32.0	8.328 16.528	—— ——	—— ——
12	7.51~ 7.99	Clay	8.2	0.0	50.0 50.0	16.528 20.503	—— ——	—— ——

2.2.5 Calculated Load

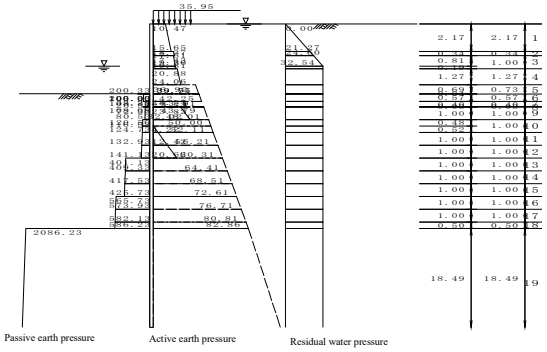
$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{269.19 + 0.00 + 0.00}{5.71}$$

$$= 47.12\ \text{kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 2.17	Sand	8.2	30.0	—— ——	35.948 53.742	0.30142 0.30142	0.29115 0.29115
2	2.17~ 2.51	Sand	7.7	27.0	—— ——	53.742 56.360	0.33738 0.33738	0.32589 0.32589
3	2.51~ 3.32	Sand	7.7	28.4	—— ——	56.360 62.597	0.32022 0.32022	0.30931 0.30931
4	3.32~ 3.51	Sand	7.7	28.4	—— ——	62.597 64.060	0.32022 0.32022	0.30931 0.30931
5	3.51~ 4.78	Sand	7.7	27.0	—— ——	64.060 73.839	0.33738 0.33738	0.32589 0.32589
6	4.78~ 5.47	Clay	8.2	——	100.0 100.0	73.839 79.497	—— ——	—— ——
7	5.47~ 5.51	Clay	8.2	——	100.0 100.0	79.497 79.825	—— ——	—— ——

13	7.99~ 8.51	Clay	8.2	0.0	50.0 50.0	20.503 24.728	—— ——	—— ——
14	8.51~ 9.51	Clay	8.2	0.0	50.0 50.0	24.728 32.928	—— ——	—— ——
15	9.51~ 10.51	Clay	8.2	0.0	50.0 50.0	32.928 41.128	—— ——	—— ——
16	10.51~ 11.51	Clay	8.2	0.0	180.0 180.0	41.128 49.328	—— ——	—— ——
17	11.51~ 12.51	Clay	8.2	0.0	180.0 180.0	49.328 57.528	—— ——	—— ——
18	12.51~ 13.51	Clay	8.2	0.0	180.0 180.0	57.528 65.728	—— ——	—— ——
19	13.51~ 14.51	Clay	8.2	0.0	250.0 250.0	65.728 73.928	—— ——	—— ——
20	14.51~ 15.51	Clay	8.2	0.0	250.0 250.0	73.928 82.128	—— ——	—— ——
21	15.51~ 16.01	Clay	8.2	0.0	250.0 250.0	82.128 86.228	—— ——	—— ——
22	16.01~ 34.50	Clay	7.2	30.0	1000.0 1000.0	86.228 219.356	—— ——	—— ——

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= -15.00、β = 0.00、θ = 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\dfrac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 2.17	10.47 15.65	—— ——	10.47 15.65	0.00 21.27	—— ——
2	2.17~ 2.51	17.51 18.37	—— ——	17.51 18.37	21.27 24.60	—— ——
3	2.51~ 3.32	17.43 19.36	—— ——	17.43 19.36	24.60 32.54	—— ——
4	3.32~ 3.51	19.36 19.81	—— ——	19.36 19.81	32.54 32.54	—— ——
5	3.51~ 4.78	20.88 24.06	—— ——	20.88 24.06	32.54 32.54	—— ——
6	4.78~ 5.47	-126.16 -120.50	36.92 39.75	36.92 39.75	32.54 32.54	—— ——
7	5.47~ 5.51	-120.50 -120.18	39.75 39.91	39.75 39.91	32.54 32.54	200.00 200.33
8	5.51~ 6.08	-20.18 -15.50	39.91 42.25	39.91 42.25	32.54 32.54	100.33 105.00
9	6.08~ 6.48	27.54 28.54	—— ——	27.54 28.54	32.54 32.54	20.59 33.26
10	6.48~ 6.51	-12.42 -12.18	43.79 43.91	43.79 43.91	32.54 32.54	108.08 108.33

11	6.51~ 7.51	23.82 32.02	43.91 48.01	43.91 48.01	32.54 32.54	72.33 80.53
12	7.51~ 7.99	-3.98 0.00	48.01 50.00	48.01 50.00	32.54 32.54	116.53 120.50
13	7.99~ 8.51	0.00 4.22	50.00 52.11	50.00 52.11	32.54 32.54	120.50 124.73
14	8.51~ 9.51	4.22 12.42	52.11 56.21	52.11 56.21	32.54 32.54	124.73 132.93
15	9.51~ 10.51	12.42 20.62	56.21 60.31	56.21 60.31	32.54 32.54	132.93 141.13
16	10.51~ 11.51	-239.38 -231.18	60.31 64.41	60.31 64.41	32.54 32.54	401.13 409.33
17	11.51~ 12.51	-231.18 -222.98	64.41 68.51	64.41 68.51	32.54 32.54	409.33 417.53
18	12.51~ 13.51	-222.98 -214.78	68.51 72.61	68.51 72.61	32.54 32.54	417.53 425.73
19	13.51~ 14.51	-354.78 -346.58	72.61 76.71	72.61 76.71	32.54 32.54	565.73 573.93
20	14.51~ 15.51	-346.58 -338.38	76.71 80.81	76.71 80.81	32.54 32.54	573.93 582.13
21	15.51~ 16.01	-338.38 -334.28	80.81 82.86	80.81 82.86	32.54 32.54	582.13 586.23
22	16.01~ 34.50	-1834.28 -1701.15	82.86 149.43	82.86 149.43	32.54 32.54	2086.23 2219.36

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma \gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

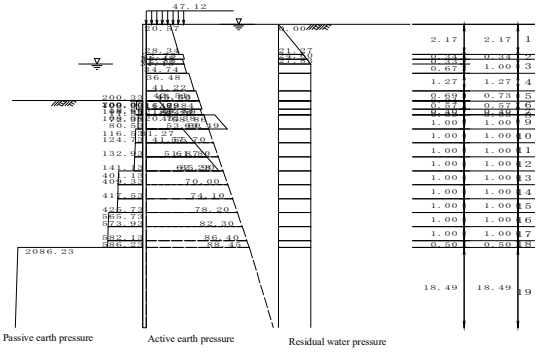
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 2.17	Sand	8.2	30.0	—— ——	47.12 64.91	0.00 21.27	0.200 0.200	11.31 11.31	0.45203 0.45203	0.43663 0.43663	——
2	2.17~ 2.51	Sand	7.7	27.0	—— ——	64.91 67.53	21.27 24.60	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
3	2.51~ 2.84	Sand	7.7	28.4	—— ——	67.53 70.07	24.60 27.83	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	——
4	2.84~ 3.51	Sand	7.7	28.4	—— ——	70.07 75.23	27.83 34.40	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	——
5	3.51~ 4.78	Sand	7.7	27.0	—— ——	75.23 85.01	34.40 46.84	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
6	4.78~ 5.47	Clay	8.2	——	100.0 100.0	85.01 90.67	46.84 53.61	0.200 0.200	11.31 11.31	—— ——	—— ——	42.97 42.88
7	5.47~ 5.51	Clay	8.2	——	100.0 100.0	90.67 91.00	53.61 54.00	0.200 0.200	11.31 11.31	—— ——	—— ——	42.88 42.87
8	5.51~ 6.08	Clay	8.2	——	50.0 50.0	91.00 95.67	54.00 59.58	0.200 0.200	11.31 11.31	—— ——	—— ——	40.39 40.21
9	6.08~ 6.48	Sand	7.7	27.0	—— ——	95.67 98.75	59.58 63.50	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
10	6.48~ 6.51	Clay	8.2	——	50.0 50.0	98.75 99.00	63.50 63.80	0.200 0.200	11.31 11.31	—— ——	—— ——	40.08 40.07
11	6.51~ 7.51	Clay	8.2	——	32.0 32.0	99.00 107.20	63.80 73.60	0.200 0.200	11.31 11.31	—— ——	—— ——	36.40 35.74
12	7.51~ 8.51	Clay	8.2	——	50.0 50.0	107.20 115.40	73.60 83.40	0.200 0.200	11.31 11.31	—— ——	—— ——	39.74 39.41
13	8.51~ 9.51	Clay	8.2	——	50.0 50.0	115.40 123.60	83.40 93.20	0.200 0.200	11.31 11.31	—— ——	—— ——	39.41 39.06
14	9.51~ 10.51	Clay	8.2	——	50.0 50.0	123.60 131.80	93.20 103.00	0.200 0.200	11.31 11.31	—— ——	—— ——	39.06 38.71
15	10.51~ 11.51	Clay	8.2	——	180.0 180.0	131.80 140.00	103.00 112.80	0.200 0.200	11.31 11.31	—— ——	—— ——	43.50 43.43
16	11.51~ 12.51	Clay	8.2	——	180.0 180.0	140.00 148.20	112.80 122.60	0.200 0.200	11.31 11.31	—— ——	—— ——	43.43 43.36
17	12.51~ 13.51	Clay	8.2	——	180.0 180.0	148.20 156.40	122.60 132.40	0.200 0.200	11.31 11.31	—— ——	—— ——	43.36 43.28
18	13.51~ 14.51	Clay	8.2	——	250.0 250.0	156.40 164.60	132.40 142.20	0.200 0.200	11.31 11.31	—— ——	—— ——	43.78 43.73
19	14.51~ 15.51	Clay	8.2	——	250.0 250.0	164.60 172.80	142.20 152.00	0.200 0.200	11.31 11.31	—— ——	—— ——	43.73 43.68
20	15.51~ 16.01	Clay	8.2	——	250.0 250.0	172.80 176.90	152.00 156.90	0.200 0.200	11.31 11.31	—— ——	—— ——	43.68 43.66
21	16.01~ 34.50	Clay	7.2	——	1000.0 1000.0	176.90 310.02	156.90 338.10	0.200 0.200	11.31 11.31	—— ——	—— ——	44.68 44.48

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
7	5.47~ 5.51	Clay	8.20	0.0	100.0 100.0	0.000 0.328	0.00 0.39	0.200 0.200	11.31 11.31	—— ——	—— ——
8	5.51~ 6.08	Clay	8.20	0.0	50.0 50.0	0.328 5.002	0.39 5.98	0.200 0.200	11.31 11.31	—— ——	—— ——
9	6.08~ 6.48	Sand	7.70	27.0	—— ——	5.002 8.082	5.98 9.90	0.200 0.200	11.31 11.31	2.30874 2.30874	2.30874 2.30874
10	6.48~ 6.51	Clay	8.20	0.0	50.0 50.0	8.082 8.328	9.90 10.19	0.200 0.200	11.31 11.31	—— ——	—— ——
11	6.51~ 7.51	Clay	8.20	0.0	32.0 32.0	8.328 16.528	10.19 19.99	0.200 0.200	11.31 11.31	—— ——	—— ——
12	7.51~ 8.51	Clay	8.20	0.0	50.0 50.0	16.528 24.728	19.99 29.79	0.200 0.200	11.31 11.31	—— ——	—— ——
13	8.51~ 9.51	Clay	8.20	0.0	50.0 50.0	24.728 32.928	29.79 39.59	0.200 0.200	11.31 11.31	—— ——	—— ——
14	9.51~ 10.51	Clay	8.20	0.0	50.0 50.0	32.928 41.128	39.59 49.39	0.200 0.200	11.31 11.31	—— ——	—— ——
15	10.51~ 11.51	Clay	8.20	0.0	180.0 180.0	41.128 49.328	49.39 59.19	0.200 0.200	11.31 11.31	—— ——	—— ——
16	11.51~ 12.51	Clay	8.20	0.0	180.0 180.0	49.328 57.528	59.19 68.99	0.200 0.200	11.31 11.31	—— ——	—— ——
17	12.51~ 13.51	Clay	8.20	0.0	180.0 180.0	57.528 65.728	68.99 78.79	0.200 0.200	11.31 11.31	—— ——	—— ——
18	13.51~ 14.51	Clay	8.20	0.0	250.0 250.0	65.728 73.928	78.79 88.59	0.200 0.200	11.31 11.31	—— ——	—— ——
19	14.51~ 15.51	Clay	8.20	0.0	250.0 250.0	73.928 82.128	88.59 98.39	0.200 0.200	11.31 11.31	—— ——	—— ——
20	15.51~ 16.01	Clay	8.20	0.0	250.0 250.0	82.128 86.228	98.39 103.29	0.200 0.200	11.31 11.31	—— ——	—— ——
21	16.01~ 34.50	Clay	7.20	30.0	1000.0 1000.0	86.228 219.356	103.29 284.49	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.
δ = 0.00 degrees, β = 0.00 degrees
Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 2.17	20.57 28.34	—— ——	20.57 28.34	0.00 21.27	——
2	2.17~ 2.51	31.48 32.75	—— ——	31.48 32.75	21.27 24.60	——
3	2.51~ 2.84	31.18 32.35	—— ——	31.18 32.35	24.60 27.83	——
4	2.84~ 3.51	32.35 34.74	—— ——	32.35 34.74	27.83 27.83	——
5	3.51~ 4.78	36.48 41.22	—— ——	36.48 41.22	27.83 27.83	——
6	4.78~ 5.47	-97.24 -90.35	42.51 45.33	42.51 45.33	27.83 27.83	——
7	5.47~ 5.51	-90.35 -89.95	45.33 45.50	45.33 45.50	27.83 27.83	200.00 200.33
8	5.51~ 6.08	11.08 16.89	45.50 47.84	45.50 47.84	27.83 27.83	100.33 105.00
9	6.08~ 6.48	46.39 47.88	—— ——	46.39 47.88	27.83 27.83	11.55 18.66
10	6.48~ 6.51	20.73 21.03	49.38 49.50	49.38 49.50	27.83 27.83	108.08 108.33
11	6.51~ 7.51	58.86 69.49	49.50 53.60	58.86 69.49	27.83 27.83	72.33 80.53
12	7.51~ 8.51	31.27 41.55	53.60 57.70	53.60 57.70	27.83 27.83	116.53 124.73
13	8.51~ 9.51	41.55 51.87	57.70 61.80	57.70 61.80	27.83 27.83	124.73 132.93
14	9.51~ 10.51	51.87 62.23	61.80 65.90	61.80 65.90	27.83 27.83	132.93 141.13
15	10.51~ 11.51	-200.92 -190.97	65.90 70.00	65.90 70.00	27.83 27.83	401.13 409.33
16	11.51~ 12.51	-190.97 -181.01	70.00 74.10	70.00 74.10	27.83 27.83	409.33 417.53

17	12.51~ 13.51	-181.01 -171.04	74.10 78.20	74.10 78.20	27.83 27.83	417.53 425.73
18	13.51~ 14.51	-311.42 -301.48	78.20 82.30	78.20 82.30	27.83 27.83	565.73 573.93
19	14.51~ 15.51	-301.48 -291.55	82.30 86.40	82.30 86.40	27.83 27.83	573.93 582.13
20	15.51~ 16.01	-291.55 -286.57	86.40 88.45	86.40 88.45	27.83 27.83	582.13 586.23
21	16.01~ 34.50	-1787.45 -1627.16	88.45 155.01	88.45 155.01	27.83 27.83	2086.23 2219.36

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma \gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	2.84	0.00	0.00
2	3.84	1.00	2.78
3	4.84	2.00	3.93
4	5.47	2.63	4.51

$$p_{dx} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

y : depth from water surface to the point where active water pressure is calculated

5	3.51~ 4.78	20.88 24.06	32.54 32.54	—— ——	53.41 56.60
6	4.78~ 5.47	36.92 39.75	32.54 32.54	—— ——	69.46 72.28
7	5.47~ 5.51	39.75 39.91	32.54 32.54	200.00 200.33	-127.72 -127.88

P_a : Active earth pressure

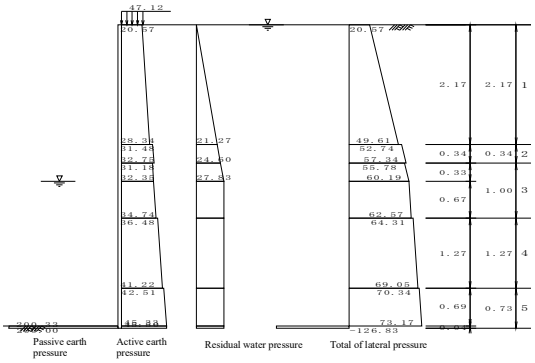
P_w : Residual water pressure

P_p : Passive earth pressure

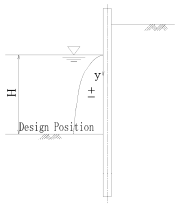
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.47 m)

4.2 Seismic Condition



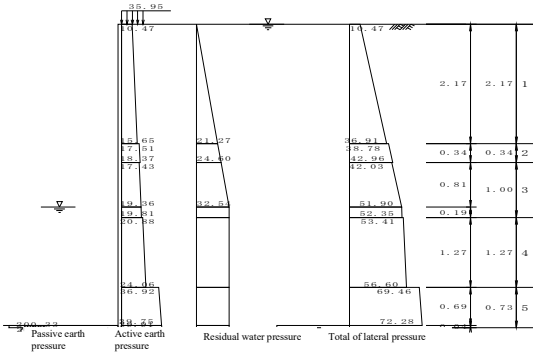
No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.17	20.57 28.34	0.00 21.27	—— ——	20.57 49.61
2	2.17~ 2.51	31.48 32.75	21.27 24.60	—— ——	52.74 57.34
3	2.51~ 2.84	31.18 32.35	24.60 27.83	—— ——	55.78 60.19
4	2.84~ 3.51	32.35 34.74	27.83 27.83	—— ——	60.19 62.57
5	3.51~ 4.78	36.48 41.22	27.83 27.83	—— ——	64.31 69.05
6	4.78~ 5.47	42.51 45.33	27.83 27.83	—— ——	70.34 73.17
7	5.47~ 5.51	45.33 45.50	27.83 27.83	200.00 200.33	-126.83 -127.00



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.17	10.47 15.65	0.00 21.27	—— ——	10.47 36.91
2	2.17~ 2.51	17.51 18.37	21.27 24.60	—— ——	38.78 42.96
3	2.51~ 3.32	17.43 19.36	24.60 32.54	—— ——	42.03 51.90
4	3.32~ 3.51	19.36 19.81	32.54 32.54	—— ——	51.90 52.35

P_a : Active earth pressure

P_w : Residual water pressure

P_p : Passive earth pressure

P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.47 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name	25 H _ H 1000 -300 -16 -22 -18		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	962300 cm^4(original condition)
	I	=	837201 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 837201 \times 10^{-8} = 1.674 \times 10^6$

No	Depth m	N Value
1	1.00	15
2	2.00	15
3	2.01	4
4	3.01	12
5	4.01	8
6	5.01	11
7	6.01	7
8	7.01	4
9	8.01	6
10	9.01	6

No	Depth m	N Value
11	10.01	5
12	11.01	24
13	12.01	24
14	13.01	30
15	14.01	32
16	15.01	45
17	16.01	50

5.2 Normal Condition

Assuming Kh = 5607 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.170 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 5.88 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.47 m) to 5.88 m depth (GL -11.35 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.47	0.54	9.2	7.0	4.36
2	6.01	1.00	7.0	4.0	5.50
3	7.01	1.00	4.0	6.0	5.00
4	8.01	1.00	6.0	6.0	6.00
5	9.01	1.00	6.0	5.0	5.50
6	10.01	1.00	5.0	24.0	14.50
7	11.01	0.34	24.0	24.0	8.13
		L = Σh = 5.88		Σ A = 49.00	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{49.00}{5.88} = 8.33$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 8.33 = 23335 \text{ kN/m}^2$

$K_{s0} = \frac{1}{0.3} \times \alpha \times 23335 = 77784 \text{ kN/m}^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{s0}(B_u/0.3)^{-3/4} = 77784(10.00/0.3)^{-3/4} = 5607 \text{ kN/m}^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 5607 kN/m3.

5.3 Seismic Condition

Assuming Kh = 8870 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.191 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 5.24 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.47 m) and 5.24 m depth (GL -10.71 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.47	0.54	9.2	7.0	4.36
2	6.01	1.00	7.0	4.0	5.50
3	7.01	1.00	4.0	6.0	5.00
4	8.01	1.00	6.0	6.0	6.00
5	9.01	1.00	6.0	5.0	5.50
6	10.01	0.70	5.0	18.3	8.19
		L = Σh = 5.24		Σ A = 34.56	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{34.56}{5.24} = 6.59$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 6.59 = 18457 \text{ kN/m}^2$

$K_{s0} = \frac{1}{0.3} \times \alpha \times 18457 = 123045 \text{ kN/m}^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{s0}(B_u/0.3)^{-3/4} = 123045(10.00/0.3)^{-3/4} = 8870 \text{ kN/m}^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 8870 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.17	2.17	10.47 36.91	11.36 40.05	4.75 4.02	53.90 161.14
2	2.17~ 2.51	0.34	38.78 42.96	6.59 7.30	3.19 3.07	21.01 22.45
3	2.51~ 3.32	0.81	42.03 51.90	17.02 21.02	2.69 2.42	45.79 50.87
4	3.32~ 3.51	0.19	51.90 52.35	4.93 4.97	2.09 2.02	10.29 10.06
5	3.51~ 4.78	1.27	53.41 56.60	33.92 35.94	1.54 1.11	52.12 40.01
6	4.78~ 5.47	0.69	69.46 72.28	23.96 24.94	0.46 0.23	11.02 5.74
				Σ P = 232.00	Σ M = 484.39	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	23.4 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.47 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 128.00$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{612.39}{255.40} = 2.40 \text{ m}$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 255.40}{5.47} = 93.38 \text{ kN/m}$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.17	2.17	20.57 49.61	22.32 53.83	4.75 4.02	105.96 216.56
2	2.17~ 2.51	0.34	52.74 57.34	8.97 9.75	3.19 3.07	28.57 29.96
3	2.51~ 2.84	0.33	55.78 60.19	9.20 9.93	2.85 2.74	26.23 27.21
4	2.84~ 3.51	0.67	60.19 62.57	20.16 20.96	2.41 2.18	48.52 45.76
5	3.51~ 4.78	1.27	64.31 69.05	40.84 43.85	1.54 1.11	62.75 48.82
6	4.78~ 5.47	0.69	70.34 73.17	24.27 25.24	0.46 0.23	11.16 5.81
				Σ P = 289.32	Σ M = 657.32	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	62.8 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	33.9 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.47 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 377.42$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	2.84~ 3.84	1.00	0.0 2.8	0.00 1.39	2.30 1.96	0.00 2.73
2	3.84~ 4.84	1.00	2.8 3.9	1.39 1.97	1.30 0.96	1.80 1.89
3	4.84~ 5.47	0.63	3.9 4.5	1.24 1.42	0.42 0.21	0.52 0.30
				Σ Pdw = 7.41	Σ Mdw = 7.25	

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1041.98}{359.52} = 2.90 \text{ m}$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 359.52}{5.47} = 131.45 \text{ kN/m}$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name			25 H _ H 1000 -300 -16 -22 -18
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	962300 cm^4 (original condition)
	I	=	837201 cm^4 (after reduction by corrosion and section)
$EI = 200000 \times 10^3 \times 837201 \times 10^{-8}$		=	1.674×10^6

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

6.2.2 Normal Condition

modulus of lateral subgrade reaction	K_h	=	5607 kN/m³
calculated value	β	=	0.17010 m⁻¹
resultant earth force (lateral)	P_0	=	255.40 kN/m
height of acting position of load	h_0	=	2.40 m
moment	M_0	=	612.39 kN·m/m
in consideration of ψ_m = 1.536,			
maximum moment	M_{max}	=	940.66 kN·m/m
depth of generated position of M_{max}	l_m	=	2.960 m
depth of 1st fixed point	l_i	=	7.577 m

6.2.3 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	8870 kN/m³
calculated value	β	=	0.19076 m⁻¹
resultant earth force (lateral)	P_0	=	359.52 kN/m
height of acting position of load	h_0	=	2.90 m
moment	M_0	=	1041.98 kN·m/m
in consideration of ψ_m = 1.353,			
maximum moment	M_{max}	=	1410.01 kN·m/m
depth of generated position of M_{max}	l_m	=	2.324 m
depth of 1st fixed point	l_i	=	6.441 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	25 H _ H 1000 -300 -16 -22 -18		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.88
Section efficiency	μ	=	1.00
Module of section	Z_0	=	13420 cm³ (original condition)
	Z	=	11810 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{940.66\times10^6}{11810\times10^3} = 80 \text{ N/mm}^2 \leqq \sigma_a = 180 \text{ N/mm}^2$$

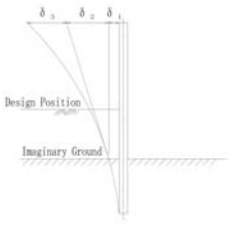
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1410.01\times10^6}{11810\times10^3} = 119 \text{ N/mm}^2 \leqq \sigma_a = 270 \text{ N/mm}^2$$

6.4 Displacement Calculation

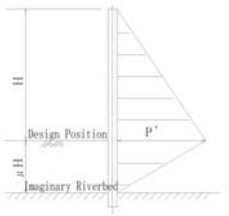
6.4.1 Normal Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.1701\times2.40)\times255.40}{2\times2.00\times10^8\times837201\times10^{-8}\times0.1701^3} = 0.02182 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.1701\times2.40)\times255.40}{2\times2.00\times10^8\times837201\times10^{-8}\times0.1701^2}\times(5.47+0.00) = 0.02618 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.47} = 0.000$$

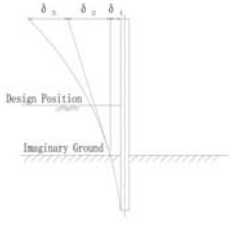
$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{93.38\times5.47^4}{120\times2.00\times10^8\times837201\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4) = 0.00166 \text{ m}$$

$\delta = \delta1 + \delta2 + \delta3$
$= 0.02182 + 0.02618 + 0.00166$
$= 0.04966$ m
Size = 49.66 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

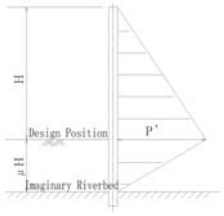
6.4.2 Seismic Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.1908\times2.90)\times359.52}{2\times2.00\times10^8\times837201\times10^{-8}\times0.1908^3} = 0.02402 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.1908\times2.90)\times359.52}{2\times2.00\times10^8\times837201\times10^{-8}\times0.1908^2}\times(5.47+0.00) = 0.03398 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.47} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{131.45\times5.47^4}{120\times2.00\times10^8\times837201\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4) = 0.00234 \text{ m}$$

$\delta = \delta1 + \delta2 + \delta3$
$= 0.02402 + 0.03398 + 0.00234$
$= 0.06034$ m
Size = 60.34 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name	25 H _ H 1000 -300 -16 -22 -18		
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²

Inertia sectional moment I_0 = 962300 cm^4 (original condition)
I = 962300 cm^4 (after reduction by corrosion and section)
$EI = 200000 \times 10^3 \times 962300 \times 10^{-8}$ = 1.925×10^6

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$
$$L = H - H_{ik} + D$$
$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 5607 kN/m^3
Calculated value β = 0.16428 m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.164} = 18.26$ m
Whole length of SSP $L = 5.47 - 0.40 + 18.26 = 23.33$ m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction K_h = 8870 kN/m^3
Calculated value β = 0.18424 m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.184} = 16.28$ m
Whole length of SSP $L = 5.47 - 0.40 + 16.28 = 21.35$ m

Therefore, the total length of the sheet pile is 23.50 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 25 H _ H 1000 -300 -16 -22 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	962300		
Sectional Modulus	Z (cm3)	13420		
Maximum bending moment	Mmax (kN・m・m)		940.66	1410.01
Stress intensity	σ (N/mm2)		80 (180)	119 (270)
Lateral displacement	δ (mm)		49.66 (50.0)	60.34 (75.0)
Penetration depths	D (m)		18.26	16.28
Whole length of SSP	L (m)	23.50		

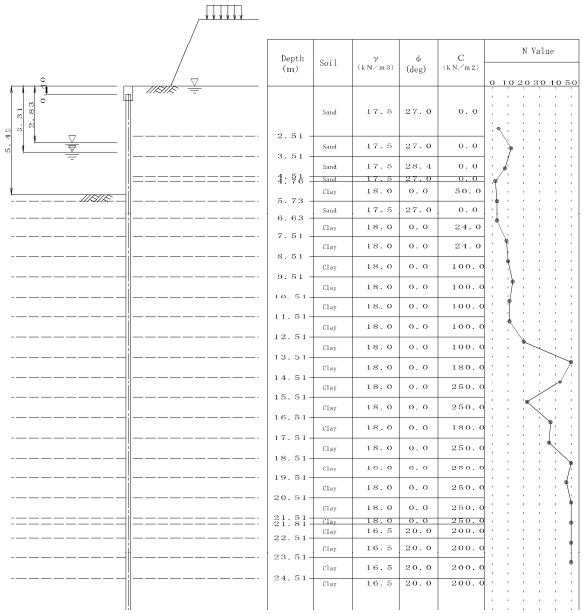
Block No. : R-9
Sta. : 6+920~7+220

Design Cross Section : Sta 7+000
Boring Name : DD-BH-R03

Specification : SSP SP-10H
(Combined) : H 1000-250-16-32-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.42 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_{ik}	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.31 m (Normal Condition)
	L_{wp}'	=	2.83 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress Chang's formula
Penetration depths $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water γ_w = 9.8 kN/m^3

Type of water pressure trapezoidal water pressure

Lateral pressure calculated in consideration of site conditions

Study case
- Normal Condition
- Seismic Condition

Design earthquake intensity k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	17.4 kN/m	(Normal Condition)
		Pt'	=	50.3 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	M_m	=	0.0 kN・m/m	(Normal Condition)
		M_m'	=	14.0 kN・m/m	(Seismic Condition)
	Depth of acting point	H_m'	=	0.00 m	(Seismic Condition)
		H_m	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load not considered

Minimum angle of rupture ζ_0 = 10 degrees

Rear side angle of slope not considered

Angle of rupture (clayey soil) $\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C} \cdot \tan\theta}$

Equilibrium factor of compression K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula
$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$
$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$
B_H = 10.00 m
E_0 = 2800N

Average N-value calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value
1	2.11	4	11	11.74	11	21	21.74	50
2	3.11	12	12	12.74	20	22	22.74	50
3	4.11	8	13	13.74	50	23	23.74	50
4	4.74	2	14	14.74	43			
5	5.74	3	15	15.74	22			
6	6.74	3	16	16.74	37			
7	7.74	9	17	17.74	36			
8	8.74	10	18	18.74	50			
9	9.74	13	19	19.74	47			
10	10.74	11	20	20.74	50			

1.6 Vertical Load

Vertical load on landside　　calculated in consideration of embankment shape on landside

Vertical load on riverside　　not considered

1.7 Soil Modulus

Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	2.51	2.51
2	3.51	1.00
3	4.51	1.00
4	4.76	0.25
5	5.73	0.97
6	6.63	0.90
7	7.51	0.88
8	8.51	1.00
9	9.51	1.00
10	10.51	1.00
11	11.51	1.00
12	12.51	1.00
13	13.51	1.00
14	14.51	1.00
15	15.51	1.00
16	16.51	1.00
17	17.51	1.00
18	18.51	1.00
19	19.51	1.00
20	20.51	1.00
21	21.51	1.00
22	21.81	0.30
23	22.51	0.70
24	23.51	1.00
25	24.51	1.00
26	25.01	0.50

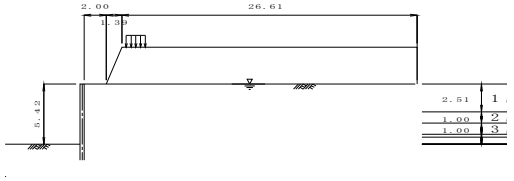
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	2.51	S	4.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
2	3.51	S	4.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
3	4.51	S	12.0	17.50	7.70	28.4	0.0	0.0	0.200	Auto	Auto
4	4.76	S	8.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
5	5.73	C	8.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
6	6.63	S	8.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
7	7.51	C	3.0	18.00	8.20	0.0	24.0	0.0	0.200	Auto	Auto
8	8.51	C	3.0	18.00	8.20	0.0	24.0	0.0	0.200	Auto	Auto
9	9.51	C	9.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
10	10.51	C	10.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
11	11.51	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
12	12.51	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
13	13.51	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
14	14.51	C	20.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
15	15.51	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
16	16.51	C	43.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
17	17.51	C	22.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
18	18.51	C	37.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
19	19.51	C	36.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
20	20.51	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
21	21.51	C	47.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
22	21.81	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
23	22.51	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto
24	23.51	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto
25	24.51	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto
26	25.01	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto

Note)　depth : from top of coping to bottom of the layer　　C_o : soil adhesion
soil : sandy(S), clayey(C), mixed (M)　　a : slope of soil adhesion
N-value : average N-value in the layer　　k' : design seismic coefficient (underwater)
γ : wet unit weight of soil　　ζ : angle of active rupture
γ' : saturated unit weight of soil　　kh : modulus of subgrade reaction
φ : internal friction angle of soil

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	2.00	3.39	30.00	30.00	3.32	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	load area End point m	load strength Normal Condition kN/m2	load strength Seismic Condition kN/m2
1	3.79	5.49	5.0	0.0

Angle of rapture in embankment　　calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name　　10 H _ H 1000 -250 -16 -32 -18
Young's modulus　　E = 200000 N/mm^2
Inertia sectional moment　　I_0 = 896800 cm^4
Sectional factor　　Z_0 = 13590 cm^3

Corrosion margin　　t_1 = 1.00 mm (riverside)　　t_2 = 1.00 mm (landside)

Corrosion rate (to I_0)　　η = 0.88
Corrosion rate (to Z_0)　　η = 0.90
Section efficiency (to I_0)　　μ = 1.00
Section efficiency (to Z_0)　　μ = 1.00

Round unit of SSP length　　0.50 m

Allowable stress　　σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

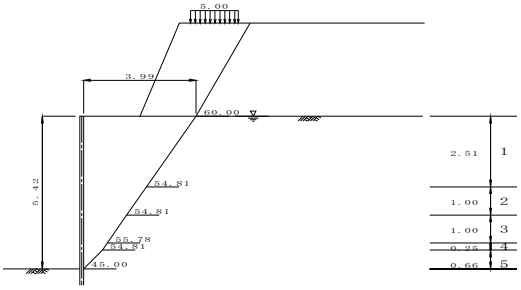
Allowable displacement　　δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam　　calculated as distributed load of each layer

Reduction of material modulus　　Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	5.42 ~ 4.76	Clay	0.0	15.0	50.0	42.06	37.77	53.12	45.00
2	4.76 ~ 4.51	Sand	27.0	15.0	0.0	36.65	37.77	46.65	54.81
3	4.51 ~ 3.51	Sand	28.4	15.0	0.0	34.73	37.77	44.20	55.78
4	3.51 ~ 2.51	Sand	27.0	15.0	0.0	27.03	37.77	34.40	54.81
5	2.51 ~ 0.00	Sand	27.0	15.0	0.0	19.33	37.77	24.60	54.81
6		embankment	30.0	——	0.0	63.08	5.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}}\cdot\tan\theta$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°
Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan^{-1}k or θ = tan^{-1}k'
γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
h : thickness of layer (m)

Q : surcharge load (kN/m^2)
C cohesive force of soil (kN/m^2)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.00	0.66	0.00	0.00	0.66	0.66
2	54.81	0.25	0.66	0.66	0.84	0.91
3	55.78	1.00	0.84	0.91	1.52	1.91
4	54.81	1.00	1.52	1.91	2.22	2.91
5	54.81	2.51	2.22	2.91	3.99	5.42
6	60.00	3.32	3.99	5.42	5.91	8.74

From the above table, the loading width (L) on the ground surface is 3.99 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	7.49	142.24
Σ			142.24

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	1.70	8.50
Σ			8.50

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

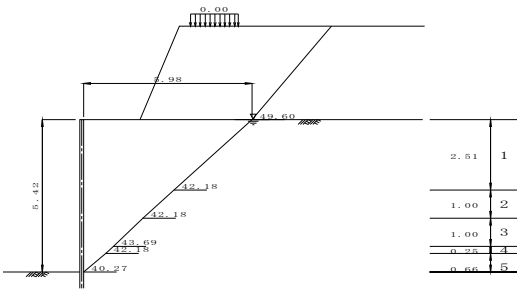
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{142.24 + 8.50 + 0.00}{3.99}$$

$$= 37.77 \text{ kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.42 ~ 4.76	Clay	0.0	15.0	50.0	42.06	49.54	53.12	0.200	11.31	40.27
2	4.76 ~ 4.51	Sand	27.0	15.0	0.0	36.65	49.54	46.65	0.200	11.31	42.18
3	4.51 ~ 3.51	Sand	28.4	15.0	0.0	34.73	49.54	44.20	0.200	11.31	43.69
4	3.51 ~ 2.51	Sand	27.0	15.0	0.0	27.03	49.54	34.40	0.200	11.31	42.18
5	2.51 ~ 0.00	Sand	27.0	15.0	0.0	19.33	49.54	24.60	0.200	11.31	42.18
6		embankment	30.0	——	0.0	63.08	0.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma\gamma h + 2Q}{2C}\cdot\tan\theta}$$

Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00º)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan^{-1}k or θ = tan^{-1}k'
γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m^2)
C cohesive force of soil (kN/m^2)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	40.27	0.66	0.00	0.00	0.78	0.66
2	42.18	0.25	0.78	0.66	1.05	0.91
3	43.69	1.00	1.05	0.91	2.10	1.91
4	42.18	1.00	2.10	1.91	3.21	2.91
5	42.18	2.51	3.21	2.91	5.98	5.42
6	49.60	3.32	5.98	5.42	8.80	8.74

From the above table, the loading width (L) on the ground surface is 5.98 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	15.58	296.04
Σ			296.04

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	0.0	1.70	0.00
Σ			0.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

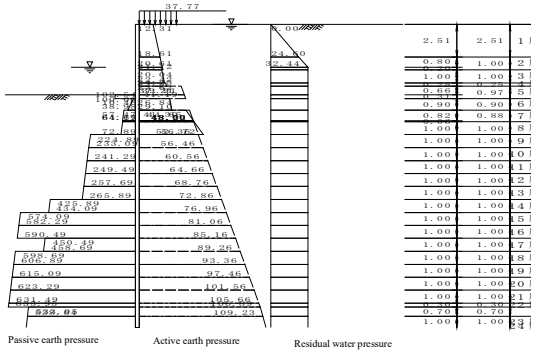
$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{296.04 + 0.00 + 0.00}{5.98}$$

$$= 49.54 \text{ kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 2.51	Sand	7.7	27.0	——	37.766 57.093	0.33738 0.33738	0.32589 0.32589
2	2.51~ 3.31	Sand	7.7	27.0	—— ——	57.093 63.253	0.33738 0.33738	0.32589 0.32589
3	3.31~ 3.51	Sand	7.7	27.0	—— ——	63.253 64.793	0.33738 0.33738	0.32589 0.32589
4	3.51~ 4.51	Sand	7.7	28.4	—— ——	64.793 72.493	0.32022 0.32022	0.30931 0.30931
5	4.51~ 4.76	Sand	7.7	27.0	—— ——	72.493 74.418	0.33738 0.33738	0.32589 0.32589
6	4.76~ 5.42	Clay	8.2	——	50.0 50.0	74.418 79.830	—— ——	—— ——
7	5.42~ 5.73	Clay	8.2	——	50.0 50.0	79.830 82.372	—— ——	—— ——
8	5.73~ 6.63	Sand	7.7	27.0	—— ——	82.372 89.302	0.33738 0.33738	0.32589 0.32589
9	6.63~ 7.45	Clay	8.2	——	24.0 24.0	89.302 96.000	—— ——	—— ——
10	7.45~ 7.51	Clay	8.2	——	24.0 24.0	96.000 96.518	—— ——	—— ——
11	7.51~ 8.51	Clay	8.2	——	24.0 24.0	96.518 104.718	—— ——	—— ——
12	8.51~ 9.51	Clay	8.2	——	100.0 100.0	104.718 112.918	—— ——	—— ——

13	9.51~ 10.51	Clay	8.2	——	100.0 100.0	112.918 121.118	——	——
14	10.51~ 11.51	Clay	8.2	——	100.0 100.0	121.118 129.318	——	——
15	11.51~ 12.51	Clay	8.2	——	100.0 100.0	129.318 137.518	——	——
16	12.51~ 13.51	Clay	8.2	——	100.0 100.0	137.518 145.718	——	——
17	13.51~ 14.51	Clay	8.2	——	180.0 180.0	145.718 153.918	——	——
18	14.51~ 15.51	Clay	8.2	——	250.0 250.0	153.918 162.118	——	——
19	15.51~ 16.51	Clay	8.2	——	250.0 250.0	162.118 170.318	——	——
20	16.51~ 17.51	Clay	8.2	——	180.0 180.0	170.318 178.518	——	——
21	17.51~ 18.51	Clay	8.2	——	250.0 250.0	178.518 186.718	——	——
22	18.51~ 19.51	Clay	8.2	——	250.0 250.0	186.718 194.918	——	——
23	19.51~ 20.51	Clay	8.2	——	250.0 250.0	194.918 203.118	——	——
24	20.51~ 21.51	Clay	8.2	——	250.0 250.0	203.118 211.318	——	——
25	21.51~ 21.81	Clay	8.2	——	250.0 250.0	211.318 213.778	——	——
26	21.81~ 22.51	Clay	6.7	——	200.0 200.0	213.778 218.468	——	——
27	22.51~ 23.51	Clay	6.7	——	200.0 200.0	218.468 225.168	——	——
28	23.51~ 24.51	Clay	6.7	——	200.0 200.0	225.168 231.868	——	——
29	24.51~ 25.01	Clay	6.7	——	200.0 200.0	231.868 235.218	——	——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
7	5.42~ 5.73	Clay	8.2	0.0	50.0 50.0	0.000 2.542	——	——
8	5.73~ 6.63	Sand	7.7	27.0	—— ——	2.542 9.472	4.26080 4.26080	4.11561 4.11561
9	6.63~ 7.45	Clay	8.2	0.0	24.0 24.0	9.472 16.170	——	——
10	7.45~ 7.51	Clay	8.2	0.0	24.0 24.0	16.170 16.688	——	——

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 2.51	12.31 18.61	——	12.31 18.61	0.00 24.60	——
2	2.51~ 3.31	18.61 20.61	——	18.61 20.61	24.60 32.44	——
3	3.31~ 3.51	20.61 21.12	——	20.61 21.12	32.44 32.44	——
4	3.51~ 4.51	20.04 22.42	——	20.04 22.42	32.44 32.44	——
5	4.51~ 4.76	23.62 24.25	——	23.62 24.25	32.44 32.44	——
6	4.76~ 5.42	-25.58 -20.17	37.21 39.91	37.21 39.91	32.44 32.44	——
7	5.42~ 5.73	-20.17 -17.63	39.91 41.19	39.91 41.19	32.44 32.44	100.00 102.54
8	5.73~ 6.63	26.84 29.10	——	26.84 29.10	32.44 32.44	10.46 38.98
9	6.63~ 7.45	41.30 48.00	44.65 48.00	44.65 48.00	32.44 32.44	57.47 64.17
10	7.45~ 7.51	48.00 48.52	48.00 48.26	48.00 48.52	32.44 32.44	64.17 64.69
11	7.51~ 8.51	48.52 56.72	48.26 52.36	48.52 56.72	32.44 32.44	64.69 72.89
12	8.51~ 9.51	-95.28 -87.08	52.36 56.46	52.36 56.46	32.44 32.44	224.89 233.09
13	9.51~ 10.51	-87.08 -78.88	56.46 60.56	56.46 60.56	32.44 32.44	233.09 241.29
14	10.51~ 11.51	-78.88 -70.68	60.56 64.66	60.56 64.66	32.44 32.44	241.29 249.49
15	11.51~ 12.51	-70.68 -62.48	64.66 68.76	64.66 68.76	32.44 32.44	249.49 257.69
16	12.51~ 13.51	-62.48 -54.28	68.76 72.86	68.76 72.86	32.44 32.44	257.69 265.89
17	13.51~ 14.51	-214.28 -206.08	72.86 76.96	72.86 76.96	32.44 32.44	425.89 434.09
18	14.51~ 15.51	-346.08 -337.88	76.96 81.06	76.96 81.06	32.44 32.44	574.09 582.29
19	15.51~ 16.51	-337.88 -329.68	81.06 85.16	81.06 85.16	32.44 32.44	582.29 590.49
20	16.51~ 17.51	-189.68 -181.48	85.16 89.26	85.16 89.26	32.44 32.44	450.49 458.69
21	17.51~ 18.51	-321.48 -313.28	89.26 93.36	89.26 93.36	32.44 32.44	598.69 606.89
22	18.51~ 19.51	-313.28 -305.08	93.36 97.46	93.36 97.46	32.44 32.44	606.89 615.09
23	19.51~ 20.51	-305.08 -296.88	97.46 101.56	97.46 101.56	32.44 32.44	615.09 623.29
24	20.51~ 21.51	-296.88 -288.68	101.56 105.66	101.56 105.66	32.44 32.44	623.29 631.49

11	7.51~ 8.51	Clay	8.2	0.0	24.0 24.0	16.688 24.888	——	——
12	8.51~ 9.51	Clay	8.2	0.0	100.0 100.0	24.888 33.088	——	——
13	9.51~ 10.51	Clay	8.2	0.0	100.0 100.0	33.088 41.288	——	——
14	10.51~ 11.51	Clay	8.2	0.0	100.0 100.0	41.288 49.488	——	——
15	11.51~ 12.51	Clay	8.2	0.0	100.0 100.0	49.488 57.688	——	——
16	12.51~ 13.51	Clay	8.2	0.0	100.0 100.0	57.688 65.888	——	——
17	13.51~ 14.51	Clay	8.2	0.0	180.0 180.0	65.888 74.088	——	——
18	14.51~ 15.51	Clay	8.2	0.0	250.0 250.0	74.088 82.288	——	——
19	15.51~ 16.51	Clay	8.2	0.0	250.0 250.0	82.288 90.488	——	——
20	16.51~ 17.51	Clay	8.2	0.0	180.0 180.0	90.488 98.688	——	——
21	17.51~ 18.51	Clay	8.2	0.0	250.0 250.0	98.688 106.888	——	——
22	18.51~ 19.51	Clay	8.2	0.0	250.0 250.0	106.888 115.088	——	——
23	19.51~ 20.51	Clay	8.2	0.0	250.0 250.0	115.088 123.288	——	——
24	20.51~ 21.51	Clay	8.2	0.0	250.0 250.0	123.288 131.488	——	——
25	21.51~ 21.81	Clay	8.2	0.0	250.0 250.0	131.488 133.948	——	——
26	21.81~ 22.51	Clay	6.7	20.0	200.0 200.0	133.948 138.638	——	——
27	22.51~ 23.51	Clay	6.7	20.0	200.0 200.0	138.638 145.338	——	——
28	23.51~ 24.51	Clay	6.7	20.0	200.0 200.0	145.338 152.038	——	——
29	24.51~ 25.01	Clay	6.7	20.0	200.0 200.0	152.038 155.388	——	——

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= -15.00、β = 0.00、θ = 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

25	21.51~ 21.81	-288.68 -286.22	105.66 106.89	105.66 106.89	32.44 32.44	631.49 633.95
26	21.81~ 22.51	-186.22 -181.53	106.89 109.23	106.89 109.23	32.44 32.44	533.95 538.64
27	22.51~ 23.51	-181.53 -174.83	109.23 112.58	109.23 112.58	32.44 32.44	538.64 545.34
28	23.51~ 24.51	-174.83 -168.13	112.58 115.93	112.58 115.93	32.44 32.44	545.34 552.04
29	24.51~ 25.01	-168.13 -164.78	115.93 117.61	115.93 117.61	32.44 32.44	552.04 555.39

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

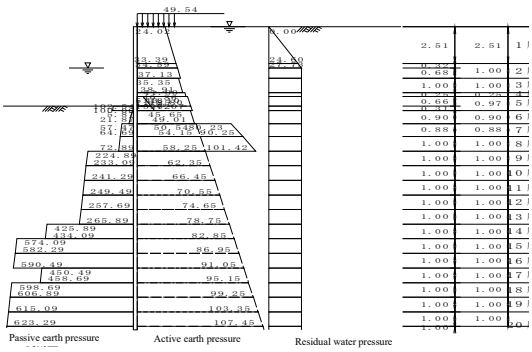
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 2.51	Sand	7.7	27.0	—— ——	49.54 68.87	0.00 24.60	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
2	2.51~ 2.83	Sand	7.7	27.0	—— ——	68.87 71.33	24.60 27.73	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
3	2.83~ 3.51	Sand	7.7	27.0	—— ——	71.33 76.57	27.73 34.40	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
4	3.51~ 4.51	Sand	7.7	28.4	—— ——	76.57 84.27	34.40 44.20	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	—— ——
5	4.51~ 4.76	Sand	7.7	27.0	—— ——	84.27 86.19	44.20 46.65	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
6	4.76~ 5.42	Clay	8.2	——	50.0 50.0	86.19 91.61	46.65 53.12	0.200 0.200	11.31 11.31	—— ——	—— ——	40.48 40.27
7	5.42~ 5.73	Clay	8.2	——	50.0 50.0	91.61 94.15	53.12 56.15	0.200 0.200	11.31 11.31	—— ——	—— ——	40.27 40.17
8	5.73~ 6.63	Sand	7.7	27.0	—— ——	94.15 101.08	56.15 64.97	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
9	6.63~ 7.51	Clay	8.2	——	24.0 24.0	101.08 108.29	64.97 73.60	0.200 0.200	11.31 11.31	—— ——	—— ——	31.39 30.33
10	7.51~ 8.51	Clay	8.2	——	24.0 24.0	108.29 116.49	73.60 83.40	0.200 0.200	11.31 11.31	—— ——	—— ——	30.33 30.00
11	8.51~ 9.51	Clay	8.2	——	100.0 100.0	116.49 124.69	83.40 93.20	0.200 0.200	11.31 11.31	—— ——	—— ——	42.40 42.26
12	9.51~ 10.51	Clay	8.2	——	100.0 100.0	124.69 132.89	93.20 103.00	0.200 0.200	11.31 11.31	—— ——	—— ——	42.26 42.12
13	10.51~ 11.51	Clay	8.2	——	100.0 100.0	132.89 141.09	103.00 112.80	0.200 0.200	11.31 11.31	—— ——	—— ——	42.12 41.98
14	11.51~ 12.51	Clay	8.2	——	100.0 100.0	141.09 149.29	112.80 122.60	0.200 0.200	11.31 11.31	—— ——	—— ——	41.98 41.83
15	12.51~ 13.51	Clay	8.2	——	100.0 100.0	149.29 157.49	122.60 132.40	0.200 0.200	11.31 11.31	—— ——	—— ——	41.83 41.68
16	13.51~ 14.51	Clay	8.2	——	180.0 180.0	157.49 165.69	132.40 142.20	0.200 0.200	11.31 11.31	—— ——	—— ——	43.25 43.18
17	14.51~ 15.51	Clay	8.2	——	250.0 250.0	165.69 173.89	142.20 152.00	0.200 0.200	11.31 11.31	—— ——	—— ——	43.71 43.66
18	15.51~ 16.51	Clay	8.2	——	250.0 250.0	173.89 182.09	152.00 161.80	0.200 0.200	11.31 11.31	—— ——	—— ——	43.66 43.61
19	16.51~ 17.51	Clay	8.2	——	180.0 180.0	182.09 190.29	161.80 171.60	0.200 0.200	11.31 11.31	—— ——	—— ——	43.03 42.95
20	17.51~ 18.51	Clay	8.2	——	250.0 250.0	190.29 198.49	171.60 181.40	0.200 0.200	11.31 11.31	—— ——	—— ——	43.56 43.50
21	18.51~ 19.51	Clay	8.2	——	250.0 250.0	198.49 206.69	181.40 191.20	0.200 0.200	11.31 11.31	—— ——	—— ——	43.50 43.45
22	19.51~ 20.51	Clay	8.2	——	250.0 250.0	206.69 214.89	191.20 201.00	0.200 0.200	11.31 11.31	—— ——	—— ——	43.45 43.40
23	20.51~ 21.51	Clay	8.2	——	250.0 250.0	214.89 223.09	201.00 210.80	0.200 0.200	11.31 11.31	—— ——	—— ——	43.40 43.35
24	21.51~ 21.81	Clay	8.2	——	250.0 250.0	223.09 225.55	210.80 213.74	0.200 0.200	11.31 11.31	—— ——	—— ——	43.35 43.33
25	21.81~ 22.51	Clay	6.7	——	200.0 200.0	225.55 230.24	213.74 220.60	0.200 0.200	11.31 11.31	—— ——	—— ——	42.88 42.84
26	22.51~ 23.51	Clay	6.7	——	200.0 200.0	230.24 236.94	220.60 230.40	0.200 0.200	11.31 11.31	—— ——	—— ——	42.84 42.79
27	23.51~ 24.51	Clay	6.7	——	200.0 200.0	236.94 243.64	230.40 240.20	0.200 0.200	11.31 11.31	—— ——	—— ——	42.79 42.73
28	24.51~ 25.01	Clay	6.7	——	200.0 200.0	243.64 246.99	240.20 245.10	0.200 0.200	11.31 11.31	—— ——	—— ——	42.73 42.70

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}} \cdot \tan\theta$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
7	5.42~ 5.73	Clay	8.20	0.0	50.0 50.0	0.000 2.542	0.00 3.04	0.200 0.200	11.31 11.31	—— ——	—— ——
8	5.73~ 6.63	Sand	7.70	27.0	—— ——	2.542 9.472	3.04 11.86	0.200 0.200	11.31 11.31	2.30874 2.30874	2.30874 2.30874
9	6.63~ 7.51	Clay	8.20	0.0	24.0 24.0	9.472 16.688	11.86 20.48	0.200 0.200	11.31 11.31	—— ——	—— ——
10	7.51~ 8.51	Clay	8.20	0.0	24.0 24.0	16.688 24.888	20.48 30.28	0.200 0.200	11.31 11.31	—— ——	—— ——
11	8.51~ 9.51	Clay	8.20	0.0	100.0 100.0	24.888 33.088	30.28 40.08	0.200 0.200	11.31 11.31	—— ——	—— ——
12	9.51~ 10.51	Clay	8.20	0.0	100.0 100.0	33.088 41.288	40.08 49.88	0.200 0.200	11.31 11.31	—— ——	—— ——
13	10.51~ 11.51	Clay	8.20	0.0	100.0 100.0	41.288 49.488	49.88 59.68	0.200 0.200	11.31 11.31	—— ——	—— ——
14	11.51~ 12.51	Clay	8.20	0.0	100.0 100.0	49.488 57.688	59.68 69.48	0.200 0.200	11.31 11.31	—— ——	—— ——
15	12.51~ 13.51	Clay	8.20	0.0	100.0 100.0	57.688 65.888	69.48 79.28	0.200 0.200	11.31 11.31	—— ——	—— ——
16	13.51~ 14.51	Clay	8.20	0.0	180.0 180.0	65.888 74.088	79.28 89.08	0.200 0.200	11.31 11.31	—— ——	—— ——
17	14.51~ 15.51	Clay	8.20	0.0	250.0 250.0	74.088 82.288	89.08 98.88	0.200 0.200	11.31 11.31	—— ——	—— ——
18	15.51~ 16.51	Clay	8.20	0.0	250.0 250.0	82.288 90.488	98.88 108.68	0.200 0.200	11.31 11.31	—— ——	—— ——
19	16.51~ 17.51	Clay	8.20	0.0	180.0 180.0	90.488 98.688	108.68 118.48	0.200 0.200	11.31 11.31	—— ——	—— ——
20	17.51~ 18.51	Clay	8.20	0.0	250.0 250.0	98.688 106.888	118.48 128.28	0.200 0.200	11.31 11.31	—— ——	—— ——
21	18.51~ 19.51	Clay	8.20	0.0	250.0 250.0	106.888 115.088	128.28 138.08	0.200 0.200	11.31 11.31	—— ——	—— ——
22	19.51~ 20.51	Clay	8.20	0.0	250.0 250.0	115.088 123.288	138.08 147.88	0.200 0.200	11.31 11.31	—— ——	—— ——
23	20.51~ 21.51	Clay	8.20	0.0	250.0 250.0	123.288 131.488	147.88 157.68	0.200 0.200	11.31 11.31	—— ——	—— ——
24	21.51~ 21.81	Clay	8.20	0.0	250.0 250.0	131.488 133.948	157.68 160.62	0.200 0.200	11.31 11.31	—— ——	—— ——
25	21.81~ 22.51	Clay	6.70	20.0	200.0 200.0	133.948 138.638	160.62 167.48	0.200 0.200	11.31 11.31	—— ——	—— ——
26	22.51~ 23.51	Clay	6.70	20.0	200.0 200.0	138.638 145.338	167.48 177.28	0.200 0.200	11.31 11.31	—— ——	—— ——
27	23.51~ 24.51	Clay	6.70	20.0	200.0 200.0	145.338 152.038	177.28 187.08	0.200 0.200	11.31 11.31	—— ——	—— ——
28	24.51~ 25.01	Clay	6.70	20.0	200.0 200.0	152.038 155.388	187.08 191.98	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 2.51	24.02 33.39	—— ——	24.02 33.39	0.00 24.60	—— ——
2	2.51~ 2.83	33.39 34.59	—— ——	33.39 34.59	24.60 27.73	—— ——
3	2.83~ 3.51	34.59 37.13	—— ——	34.59 37.13	27.73 27.73	—— ——
4	3.51~ 4.51	35.35 38.91	—— ——	35.35 38.91	27.73 27.73	—— ——
5	4.51~ 4.76	40.86 41.80	—— ——	40.86 41.80	27.73 27.73	—— ——
6	4.76~ 5.42	5.13 11.85	43.10 45.80	43.10 45.80	27.73 27.73	—— ——
7	5.42~ 5.73	11.85 15.02	45.80 47.07	45.80 47.07	27.73 27.73	100.00 102.54
8	5.73~ 6.63	45.65 49.01	—— ——	45.65 49.01	27.73 27.73	5.87 21.87
9	6.63~ 7.51	80.23 90.25	50.54 54.15	80.23 90.25	27.73 27.73	57.47 64.69
10	7.51~ 8.51	90.25 101.42	54.15 58.25	90.25 101.42	27.73 27.73	64.69 72.89
11	8.51~ 9.51	-58.82 -48.78	58.25 62.35	58.25 62.35	27.73 27.73	224.89 233.09
12	9.51~ 10.51	-48.78 -38.73	62.35 66.45	62.35 66.45	27.73 27.73	233.09 241.29
13	10.51~ 11.51	-38.73 -28.66	66.45 70.55	66.45 70.55	27.73 27.73	241.29 249.49
14	11.51~ 12.51	-28.66 -18.58	70.55 74.65	70.55 74.65	27.73 27.73	249.49 257.69
15	12.51~ 13.51	-18.58 -8.48	74.65 78.75	74.65 78.75	27.73 27.73	257.69 265.89
16	13.51~ 14.51	-169.69 -159.72	78.75 82.85	78.75 82.85	27.73 27.73	425.89 434.09
17	14.51~ 15.51	-300.15 -290.21	82.85 86.95	82.85 86.95	27.73 27.73	574.09 582.29
18	15.51~ 16.51	-290.21 -280.26	86.95 91.05	86.95 91.05	27.73 27.73	582.29 590.49
19	16.51~ 17.51	-139.74 -129.75	91.05 95.15	91.05 95.15	27.73 27.73	450.49 458.69
20	17.51~ 18.51	-270.31 -260.36	95.15 99.25	95.15 99.25	27.73 27.73	598.69 606.89
21	18.51~ 19.51	-260.36 -250.40	99.25 103.35	99.25 103.35	27.73 27.73	606.89 615.09
22	19.51~ 20.51	-250.40 -240.44	103.35 107.45	103.35 107.45	27.73 27.73	615.09 623.29
23	20.51~ 21.51	-240.44 -230.47	107.45 111.55	107.45 111.55	27.73 27.73	623.29 631.49
24	21.51~ 21.81	-230.47 -227.48	111.55 112.78	111.55 112.78	27.73 27.73	631.49 633.95
25	21.81~ 22.51	-126.97 -121.24	112.78 115.12	112.78 115.12	27.73 27.73	533.95 538.64
26	22.51~ 23.51	-121.24 -113.05	115.12 118.47	115.12 118.47	27.73 27.73	538.64 545.34
27	23.51~ 24.51	-113.05 -104.86	118.47 121.82	118.47 121.82	27.73 27.73	545.34 552.04
28	24.51~ 25.01	-104.86 -100.77	121.82 123.50	121.82 123.50	27.73 27.73	552.04 555.39

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_o \cdot (\Sigma\gamma h + Q)$

K_o : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

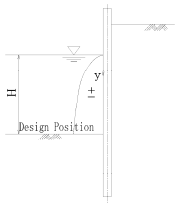
3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	2.83	0.00	0.00
2	3.83	1.00	2.76
3	4.83	2.00	3.90
4	5.42	2.59	4.44

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

Where,

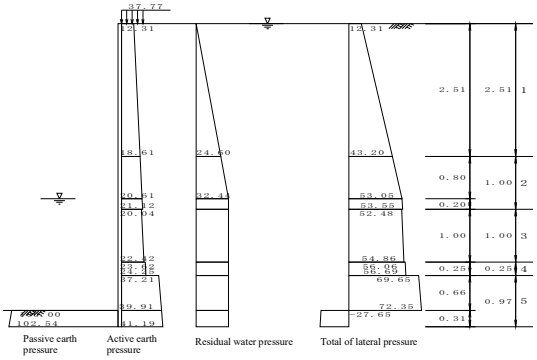
k_{hs}: design seismic coefficient
γ_w : unit weight of water
H : water depth of riverside
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition

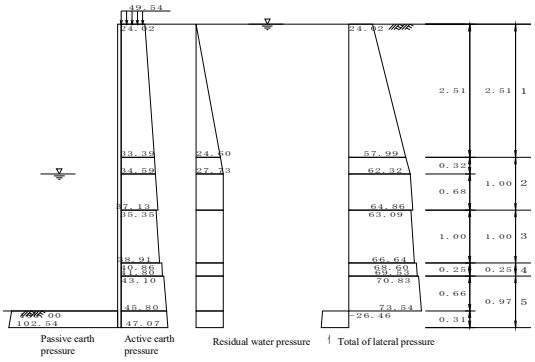


No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.51	12.31 18.61	0.00 24.60	——— ———	12.31 43.20
2	2.51~ 3.31	18.61 20.61	24.60 32.44	——— ———	43.20 53.05
3	3.31~ 3.51	20.61 21.12	32.44 32.44	——— ———	53.05 53.55
4	3.51~ 4.51	20.04 22.42	32.44 32.44	——— ———	52.48 54.86
5	4.51~ 4.76	23.62 24.25	32.44 32.44	——— ———	56.06 56.69
6	4.76~ 5.42	37.21 39.91	32.44 32.44	——— ———	69.65 72.35
7	5.42~ 5.73	39.91 41.19	32.44 32.44	100.00 102.54	-27.65 -28.92

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.42 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 2.51	24.02 33.39	0.00 24.60	——— ———	24.02 57.99
2	2.51~ 2.83	33.39 34.59	24.60 27.73	——— ———	57.99 62.32
3	2.83~ 3.51	34.59 37.13	27.73 27.73	——— ———	62.32 64.86
4	3.51~ 4.51	35.35 38.91	27.73 27.73	——— ———	63.09 66.64
5	4.51~ 4.76	40.86 41.80	27.73 27.73	——— ———	68.60 69.53
6	4.76~ 5.42	43.10 45.80	27.73 27.73	——— ———	70.83 73.54
7	5.42~ 5.73	45.80 47.07	27.73 27.73	100.00 102.54	-26.46 -27.73

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.42 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name	10 H_H 1000 -250 -16 -32 -18		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.88
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	896800 cm^4(original condition)
	I	=	789184 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 789184 \times 10^{-8} = 1.578 \times 10^6$

No	Depth m	N Value
1	2.11	4
2	3.11	12
3	4.11	8
4	4.74	2
5	5.74	3
6	6.74	3
7	7.74	9
8	8.74	10
9	9.74	13
10	10.74	11

No	Depth m	N Value
11	11.74	11
12	12.74	20
13	13.74	50
14	14.74	43
15	15.74	22
16	16.74	37
17	17.74	36
18	18.74	50
19	19.74	47
20	20.74	50

No	Depth m	N Value
21	21.74	50
22	22.74	50
23	23.74	50

5.2 Normal Condition

Assuming Kh = 5589 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.172 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 5.80 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.42 m) to 5.80 m depth (GL -11.22 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.42	0.32	2.7	3.0	0.91
2	5.74	1.00	3.0	3.0	3.00
3	6.74	1.00	3.0	9.0	6.00
4	7.74	1.00	9.0	10.0	9.50
5	8.74	1.00	10.0	13.0	11.50
6	9.74	1.00	13.0	11.0	12.00
7	10.74	0.48	11.0	11.0	5.25
L = Σh = 5.80			ΣA =	48.16	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{48.16}{5.80} = 8.31$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 8.31 = 23261$ kN/m²

$K_{h0} = \frac{1}{0.3} \times \alpha \times 23261 = 77537$ kN/m³ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 77537(10.00/0.3)^{-3/4} = 5589$ kN/m³

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 5589 kN/m3.

5.3 Seismic Condition

Assuming Kh = 10520 kN/m3,

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.202$ m⁻¹

$L = \frac{1}{\beta} = 4.95$ m

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.42 m) and 4.95 m depth (GL -10.37 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.42	0.32	2.7	3.0	0.91
2	5.74	1.00	3.0	3.0	3.00
3	6.74	1.00	3.0	9.0	6.00
4	7.74	1.00	9.0	10.0	9.50
5	8.74	1.00	10.0	13.0	11.50
6	9.74	0.63	13.0	11.7	7.79
	L = Σh = 4.95		Σ A =	38.70	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{38.70}{4.95} = 7.82$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 7.82 = 21891$ kN/m²

$K_{h0} = \frac{1}{0.3} \times \alpha \times 21891 = 145937$ kN/m³ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 145937(10.00/0.3)^{-3/4} = 10520$ kN/m³

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 10520 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.51	2.51	12.31 43.20	15.45 54.22	4.58 3.75	70.79 203.15
2	2.51~ 3.31	0.80	43.20 53.05	17.28 21.22	2.64 2.38	45.68 50.43
3	3.31~ 3.51	0.20	53.05 53.55	5.31 5.36	2.04 1.98	10.84 10.59
4	3.51~ 4.51	1.00	52.48 54.86	26.24 27.43	1.58 1.24	41.37 34.11
5	4.51~ 4.76	0.25	56.06 56.69	7.01 7.09	0.83 0.74	5.79 5.27
6	4.76~ 5.42	0.66	69.65 72.35	22.98 23.88	0.44 0.22	10.11 5.25
				Σ P = 233.45	Σ M = 493.38	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	17.4 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.42 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 94.31$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{587.69}{250.85} = 2.34$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 250.85}{5.42} = 92.57$ kN/m

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 2.51	2.51	24.02 57.99	30.15 72.78	4.58 3.75	138.18 272.69
2	2.51~ 2.83	0.32	57.99 62.32	9.28 9.97	2.80 2.70	26.01 26.89
3	2.83~ 3.51	0.68	62.32 64.86	21.19 22.05	2.36 2.14	50.08 47.12
4	3.51~ 4.51	1.00	63.09 66.64	31.54 33.32	1.58 1.24	49.73 41.43
5	4.51~ 4.76	0.25	68.60 69.53	8.57 8.69	0.83 0.74	7.09 6.46
6	4.76~ 5.42	0.66	70.83 73.54	23.37 24.27	0.44 0.22	10.28 5.34
				Σ P = 295.20	Σ M = 681.31	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	50.3 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	14.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.42 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 286.63$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	2.83~ 3.83	1.00	0.0 2.8	0.00 1.38	2.26 1.92	0.00 2.65
2	3.83~ 4.83	1.00	2.8 3.9	1.38 1.95	1.26 0.92	1.73 1.80
3	4.83~ 5.42	0.59	3.9 4.4	1.15 1.31	0.39 0.20	0.45 0.26
			Σ Pdw = 7.17		Σ Mdw = 6.90	

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{974.84}{352.67} = 2.76$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 352.67}{5.42} = 130.14$ kN/m

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name	10 H _ H 1000 -250 -16 -32 -18		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.88
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	896800 cm⁴ (original condition)
	I	=	789184 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 789184 × 10⁻⁸		=	1.578 × 10⁶

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$

$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp(-\tan^{-1}\frac{1}{1+2\beta h_0})$

$M_{max} = M_0 \cdot \phi_m$

$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$

$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$

$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	5589 kN/m³
calculated value	β	=	0.17249 m⁻¹
resultant earth force (lateral)	P_0	=	250.85 kN/m
height of acting position of load	h_0	=	2.34 m
moment	M_0	=	587.69 kN・m/m
in consideration of η_{fm} = 1.543,			
maximum moment	M_{max}	=	906.62 kN・m/m
depth of generated position of M_{max}	l_m	=	2.929 m
depth of 1st fixed point	l_i	=	7.482 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	10520	kN/m³
calculated value	β	=	0.20204	m⁻¹
resultant earth force (lateral)	P_0	=	352.67	kN/m
height of acting position of load	h_0	=	2.76	m
moment	M_0	=	974.84	kN･m/m
in consideration of γ_m = 1.348,				
maximum moment	M_{max}	=	1314.29	kN･m/m
depth of generated position of M_{max}	l_m	=	2.184	m
depth of 1st fixed point	l_i	=	6.072	m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 1000 -250 -16 -32 -18		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.90
Section efficiency	μ	=	1.00
Module of section	Z_0	=	13590 cm³ (original condition)
	Z	=	12231 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{906.62\times10^6}{12231\times10^3} = 74\ N/mm^2 \leqq \sigma_a = 180\ N/mm^2$$

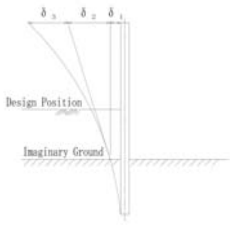
6.3.2 Seismic Condition

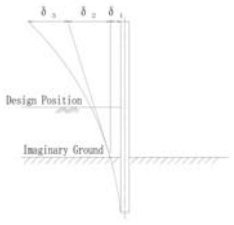
$$\sigma = \frac{M_{max}}{Z} = \frac{1314.29\times10^6}{12231\times10^3} = 107\ N/mm^2 \leqq \sigma_a = 270\ N/mm^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

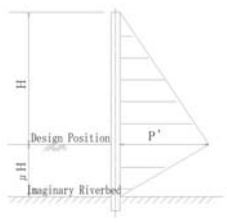
Displacement Calculation





$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.2020\times2.76)\times352.67}{2\times2.00\times10^8\times789184\times10^{-8}\times0.2020^3} = 0.02111\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.2020\times2.76)\times352.67}{2\times2.00\times10^8\times789184\times10^{-8}\times0.2020^2}\times(5.42+0.00) = 0.03140\ m$$



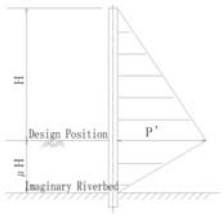
$$\mu = \frac{L_k}{H} = \frac{0.00}{5.42} = 0.000$$

$$\delta_3 = \frac{P'H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{130.14\times5.42^4}{120\times2.00\times10^8\times789184\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4) = 0.00237\ m$$

$\delta = \delta1 + \delta2 + \delta3$
= 0.02111 + 0.03140 + 0.00237
= 0.05489 m
Size = 54.89 ≦ δa = 75.00 mm

$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.1725\times2.34)\times250.85}{2\times2.00\times10^8\times789184\times10^{-8}\times0.1725^3} = 0.02174\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.1725\times2.34)\times250.85}{2\times2.00\times10^8\times789184\times10^{-8}\times0.1725^2}\times(5.42+0.00) = 0.02618\ m$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.42} = 0.000$$

$$\delta_3 = \frac{P'H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{92.57\times5.42^4}{120\times2.00\times10^8\times789184\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4) = 0.00169\ m$$

$\delta = \delta1 + \delta2 + \delta3$
= 0.02174 + 0.02618 + 0.00169
= 0.04960 m
Size = 49.60 ≦ δa = 50.00 mm

Where,
- δ_1 : Displacement at imaginary ground
- δ_2 : Displacement by angle of inclination slope at imaginary ground
- δ_3 : Displacement at higher part of imaginary ground as cantilever
- δ : Displacement at top of SSP
- δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

Where,
- δ_1 : Displacement at imaginary ground
- δ_2 : Displacement by angle of inclination slope at imaginary ground
- δ_3 : Displacement at higher part of imaginary ground as cantilever
- δ : Displacement at top of SSP
- δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name	10 H _ H 1000 -250 -16 -32 -18		
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	896800 cm⁴ (original condition)
	I	=	896800 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 896800 × 10⁻⁸		=	1.794 × 10⁶

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$
$$L = H - H_{1t} + D$$
$$\beta = \sqrt[4]{\frac{K_h\cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction	K_h	=	5589 kN/m³
Calculated value	β	=	0.16707 m⁻¹
Penetration length of SSP	D	=	$0.00 + \frac{3}{0.167}$ = 17.96 m
Whole length of SSP	L	=	5.42 − 0.40 + 17.96 = 22.98 m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction	K_h	=	10520 kN/m³
Calculated value	β	=	0.19568 m⁻¹
Penetration length of SSP	D	=	$0.00 + \frac{3}{0.196}$ = 15.33 m
Whole length of SSP	L	=	5.42 − 0.40 + 15.33 = 20.35 m

Therefore, the total length of the sheet pile is 23.00 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 10 H _ H 1000 -250 -16 -32 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	896800		
Sectional Modulus	Z (cm3)	13590		
Maximum bending moment	Mmax (kN・m・m)		906.62	1314.29
Stress intensity	σ (N/mm2)		74 (180)	107 (270)
Lateral displacement	δ (mm)		49.60 (50.0)	54.89 (75.0)
Penetration depths	D (m)		17.96	15.33
Whole length of SSP	L (m)	23.00		

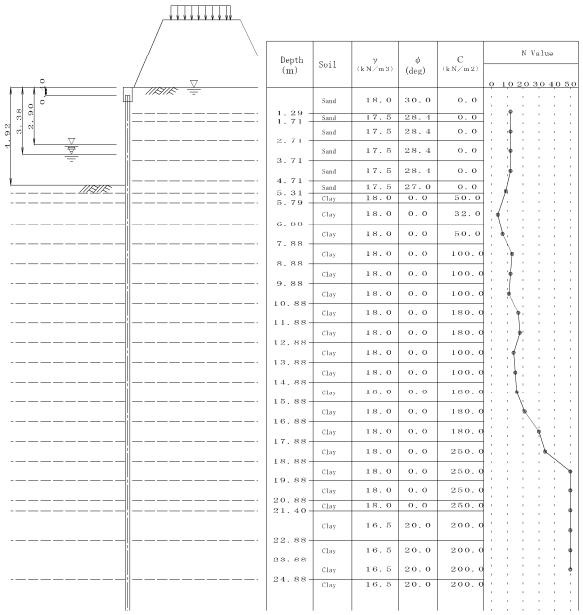
Block No. : R-10
Sta. : 7+220~7+620

Design Cross Section : Sta 7+420
Boring Name : DD-BH-R04

Specification : SSP SP-25H
（Combined） : H 1000-300-16-32-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



Depth (m)	Soil	γ (kN/m3)	φ (deg)	C (kN/m2)	N Value 0 10 20 30 40 50
	Sand	18.0	30.0	0.0	
1.29	Sand	17.5	28.4	0.0	
1.71	Sand	17.5	28.4	0.0	
2.71	Sand	17.5	28.4	0.0	
3.71	Sand	17.5	28.4	0.0	
4.71	Sand	17.5	27.0	0.0	
5.31	Clay	18.0	0.0	50.0	
5.79	Clay	18.0	0.0	32.0	
6.00	Clay	18.0	0.0	50.0	
7.88	Clay	18.0	0.0	100.0	
8.88	Clay	18.0	0.0	100.0	
9.88	Clay	18.0	0.0	100.0	
10.88	Clay	18.0	0.0	180.0	
11.88	Clay	18.0	0.0	180.0	
12.88	Clay	18.0	0.0	100.0	
13.88	Clay	18.0	0.0	100.0	
14.88	Clay	18.0	0.0	100.0	
15.88	Clay	18.0	0.0	180.0	
16.88	Clay	18.0	0.0	180.0	
17.88	Clay	18.0	0.0	250.0	
18.88	Clay	18.0	0.0	250.0	
19.88	Clay	18.0	0.0	250.0	
20.88	Clay	18.0	0.0	250.0	
21.40	Clay	16.5	20.0	200.0	
22.88	Clay	16.5	20.0	200.0	
23.88	Clay	16.5	20.0	200.0	
24.88	Clay	16.5	20.0	200.0	

1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	4.92	m
Depth from coping top to rear side ground	H_0	=	0.00	m
Depth from coping top to SSP top	H_B	=	0.40	m
Landside WL	L_{wa}	=	0.00	m (Normal Condition)
	L_{wa}'	=	0.00	m (Seismic Condition)
Riverside WL	L_{wp}	=	3.38	m (Normal Condition)
	L_{wp}'	=	2.90	m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress Chang's formula
Penetration depths $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water γ_w = 9.8 kN/m^3

Type of water pressure trapezoidal water pressure

Lateral pressure calculated in consideration of site conditions

Study case
- Normal Condition
- Seismic Condition

Design earthquake intensity k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	17.8 kN/m	(Normal Condition)
		Pt'	=	39.7 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	M_m	=	29.4 kN・m/m	(Normal Condition)
		M_m'	=	62.7 kN・m/m	(Seismic Condition)
	Depth of acting point	H_m'	=	0.00 m	(Seismic Condition)
		H_m	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load not considered

Minimum angle of rupture ζ_0 = 10 degrees

Rear side angle of slope not considered

Angle of rupture (clayey soil) $\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C} \cdot \tan\theta}$

Equilibrium factor of compression K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m
E_0 = 2800N

Average N-value calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value
1	1.21	12
2	2.21	12
3	3.21	12
4	4.21	12
5	5.21	9
6	6.38	4
7	7.38	7
8	8.38	13
9	9.38	12
10	10.38	11
11	11.38	17
12	12.38	18
13	13.38	14
14	14.38	15
15	15.38	16
16	16.38	21
17	17.38	30
18	18.38	34
19	19.38	50
20	20.38	50
21	21.38	50
22	22.38	50
23	23.38	50
24	24.38	50
25	25.38	50

1.6 Vertical Load

Vertical load on landside　　calculated in consideration of embankment shape on landside

Vertical load on riverside　　not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	1.29	1.29
2	1.71	0.42
3	2.71	1.00
4	3.71	1.00
5	4.71	1.00
6	5.31	0.60
7	5.79	0.48
8	6.88	1.09
9	7.88	1.00
10	8.88	1.00
11	9.88	1.00
12	10.88	1.00
13	11.88	1.00
14	12.88	1.00
15	13.88	1.00
16	14.88	1.00
17	15.88	1.00
18	16.88	1.00
19	17.88	1.00
20	18.88	1.00
21	19.88	1.00
22	20.88	1.00
23	21.40	0.52
24	22.88	1.48
25	23.88	1.00
26	24.88	1.00
27	25.38	0.50

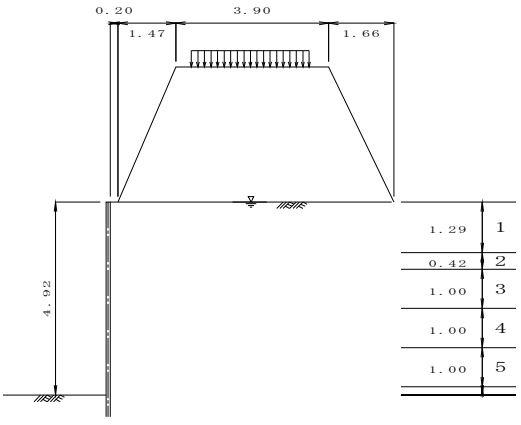
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition	Kh (kN/m3) Normal Condition	Kh (kN/m3) Seismic Condition
1	1.29	S	15.0	18.00	8.20	30.0	0.0	0.0	0.200	Auto	Auto	———	———
2	1.71	S	12.0	17.50	7.70	28.4	0.0	0.0	0.200	Auto	Auto	———	———
3	2.71	S	12.0	17.50	7.70	28.4	0.0	0.0	0.200	Auto	Auto	———	———
4	3.71	S	12.0	17.50	7.70	28.4	0.0	0.0	0.200	Auto	Auto	———	———
5	4.71	S	12.0	17.50	7.70	28.4	0.0	0.0	0.200	Auto	Auto	———	———
6	5.31	S	9.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto	———	———
7	5.79	C	6.5	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto	———	———
8	6.88	C	4.0	18.00	8.20	0.0	32.0	0.0	0.200	Auto	Auto	———	———
9	7.88	C	7.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto	———	———
10	8.88	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto	———	———
11	9.88	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto	———	———
12	10.88	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto	———	———
13	11.88	C	17.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	———	———
14	12.88	C	18.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	———	———
15	13.88	C	14.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto	———	———
16	14.88	C	15.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto	———	———
17	15.88	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	———	———
18	16.88	C	21.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	———	———
19	17.88	C	30.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto	———	———
20	18.88	C	34.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto	———	———
21	19.88	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto	———	———
22	20.88	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto	———	———
23	21.40	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto	———	———
24	22.88	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto	———	———
25	23.88	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto	———	———
26	24.88	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto	———	———
27	25.38	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto	———	———

Note) depth : from top of coping to bottom of the layer　　C_o : soil adhesion
soil : sandy(S), clayey(C), mixed (M)　　a : slope of soil adhesion
N-value : average N-value in the layer　　k' : design seismic coefficient (underwater)
γ : wet unit weight of soil　　ζ : angle of active rupture
γ' : saturated unit weight of soil　　kh : modulus of subgrade reaction
φ : internal friction angle of soil

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	0.20	1.67	5.57	7.23	3.44	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	load area End point m	load strength Normal Condition kN/m2	load strength Seismic Condition kN/m2
1	2.07	5.07	10.0	5.0

Angle of rapture in embankment　　calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name　　25 H_H 1000 -300 -16 -32 -18
Young's modulus　　E = 200000 N/mm^2
Inertia sectional moment　　I_0 = 1129800 cm^4
Sectional factor　　Z_0 = 16330 cm^3

Corrosion margin　　t_1 = 1.00 mm (riverside)　　t_2 = 1.00 mm (landside)

Corrosion rate (to I_0)　　η = 0.89
Corrosion rate (to Z_0)　　η = 0.90
Section efficiency (to I_0)　　μ = 1.00
Section efficiency (to Z_0)　　μ = 1.00

Round unit of SSP length　　0.50 m

Allowable stress　　σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

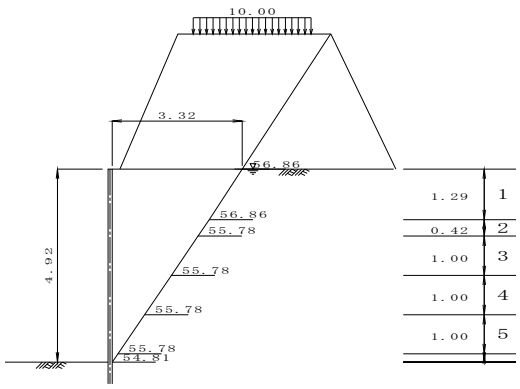
Allowable displacement　　δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam　　calculated as distributed load of each layer

Reduction of material modulus　　Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	$\Sigma\gamma h$ kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	4.92 ~ 4.71	Sand	27.0	15.0	0.0	38.53	78.11	48.22	54.81
2	4.71 ~ 3.71	Sand	28.4	15.0	0.0	36.91	78.11	46.16	55.78
3	3.71 ~ 2.71	Sand	28.4	15.0	0.0	29.21	78.11	36.36	55.78
4	2.71 ~ 1.71	Sand	28.4	15.0	0.0	21.51	78.11	26.56	55.78
5	1.71 ~ 1.29	Sand	28.4	15.0	0.0	13.81	78.11	16.76	55.78
6	1.29 ~ 0.00	Sand	30.0	15.0	0.0	10.58	78.11	12.64	56.86
7		embankment	30.0	15.0	0.0	65.36	10.00	0.00	56.86

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since $\theta = 0°$

Where,

ζ : angle of active rupture (degree, $\zeta \geq 10.00°$)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
$\theta = \tan^{-1}k$ or $\theta = \tan^{-1}k'$
γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m^2)
C : cohesive force of soil (kN/m^2)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	54.81	0.21	0.00	0.00	0.15	0.21
2	55.78	1.00	0.15	0.21	0.83	1.21
3	55.78	1.00	0.83	1.21	1.51	2.21
4	55.78	1.00	1.51	2.21	2.19	3.21
5	55.78	0.42	2.19	3.21	2.47	3.63
6	56.86	1.29	2.47	3.63	3.32	4.92
7	56.86	3.44	3.32	4.92	5.56	8.36

From the above table, the loading width (L) on the ground surface is 3.32 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	$\gamma \times A$ kN/m
1	19.0	12.06	229.05
Σ			229.05

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	3.00	30.00
Σ			30.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

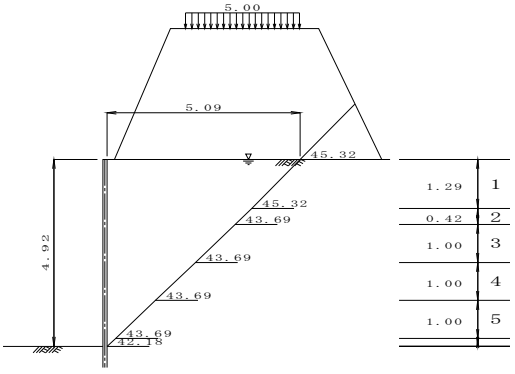
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{229.05 + 30.00 + 0.00}{3.32}$$

$$= 78.11\ \text{kN/m}^2$$

2.2 Seismic Condition



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2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	$\Sigma\gamma h$ kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	4.92 ~ 4.71	Sand	27.0	15.0	0.0	38.53	67.33	48.22	0.200	11.31	42.18
2	4.71 ~ 3.71	Sand	28.4	15.0	0.0	36.91	67.33	46.16	0.200	11.31	43.69
3	3.71 ~ 2.71	Sand	28.4	15.0	0.0	29.21	67.33	36.36	0.200	11.31	43.69
4	2.71 ~ 1.71	Sand	28.4	15.0	0.0	21.51	67.33	26.56	0.200	11.31	43.69
5	1.71 ~ 1.29	Sand	28.4	15.0	0.0	13.81	67.33	16.76	0.200	11.31	43.69
6	1.29 ~ 0.00	Sand	30.0	15.0	0.0	10.58	67.33	12.64	0.200	11.31	45.32
7		embankment	30.0	15.0	0.0	65.36	5.00	0.00	0.200	11.31	45.32

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,

ζ : angle of active rupture (degree, $\zeta \geq 10.00°$)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
$\theta = \tan^{-1}k$ or $\theta = \tan^{-1}k'$
γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m^2)
C : cohesive force of soil (kN/m^2)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	42.18	0.21	0.00	0.00	0.23	0.21
2	43.69	1.00	0.23	0.21	1.28	1.21
3	43.69	1.00	1.28	1.21	2.33	2.21
4	43.69	1.00	2.33	2.21	3.37	3.21
5	43.69	0.42	3.37	3.21	3.81	3.63
6	45.32	1.29	3.81	3.63	5.09	4.92
7	45.32	1.46	5.09	4.92	6.53	6.38

From the above table, the loading width (L) on the ground surface is 5.09 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	$\gamma \times A$ kN/m
1	19.0	17.24	327.57
Σ			327.57

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.00	15.00
Σ			15.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

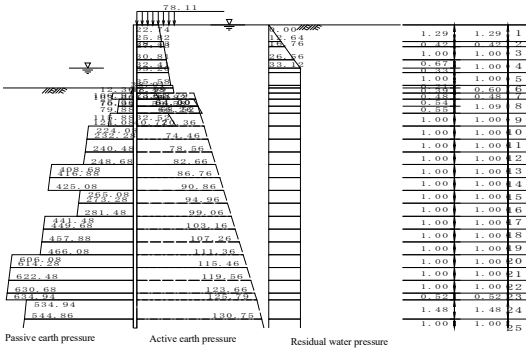
$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{327.57 + 15.00 + 0.00}{5.09}$$

$$= 67.33\ \text{kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 1.29	Sand	8.2	30.0	——— ———	78.111 88.689	0.30142 0.30142	0.29115 0.29115
2	1.29~ 1.71	Sand	7.7	28.4	——— ———	88.689 91.923	0.32022 0.32022	0.30931 0.30931
3	1.71~ 2.71	Sand	7.7	28.4	——— ———	91.923 99.623	0.32022 0.32022	0.30931 0.30931
4	2.71~ 3.38	Sand	7.7	28.4	——— ———	99.623 104.782	0.32022 0.32022	0.30931 0.30931
5	3.38~ 3.71	Sand	7.7	28.4	——— ———	104.782 107.323	0.32022 0.32022	0.30931 0.30931
6	3.71~ 4.71	Sand	7.7	28.4	——— ———	107.323 115.023	0.32022 0.32022	0.30931 0.30931
7	4.71~ 4.92	Sand	7.7	27.0	——— ———	115.023 116.640	0.33738 0.33738	0.32589 0.32589
8	4.92~ 5.31	Sand	7.7	27.0	——— ———	116.640 119.643	0.33738 0.33738	0.32589 0.32589
9	5.31~ 5.79	Clay	8.2	———	50.0 50.0	119.643 123.579	——— ———	——— ———
10	5.79~ 6.33	Clay	8.2	———	32.0 32.0	123.579 128.000	——— ———	——— ———
11	6.33~ 6.88	Clay	8.2	———	32.0 32.0	128.000 132.517	——— ———	——— ———
12	6.88~ 7.88	Clay	8.2	———	50.0 50.0	132.517 140.717	——— ———	——— ———
13	7.88~ 8.88	Clay	8.2	———	100.0 100.0	140.717 148.917	——— ———	——— ———
14	8.88~ 9.88	Clay	8.2	———	100.0 100.0	148.917 157.117	——— ———	——— ———
15	9.88~ 10.88	Clay	8.2	———	100.0 100.0	157.117 165.317	——— ———	——— ———
16	10.88~ 11.88	Clay	8.2	———	180.0 180.0	165.317 173.517	——— ———	——— ———
17	11.88~ 12.88	Clay	8.2	———	180.0 180.0	173.517 181.717	——— ———	——— ———
18	12.88~ 13.88	Clay	8.2	———	100.0 100.0	181.717 189.917	——— ———	——— ———
19	13.88~ 14.88	Clay	8.2	———	100.0 100.0	189.917 198.117	——— ———	——— ———
20	14.88~ 15.88	Clay	8.2	———	180.0 180.0	198.117 206.317	——— ———	——— ———
21	15.88~ 16.88	Clay	8.2	———	180.0 180.0	206.317 214.517	——— ———	——— ———
22	16.88~ 17.88	Clay	8.2	———	180.0 180.0	214.517 222.717	——— ———	——— ———
23	17.88~ 18.88	Clay	8.2	———	250.0 250.0	222.717 230.917	——— ———	——— ———
24	18.88~ 19.88	Clay	8.2	———	250.0 250.0	230.917 239.117	——— ———	——— ———
25	19.88~ 20.88	Clay	8.2	———	250.0 250.0	239.117 247.317	——— ———	——— ———
26	20.88~ 21.40	Clay	8.2	———	250.0 250.0	247.317 251.581	——— ———	——— ———
27	21.40~ 22.88	Clay	6.7	———	200.0 200.0	251.581 261.497	——— ———	——— ———
28	22.88~ 23.88	Clay	6.7	———	200.0 200.0	261.497 268.197	——— ———	——— ———
29	23.88~ 24.88	Clay	6.7	———	200.0 200.0	268.197 274.897	——— ———	——— ———
30	24.88~ 25.38	Clay	6.7	———	200.0 200.0	274.897 278.247	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β= 0.00、θ= 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
8	4.92~ 5.31	Sand	7.7	27.0	——— ———	0.000 3.003	4.26080 4.26080	4.11561 4.11561
9	5.31~ 5.79	Clay	8.2	0.0	50.0 50.0	3.003 6.939	——— ———	——— ———
10	5.79~ 6.33	Clay	8.2	0.0	32.0 32.0	6.939 11.360	——— ———	——— ———
11	6.33~ 6.88	Clay	8.2	0.0	32.0 32.0	11.360 15.877	——— ———	——— ———
12	6.88~ 7.88	Clay	8.2	0.0	50.0 50.0	15.877 24.077	——— ———	——— ———
13	7.88~ 8.88	Clay	8.2	0.0	100.0 100.0	24.077 32.277	——— ———	——— ———
14	8.88~ 9.88	Clay	8.2	0.0	100.0 100.0	32.277 40.477	——— ———	——— ———
15	9.88~ 10.88	Clay	8.2	0.0	100.0 100.0	40.477 48.677	——— ———	——— ———
16	10.88~ 11.88	Clay	8.2	0.0	180.0 180.0	48.677 56.877	——— ———	——— ———
17	11.88~ 12.88	Clay	8.2	0.0	180.0 180.0	56.877 65.077	——— ———	——— ———
18	12.88~ 13.88	Clay	8.2	0.0	100.0 100.0	65.077 73.277	——— ———	——— ———
19	13.88~ 14.88	Clay	8.2	0.0	100.0 100.0	73.277 81.477	——— ———	——— ———
20	14.88~ 15.88	Clay	8.2	0.0	180.0 180.0	81.477 89.677	——— ———	——— ———
21	15.88~ 16.88	Clay	8.2	0.0	180.0 180.0	89.677 97.877	——— ———	——— ———
22	16.88~ 17.88	Clay	8.2	0.0	180.0 180.0	97.877 106.077	——— ———	——— ———
23	17.88~ 18.88	Clay	8.2	0.0	250.0 250.0	106.077 114.277	——— ———	——— ———
24	18.88~ 19.88	Clay	8.2	0.0	250.0 250.0	114.277 122.477	——— ———	——— ———
25	19.88~ 20.88	Clay	8.2	0.0	250.0 250.0	122.477 130.677	——— ———	——— ———
26	20.88~ 21.40	Clay	8.2	0.0	250.0 250.0	130.677 134.941	——— ———	——— ———
27	21.40~ 22.88	Clay	6.7	20.0	200.0 200.0	134.941 144.857	——— ———	——— ———
28	22.88~ 23.88	Clay	6.7	20.0	200.0 200.0	144.857 151.557	——— ———	——— ———
29	23.88~ 24.88	Clay	6.7	20.0	200.0 200.0	151.557 158.257	——— ———	——— ———
30	24.88~ 25.38	Clay	6.7	20.0	200.0 200.0	158.257 161.607	——— ———	——— ———

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β= 0.00、θ= 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.29	22.74 25.82	——— ———	22.74 25.82	0.00 12.64	——— ———
2	1.29~ 1.71	27.43 28.43	——— ———	27.43 28.43	12.64 16.76	——— ———
3	1.71~ 2.71	28.43 30.81	——— ———	28.43 30.81	16.76 26.56	——— ———
4	2.71~ 3.38	30.81 32.41	——— ———	30.81 32.41	26.56 33.12	——— ———
5	3.38~ 3.71	32.41 33.20	——— ———	32.41 33.20	33.12 33.12	——— ———
6	3.71~ 4.71	33.20 35.58	——— ———	33.20 35.58	33.12 33.12	——— ———
7	4.71~ 4.92	37.48 38.01	——— ———	37.48 38.01	33.12 33.12	——— ———
8	4.92~ 5.31	38.01 38.99	——— ———	38.01 38.99	33.12 33.12	0.00 12.36
9	5.31~ 5.79	19.64 23.58	59.82 61.79	59.82 61.79	33.12 33.12	103.00 106.94
10	5.79~ 6.33	59.58 64.00	61.79 64.00	61.79 64.00	33.12 33.12	70.94 75.36
11	6.33~ 6.88	64.00 68.52	64.00 66.26	64.00 68.52	33.12 33.12	75.36 79.88
12	6.88~ 7.88	32.52 40.72	66.26 70.36	66.26 70.36	33.12 33.12	115.88 124.08
13	7.88~ 8.88	-59.28 -51.08	70.36 74.46	70.36 74.46	33.12 33.12	224.08 232.28
14	8.88~ 9.88	-51.08 -42.88	74.46 78.56	74.46 78.56	33.12 33.12	232.28 240.48
15	9.88~ 10.88	-42.88 -34.68	78.56 82.66	78.56 82.66	33.12 33.12	240.48 248.68
16	10.88~ 11.88	-194.68 -186.48	82.66 86.76	82.66 86.76	33.12 33.12	408.68 416.88
17	11.88~ 12.88	-186.48 -178.28	86.76 90.86	86.76 90.86	33.12 33.12	416.88 425.08
18	12.88~ 13.88	-18.28 -10.08	90.86 94.96	90.86 94.96	33.12 33.12	265.08 273.28
19	13.88~ 14.88	-10.08 -1.88	94.96 99.06	94.96 99.06	33.12 33.12	273.28 281.48
20	14.88~ 15.88	-161.88 -153.68	99.06 103.16	99.06 103.16	33.12 33.12	441.48 449.68
21	15.88~ 16.88	-153.68 -145.48	103.16 107.26	103.16 107.26	33.12 33.12	449.68 457.88
22	16.88~ 17.88	-145.48 -137.28	107.26 111.36	107.26 111.36	33.12 33.12	457.88 466.08
23	17.88~ 18.88	-277.28 -269.08	111.36 115.46	111.36 115.46	33.12 33.12	606.08 614.28
24	18.88~ 19.88	-269.08 -260.88	115.46 119.56	115.46 119.56	33.12 33.12	614.28 622.48

25	19.88~ 20.88	-260.88 -252.68	119.56 123.66	119.56 123.66	33.12 33.12	622.48 630.68
26	20.88~ 21.40	-252.68 -248.42	123.66 125.79	123.66 125.79	33.12 33.12	630.68 634.94
27	21.40~ 22.88	-148.42 -138.50	125.79 130.75	125.79 130.75	33.12 33.12	534.94 544.86
28	22.88~ 23.88	-138.50 -131.80	130.75 134.10	130.75 134.10	33.12 33.12	544.86 551.56
29	23.88~ 24.88	-131.80 -125.10	134.10 137.45	134.10 137.45	33.12 33.12	551.56 558.26
30	24.88~ 25.38	-125.10 -121.75	137.45 139.12	137.45 139.12	33.12 33.12	558.26 561.61

- Formula for active earth pressure

Sand $P_{a1}=K_a\cdot\left[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_{a1}=\Sigma\gamma h+Q-2C$

$P_{a2}=K_c\cdot(\Sigma\gamma h+Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1}=\left[K_a(\Sigma\gamma h+Q)-2C\sqrt{K_a}\right]\cdot\cos\delta$

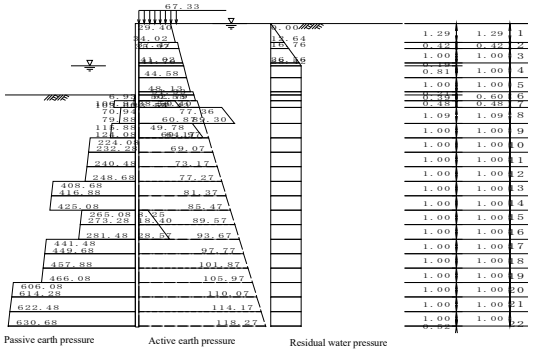
- Formula for passive earth pressure

Sand $P_p=K_p\cdot\left[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_p=\Sigma\gamma h+Q+2C$

Mixed soil $P_p=\left[K_p(\Sigma\gamma h+Q)+2C\sqrt{K_p}\right]\cdot\cos\delta$

3.2 Seismic Condition



26	21.40~ 22.88	Clay	6.7	——	200.0 200.0	240.80 250.72	209.72 224.22	0.200 0.200	11.31 11.31	—— ——	—— ——	42.61 42.52
27	22.88~ 23.88	Clay	6.7	——	200.0 200.0	250.72 257.42	224.22 234.02	0.200 0.200	11.31 11.31	—— ——	—— ——	42.52 42.47
28	23.88~ 24.88	Clay	6.7	——	200.0 200.0	257.42 264.12	234.02 243.82	0.200 0.200	11.31 11.31	—— ——	—— ——	42.47 42.41
29	24.88~ 25.38	Clay	6.7	——	200.0 200.0	264.12 267.47	243.82 248.72	0.200 0.200	11.31 11.31	—— ——	—— ——	42.41 42.38

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a=\frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta=\tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cos δ
8	4.92~ 5.31	Sand	7.70	27.0	—— ——	0.000 3.003	0.00 3.82	0.200 0.200	11.31 11.31	2.30874 2.30874	2.30874 2.30874
9	5.31~ 5.79	Clay	8.20	0.0	50.0 50.0	3.003 6.939	3.82 8.53	0.200 0.200	11.31 11.31	—— ——	—— ——
10	5.79~ 6.88	Clay	8.20	0.0	32.0 32.0	6.939 15.877	8.53 19.21	0.200 0.200	11.31 11.31	—— ——	—— ——
11	6.88~ 7.88	Clay	8.20	0.0	50.0 50.0	15.877 24.077	19.21 29.01	0.200 0.200	11.31 11.31	—— ——	—— ——
12	7.88~ 8.88	Clay	8.20	0.0	100.0 100.0	24.077 32.277	29.01 38.81	0.200 0.200	11.31 11.31	—— ——	—— ——
13	8.88~ 9.88	Clay	8.20	0.0	100.0 100.0	32.277 40.477	38.81 48.61	0.200 0.200	11.31 11.31	—— ——	—— ——
14	9.88~ 10.88	Clay	8.20	0.0	100.0 100.0	40.477 48.677	48.61 58.41	0.200 0.200	11.31 11.31	—— ——	—— ——
15	10.88~ 11.88	Clay	8.20	0.0	180.0 180.0	48.677 56.877	58.41 68.21	0.200 0.200	11.31 11.31	—— ——	—— ——
16	11.88~ 12.88	Clay	8.20	0.0	180.0 180.0	56.877 65.077	68.21 78.01	0.200 0.200	11.31 11.31	—— ——	—— ——
17	12.88~ 13.88	Clay	8.20	0.0	100.0 100.0	65.077 73.277	78.01 87.81	0.200 0.200	11.31 11.31	—— ——	—— ——
18	13.88~ 14.88	Clay	8.20	0.0	100.0 100.0	73.277 81.477	87.81 97.61	0.200 0.200	11.31 11.31	—— ——	—— ——
19	14.88~ 15.88	Clay	8.20	0.0	180.0 180.0	81.477 89.677	97.61 107.41	0.200 0.200	11.31 11.31	—— ——	—— ——
20	15.88~ 16.88	Clay	8.20	0.0	180.0 180.0	89.677 97.877	107.41 117.21	0.200 0.200	11.31 11.31	—— ——	—— ——
21	16.88~ 17.88	Clay	8.20	0.0	180.0 180.0	97.877 106.077	117.21 127.01	0.200 0.200	11.31 11.31	—— ——	—— ——
22	17.88~ 18.88	Clay	8.20	0.0	250.0 250.0	106.077 114.277	127.01 136.81	0.200 0.200	11.31 11.31	—— ——	—— ——

3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cos δ	ζ degree
1	0.00~ 1.29	Sand	8.2	30.0	—— ——	67.33 77.91	0.00 12.64	0.200 0.200	11.31 11.31	0.45203 0.45203	0.43663 0.43663	—— ——
2	1.29~ 1.71	Sand	7.7	28.4	—— ——	77.91 81.14	12.64 16.76	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	—— ——
3	1.71~ 2.71	Sand	7.7	28.4	—— ——	81.14 88.84	16.76 26.56	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	—— ——
4	2.71~ 2.90	Sand	7.7	28.4	—— ——	88.84 90.31	26.56 28.42	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	—— ——
5	2.90~ 3.71	Sand	7.7	28.4	—— ——	90.31 96.54	28.42 36.36	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	—— ——
6	3.71~ 4.71	Sand	7.7	28.4	—— ——	96.54 104.24	36.36 46.16	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	—— ——
7	4.71~ 4.92	Sand	7.7	27.0	—— ——	104.24 105.86	46.16 48.22	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
8	4.92~ 5.31	Sand	7.7	27.0	—— ——	105.86 108.86	48.22 52.04	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
9	5.31~ 5.79	Clay	8.2	——	50.0 50.0	108.86 112.80	52.04 56.74	0.200 0.200	11.31 11.31	—— ——	—— ——	38.83 38.65
10	5.79~ 6.88	Clay	8.2	——	32.0 32.0	112.80 121.74	56.74 67.42	0.200 0.200	11.31 11.31	—— ——	—— ——	33.47 32.61
11	6.88~ 7.88	Clay	8.2	——	50.0 50.0	121.74 129.94	67.42 77.22	0.200 0.200	11.31 11.31	—— ——	—— ——	38.26 37.89
12	7.88~ 8.88	Clay	8.2	——	100.0 100.0	129.94 138.14	77.22 87.02	0.200 0.200	11.31 11.31	—— ——	—— ——	41.86 41.71
13	8.88~ 9.88	Clay	8.2	——	100.0 100.0	138.14 146.34	87.02 96.82	0.200 0.200	11.31 11.31	—— ——	—— ——	41.71 41.57
14	9.88~ 10.88	Clay	8.2	——	100.0 100.0	146.34 154.54	96.82 106.62	0.200 0.200	11.31 11.31	—— ——	—— ——	41.57 41.42
15	10.88~ 11.88	Clay	8.2	——	180.0 180.0	154.54 162.74	106.62 116.42	0.200 0.200	11.31 11.31	—— ——	—— ——	43.12 43.04
16	11.88~ 12.88	Clay	8.2	——	180.0 180.0	162.74 170.94	116.42 126.22	0.200 0.200	11.31 11.31	—— ——	—— ——	43.04 42.97
17	12.88~ 13.88	Clay	8.2	——	100.0 100.0	170.94 179.14	126.22 136.02	0.200 0.200	11.31 11.31	—— ——	—— ——	41.11 40.96
18	13.88~ 14.88	Clay	8.2	——	100.0 100.0	179.14 187.34	136.02 145.82	0.200 0.200	11.31 11.31	—— ——	—— ——	40.96 40.80
19	14.88~ 15.88	Clay	8.2	——	180.0 180.0	187.34 195.54	145.82 155.62	0.200 0.200	11.31 11.31	—— ——	—— ——	42.82 42.74
20	15.88~ 16.88	Clay	8.2	——	180.0 180.0	195.54 203.74	155.62 165.42	0.200 0.200	11.31 11.31	—— ——	—— ——	42.74 42.66
21	16.88~ 17.88	Clay	8.2	——	180.0 180.0	203.74 211.94	165.42 175.22	0.200 0.200	11.31 11.31	—— ——	—— ——	42.66 42.59
22	17.88~ 18.88	Clay	8.2	——	250.0 250.0	211.94 220.14	175.22 185.02	0.200 0.200	11.31 11.31	—— ——	—— ——	43.30 43.25
23	18.88~ 19.88	Clay	8.2	——	250.0 250.0	220.14 228.34	185.02 194.82	0.200 0.200	11.31 11.31	—— ——	—— ——	43.25 43.20
24	19.88~ 20.88	Clay	8.2	——	250.0 250.0	228.34 236.54	194.82 204.62	0.200 0.200	11.31 11.31	—— ——	—— ——	43.20 43.15
25	20.88~ 21.40	Clay	8.2	——	250.0 250.0	236.54 240.80	204.62 209.72	0.200 0.200	11.31 11.31	—— ——	—— ——	43.15 43.12

23	18.88~ 19.88	Clay	8.20	0.0	250.0 250.0	114.277 122.477	136.81 146.61	0.200 0.200	11.31 11.31	—— ——	—— ——
24	19.88~ 20.88	Clay	8.20	0.0	250.0 250.0	122.477 130.677	146.61 156.41	0.200 0.200	11.31 11.31	—— ——	—— ——
25	20.88~ 21.40	Clay	8.20	0.0	250.0 250.0	130.677 134.941	156.41 161.50	0.200 0.200	11.31 11.31	—— ——	—— ——
26	21.40~ 22.88	Clay	6.70	20.0	200.0 200.0	134.941 144.857	161.50 176.01	0.200 0.200	11.31 11.31	—— ——	—— ——
27	22.88~ 23.88	Clay	6.70	20.0	200.0 200.0	144.857 151.557	176.01 185.81	0.200 0.200	11.31 11.31	—— ——	—— ——
28	23.88~ 24.88	Clay	6.70	20.0	200.0 200.0	151.557 158.257	185.81 195.61	0.200 0.200	11.31 11.31	—— ——	—— ——
29	24.88~ 25.38	Clay	6.70	20.0	200.0 200.0	158.257 161.607	195.61 200.51	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p=\frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.29	29.40 34.02	—— ——	29.40 34.02	0.00 12.64	—— ——
2	1.29~ 1.71	35.97 37.47	—— ——	35.97 37.47	12.64 16.76	—— ——
3	1.71~ 2.71	37.47 41.02	—— ——	37.47 41.02	16.76 26.56	—— ——
4	2.71~ 2.90	41.02 41.70	—— ——	41.02 41.70	26.56 28.42	—— ——
5	2.90~ 3.71	41.70 44.58	—— ——	41.70 44.58	28.42 28.42	—— ——
6	3.71~ 4.71	44.58 48.13	—— ——	44.58 48.13	28.42 28.42	—— ——
7	4.71~ 4.92	50.55 51.33	—— ——	50.55 51.33	28.42 28.42	—— ——
8	4.92~ 5.31	51.33 52.79	—— ——	51.33 52.79	28.42 28.42	0.00 6.93
9	5.31~ 5.79	33.55 38.50	54.43 56.40	54.43 56.40	28.42 28.42	103.00 106.94
10	5.79~ 6.88	77.36 89.30	56.40 60.87	77.36 89.30	28.42 28.42	70.94 79.88
11	6.88~ 7.88	49.78 60.17	60.87 64.97	60.87 64.97	28.42 28.42	115.88 124.08
12	7.88~ 8.88	-42.27 -32.19	64.97 69.07	64.97 69.07	28.42 28.42	224.08 232.28

13	8.88~ 9.88	-32.19 -22.10	69.07 73.17	69.07 73.17	28.42 28.42	232.28 240.48
14	9.88~ 10.88	-22.10 -12.00	73.17 77.27	73.17 77.27	28.42 28.42	240.48 248.68
15	10.88~ 11.88	-173.23 -163.25	77.27 81.37	77.27 81.37	28.42 28.42	408.68 416.88
16	11.88~ 12.88	-163.25 -153.27	81.37 85.47	81.37 85.47	28.42 28.42	416.88 425.08
17	12.88~ 13.88	8.25 18.40	85.47 89.57	85.47 89.57	28.42 28.42	265.08 273.28
18	13.88~ 14.88	18.40 28.57	89.57 93.67	89.57 93.67	28.42 28.42	273.28 281.48
19	14.88~ 15.88	-133.27 -123.27	93.67 97.77	93.67 97.77	28.42 28.42	441.48 449.68
20	15.88~ 16.88	-123.27 -113.25	97.77 101.87	97.77 101.87	28.42 28.42	449.68 457.88
21	16.88~ 17.88	-113.25 -103.23	101.87 105.97	101.87 105.97	28.42 28.42	457.88 466.08
22	17.88~ 18.88	-243.97 -234.00	105.97 110.07	105.97 110.07	28.42 28.42	606.08 614.28
23	18.88~ 19.88	-234.00 -224.02	110.07 114.17	110.07 114.17	28.42 28.42	614.28 622.48
24	19.88~ 20.88	-224.02 -214.04	114.17 118.27	114.17 118.27	28.42 28.42	622.48 630.68
25	20.88~ 21.40	-214.04 -208.85	118.27 120.40	118.27 120.40	28.42 28.42	630.68 634.94
26	21.40~ 22.88	-108.24 -96.10	120.40 125.36	120.40 125.36	28.42 28.42	534.94 544.86
27	22.88~ 23.88	-96.10 -87.90	125.36 128.71	125.36 128.71	28.42 28.42	544.86 551.56
28	23.88~ 24.88	-87.90 -79.69	128.71 132.06	128.71 132.06	28.42 28.42	551.56 558.26
29	24.88~ 25.38	-79.69 -75.59	132.06 133.73	132.06 133.73	28.42 28.42	558.26 561.61

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma \gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	2.90	0.00	0.00
2	3.90	1.00	2.44
3	4.90	2.00	3.45
4	4.92	2.02	3.46

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

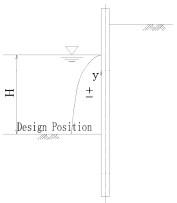
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

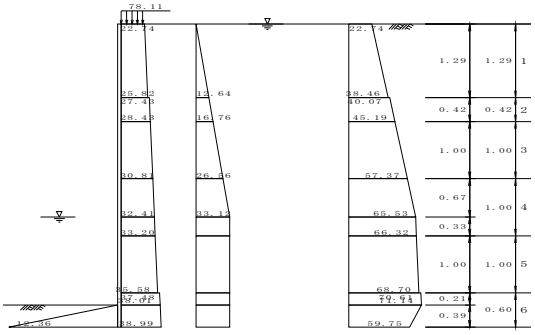
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.29	22.74 25.82	0.00 12.64	—— ——	22.74 38.46
2	1.29~ 1.71	27.43 28.43	12.64 16.76	—— ——	40.07 45.19
3	1.71~ 2.71	28.43 30.81	16.76 26.56	—— ——	45.19 57.37
4	2.71~ 3.38	30.81 32.41	26.56 33.12	—— ——	57.37 65.53
5	3.38~ 3.71	32.41 33.20	33.12 33.12	—— ——	65.53 66.32
6	3.71~ 4.71	33.20 35.58	33.12 33.12	—— ——	66.32 68.70
7	4.71~ 4.92	37.48 38.01	33.12 33.12	—— ——	70.61 71.14
8	4.92~ 5.31	38.01 38.99	33.12 33.12	0.00 12.36	71.14 59.75
9	5.31~ 5.79	59.82 61.79	33.12 33.12	103.00 106.94	-10.06 -12.03

P_a : Active earth pressure

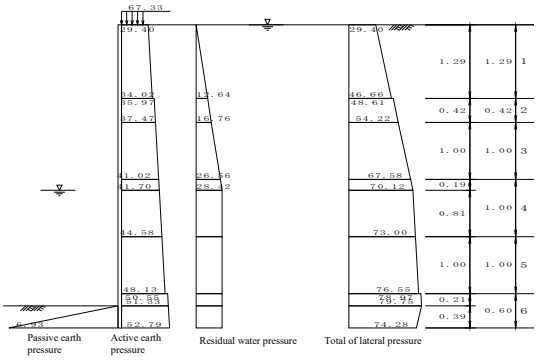
P_w : Residual water pressure

P_p : Passive earth pressure

P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.39 m (GL -5.31 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.29	29.40 34.02	0.00 12.64	—— ——	29.40 46.66
2	1.29~ 1.71	35.97 37.47	12.64 16.76	—— ——	48.61 54.22
3	1.71~ 2.71	37.47 41.02	16.76 26.56	—— ——	54.22 67.58
4	2.71~ 2.90	41.02 41.70	26.56 28.42	—— ——	67.58 70.12
5	2.90~ 3.71	41.70 44.58	28.42 28.42	—— ——	70.12 73.00
6	3.71~ 4.71	44.58 48.13	28.42 28.42	—— ——	73.00 76.55
7	4.71~ 4.92	50.55 51.33	28.42 28.42	—— ——	78.97 79.75
8	4.92~ 5.31	51.33 52.79	28.42 28.42	0.00 6.93	79.75 74.28
9	5.31~ 5.79	54.43 56.40	28.42 28.42	103.00 106.94	-20.15 -22.12

P_a : Active earth pressure

P_w : Residual water pressure

P_p : Passive earth pressure

P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.39 m (GL -5.31 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name			25 H _ H 1000 -300 -16 -32 -18
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.89
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	1129800 cm^4(original condition)
	I	=	1005522 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 1005522 \times 10^{-8} = 2.011 \times 10^6$

No	Depth m	N Value
1	1.21	12
2	2.21	12
3	3.21	12
4	4.21	12
5	5.21	9
6	6.38	4
7	7.38	7
8	8.38	13
9	9.38	12
10	10.38	11

No	Depth m	N Value
11	11.38	17
12	12.38	18
13	13.38	14
14	14.38	15
15	15.38	16
16	16.38	21
17	17.38	30
18	18.38	34
19	19.38	50
20	20.38	50

No	Depth m	N Value
21	21.38	50
22	22.38	50
23	23.38	50
24	24.38	50
25	25.38	50

5.2 Normal Condition

Assuming Kh = 6560 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.169\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 5.92\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.31 m) to 5.92 m depth (GL -11.23 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.31	1.07	8.6	4.0	6.73
2	6.38	1.00	4.0	7.0	5.50
3	7.38	1.00	7.0	13.0	10.00
4	8.38	1.00	13.0	12.0	12.50
5	9.38	1.00	12.0	11.0	11.50
6	10.38	0.85	11.0	16.1	11.48
		L = Σh = 5.92		ΣA =	57.70

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L}$

$$= \frac{57.70}{5.92}$$

$$= 9.75$$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 9.75 = 27303\ \text{kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 27303 = 91010\ \text{kN/m}^3 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 91010(10.00/0.3)^{-3/4} = 6560\ \text{kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 6560 kN/m3.

5.3 Seismic Condition

Assuming Kh = 12263 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.198\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 5.06\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.31 m) and 5.06 m depth (GL -10.37 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.31	1.07	8.6	4.0	6.73
2	6.38	1.00	4.0	7.0	5.50
3	7.38	1.00	7.0	13.0	10.00
4	8.38	1.00	13.0	12.0	12.50
5	9.38	0.99	12.0	11.0	11.40
		L = Σh = 5.06		ΣA =	46.13

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L}$

$$= \frac{46.13}{5.06}$$

$$= 9.11$$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 9.11 = 25519\ \text{kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 25519 = 170124\ \text{kN/m}^3 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 170124(10.00/0.3)^{-3/4} = 12263\ \text{kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 12263 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.29	1.29	22.74 38.46	14.67 24.81	4.88 4.45	71.58 110.40
2	1.29~ 1.71	0.42	40.07 45.19	8.42 9.49	3.88 3.74	32.65 35.49
3	1.71~ 2.71	1.00	45.19 57.37	22.60 28.69	3.27 2.93	73.81 84.15
4	2.71~ 3.38	0.67	57.37 65.53	19.22 21.95	2.38 2.15	45.68 47.27
5	3.38~ 3.71	0.33	65.53 66.32	10.81 10.94	1.82 1.71	19.68 18.71
6	3.71~ 4.71	1.00	66.32 68.70	33.16 34.35	1.27 0.93	42.00 32.06
7	4.71~ 4.92	0.21	70.61 71.14	7.41 7.47	0.53 0.46	3.93 3.44
8	4.92~ 5.31	0.39	71.14 59.75	13.87 11.65	0.26 0.13	3.61 1.51
			ΣP = 279.51		ΣM =	625.98

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	17.8 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	29.4 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	4.92 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 123.92$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t}$$

$$= \frac{749.90}{297.31} = 2.52\ \text{m}$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 297.31}{5.31} = 111.98\ \text{kN/m}$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.29	1.29	29.40 46.66	18.96 30.10	4.88 4.45	92.54 133.92
2	1.29~ 1.71	0.42	48.61 54.22	10.21 11.39	3.88 3.74	39.61 42.59
3	1.71~ 2.71	1.00	54.22 67.58	27.11 33.79	3.27 2.93	88.56 99.12
4	2.71~ 2.90	0.19	67.58 70.12	6.42 6.66	2.54 2.47	16.29 16.47
5	2.90~ 3.71	0.81	70.12 73.00	28.40 29.56	2.14 1.87	60.77 55.28
6	3.71~ 4.71	1.00	73.00 76.55	36.50 38.28	1.27 0.93	46.23 35.72
7	4.71~ 4.92	0.21	78.97 79.75	8.29 8.37	0.53 0.46	4.39 3.85
8	4.92~ 5.31	0.39	79.75 74.28	15.55 14.48	0.26 0.13	4.04 1.88
			ΣP = 324.07		ΣM =	741.28

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	39.7 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	62.7 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	4.92 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 273.51$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	2.90~ 3.90	1.00	0.0 2.4	0.00 1.22	2.08 1.74	0.00 2.12
2	3.90~ 4.90	1.00	2.4 3.4	1.22 1.72	1.08 0.74	1.31 1.28
3	4.90~ 4.92	0.02	3.4 3.5	0.03 0.03	0.40 0.40	0.01 0.01
			Σ Pdw =	4.23	Σ Mdw =	4.75

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_s + \Sigma M_{dw}}{\Sigma P + P_s + \Sigma P_{dw}} = \frac{1019.53}{368.00} = 2.77 \text{ m}$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 368.00}{5.31} = 138.61 \text{ kN/m}$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name			25 H _ H 1000 -300 -16 -32 -18
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.89
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	1129800cm^4 (original condition)
	I	=	1005522 cm^4 (after reduction by corrosion and section)

$EI = 200000 \times 10^3 \times 1005522 \times 10^{-8} = 2.011 \times 10^6$

$$\beta = 4\sqrt{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	6560 kN/m^3
calculated value	β	=	0.16899 m^{-1}
resultant earth force (lateral)	P_0	=	297.31 kN/m
height of acting position of load	h_0	=	2.52 m
moment	M_0	=	297.31 kN・m/m
in consideration of ψ_m = 1.505,			
maximum moment	M_{max}	=	1128.83 kN・m/m
depth of generated position of M_{max}	l_m	=	2.929 m
depth of 1st fixed point	l_i	=	7.577 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	12263 kN/m^3
calculated value	β	=	0.19760 m^{-1}
resultant earth force (lateral)	P_0	=	368.00 kN/m
height of acting position of load	h_0	=	2.77 m
Moment	M_0	=	1019.53 kN・m/m
in consideration of ψ_m = 1.358,			
maximum moment	M_{max}	=	1384.68 kN・m/m
depth of generated position of M_{max}	l_m	=	2.254 m
depth of 1st fixed point	l_i	=	6.229 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name			25 H _ H 1000 -300 -16 -32 -18
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.90
Section efficiency	μ	=	1.00
Module of section	Z_0	=	16330 cm^3 (original condition)
	Z	=	14697 cm^3 (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1128.83 \times 10^6}{14697 \times 10^3} = 77 \text{ N/mm}^2 \leqq \sigma_a = 180 \text{ N/mm}^2$$

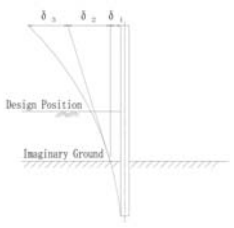
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1384.68 \times 10^6}{14697 \times 10^3} = 94 \text{ N/mm}^2 \leqq \sigma_a = 270 \text{ N/mm}^2$$

6.4 Displacement Calculation

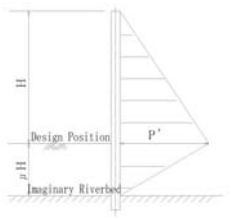
6.4.1 Normal Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0) \times P_0}{2EI\beta^3} = \frac{(1+0.1690 \times 2.52) \times 297.31}{2 \times 2.00 \times 10^8 \times 1005522 \times 10^{-8} \times 0.1690^3} = 0.02185 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0) \times P_0}{2EI\beta^2} \times (H+L_k) = \frac{(1+2 \times 0.1690 \times 2.52) \times 297.31}{2 \times 2.00 \times 10^8 \times 1005522 \times 10^{-8} \times 0.1690^2} \times (4.92+0.39) = 0.02546 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.39}{4.92} = 0.079$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{111.98 \times 4.92^4}{120 \times 2.00 \times 10^8 \times 1005522 \times 10^{-8}}(4+20 \times 0.079+40 \times 0.079^2+35 \times 0.079^3+11 \times 0.079^4) = 0.00159 \text{ m}$$

$$\delta = \delta 1 + \delta 2 + \delta 3 = 0.02185 + 0.02546 + 0.00159 = 0.04890 \text{ m}$$

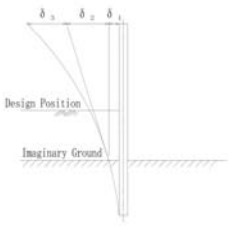
Size = 48.90 ≦ δa = 50.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

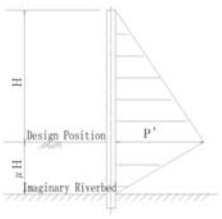
6.4.2 Seismic Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0) \times P_0}{2EI\beta^3} = \frac{(1+0.1976 \times 2.77) \times 368.00}{2 \times 2.00 \times 10^8 \times 1005522 \times 10^{-8} \times 0.1976^3} = 0.01835 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0) \times P_0}{2EI\beta^2} \times (H+L_k) = \frac{(1+2 \times 0.1976 \times 2.77) \times 368.00}{2 \times 2.00 \times 10^8 \times 1005522 \times 10^{-8} \times 0.1976^2} \times (4.92+0.39) = 0.02607 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.39}{4.92} = 0.079$$

$$\delta_3 = \frac{P' H^4}{120 E I}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{138.61\times4.92^4}{120\times2.00\times10^8\times1005522\times10^{-8}}(4+20\times0.079+40\times0.079^2+35\times0.079^3+11\times0.079^4)$$

$$= 0.00197 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.01835 + 0.02607 + 0.00197
= 0.04639 m
Size = 46.39 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name			25 H _ H 1000 -300 -16 -32 -18
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	1129800 cm⁴ (original condition)
	I	=	1129800 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 1129800 × 10⁻⁸		=	2.260 × 10⁶

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{ft} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction $K_h = 6560$ kN/m³
Calculated value $\beta = 0.16414$ m⁻¹

Penetration length of SSP $D = 0.39 + \frac{3}{0.164} = 18.67$ m
Whole length of SSP $L = 4.92 - 0.40 + 18.67 = 23.19$ m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction $K_h = 12263$ kN/m³
Calculated value $\beta = 0.19192$ m⁻¹

Penetration length of SSP $D = 0.39 + \frac{3}{0.192} = 16.02$ m
Whole length of SSP $L = 4.92 - 0.40 + 16.02 = 20.54$ m

Therefore, the total length of the sheet pile is 23.50 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 25 H _ H 1000 -300 -16 -32 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	1129800		
Sectional Modulus	Z (cm3)	16330		
Maximum bending moment	Mmax (kN・m・m)		1128.83	1384.68
Stress intensity	σ (N/mm2)		77 (180)	94 (270)
Lateral displacement	δ (mm)		48.90 (50.0)	46.39 (75.0)
Penetration depths	D (m)		18.67	16.02
Whole length of SSP	L (m)	23.50		

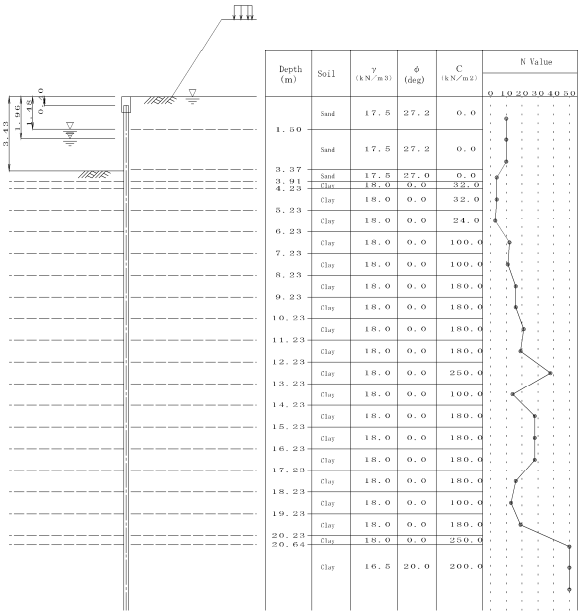
Block No. : R-11
Sta. : 7+620~7+900

Design Cross Section : Sta 7+780
Boring Name : DD-BH-R06

Specification : SSP SP-10H
(Combined) : H 700-200-12-16-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



Depth (m)	Soil	γ (kN/m3)	φ (deg)	C (kN/m2)	N Value
1.50	Sand	17.5	27.2	0.0	
	Sand	17.5	27.2	0.0	
3.37	Sand	17.5	27.0	0.0	
3.91	Clay	18.0	0.0	32.0	
4.23	Clay	18.0	0.0	32.0	
5.23	Clay	18.0	0.0	24.0	
6.23	Clay	18.0	0.0	100.0	
7.23	Clay	18.0	0.0	100.0	
8.23	Clay	18.0	0.0	180.0	
9.23	Clay	18.0	0.0	180.0	
10.23	Clay	18.0	0.0	180.0	
11.23	Clay	18.0	0.0	180.0	
12.23	Clay	18.0	0.0	250.0	
13.23	Clay	18.0	0.0	100.0	
14.23	Clay	18.0	0.0	180.0	
15.23	Clay	18.0	0.0	180.0	
16.23	Clay	18.0	0.0	180.0	
17.23	Clay	18.0	0.0	180.0	
18.23	Clay	18.0	0.0	100.0	
19.23	Clay	18.0	0.0	180.0	
20.23	Clay	18.0	0.0	250.0	
20.64	Clay	16.5	20.0	200.0	

N Value: 0 10 20 30 40 50

1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	3.43 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_{ft}	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	1.96 m (Normal Condition)
	L_{wp}'	=	1.48 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress　Chang's formula

Penetration depths　$L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water　γ_w = 9.8 kN/m³

Type of water pressure　trapezoidal water pressure

Lateral pressure　calculated in consideration of site conditions

Study case　- Normal Condition
- Seismic Condition

Design earthquake intensity　k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	44.8 kN/m	(Normal Condition)
		Pt'	=	105.5 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	Mm	=	11.9 kN･m/m	(Normal Condition)
		Mm'	=	122.9 kN･m/m	(Seismic Condition)
	Depth of acting point	Hm'	=	0.00 m	(Seismic Condition)
		Hm	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load　not considered

Minimum angle of rupture　ζ_0 = 10 degrees

Rear side angle of slope　not considered

Angle of rupture (clayey soil)　$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$

Equilibrium factor of compression　K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m

E_0 = 2800N

Average N-value　calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value
1	1.00	10	11	10.73	21	21	20.73	50
2	2.00	10	12	11.73	19	22	21.73	50
3	3.00	10	13	12.73	38	23	22.73	50
4	3.73	4	14	13.73	14			
5	4.73	4	15	14.73	28			
6	5.73	3	16	15.73	28			
7	6.73	12	17	16.73	28			
8	7.73	11	18	17.73	16			
9	8.73	16	19	18.73	13			
10	9.73	16	20	19.73	19			

1.6 Vertical Load

Vertical load on landside　calculated in consideration of embankment shape on landside

Vertical load on riverside　not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	1.50	1.50
2	3.37	1.87
3	3.91	0.54
4	4.23	0.32
5	5.23	1.00
6	6.23	1.00
7	7.23	1.00
8	8.23	1.00
9	9.23	1.00
10	10.23	1.00
11	11.23	1.00
12	12.23	1.00
13	13.23	1.00
14	14.23	1.00
15	15.23	1.00
16	16.23	1.00
17	17.23	1.00
18	18.23	1.00
19	19.23	1.00
20	20.23	1.00

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
21	20.64	0.41
22	22.73	2.09

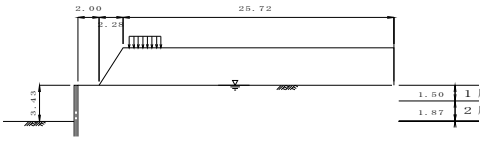
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition	Kh (kN/m3) Normal Condition	Kh (kN/m3) Seismic Condition
1	1.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto		
2	3.37	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto		
3	3.91	S	4.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto		
4	4.23	C	4.0	18.00	8.20	0.0	32.0	0.0	0.200	Auto	Auto		
5	5.23	C	4.0	18.00	8.20	0.0	32.0	0.0	0.200	Auto	Auto		
6	6.23	C	3.0	18.00	8.20	0.0	24.0	0.0	0.200	Auto	Auto		
7	7.23	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto		
8	8.23	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto		
9	9.23	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
10	10.23	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
11	11.23	C	21.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
12	12.23	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
13	13.23	C	38.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto		
14	14.23	C	14.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto		
15	15.23	C	28.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
16	16.23	C	28.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
17	17.23	C	28.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
18	18.23	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
19	19.23	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto		
20	20.23	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
21	20.64	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto		
22	22.73	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto		

Note) depth : from top of coping to bottom of the layer　C_o : soil adhesion
soil : sandy(S), clayey(C), mixed (M)　a : slope of soil adhesion
N-value : average N-value in the layer　k' : design seismic coefficient (underwater)
γ : wet unit weight of soil　ζ : angle of active rupture
γ' : saturated unit weight of soil　kh : modulus of subgrade reaction
φ : internal friction angle of soil

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	2.00	4.28	30.00	30.00	3.56	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	load area End point m	load strength Normal Condition kN/m2	load strength Seismic Condition kN/m2
1	4.86	7.86	10.0	5.0

Angle of rapture in embankment　calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name　10 H _ H 700 -200 - 12-16-18
Young's modulus　E = 200000 N/mm²
Inertia sectional moment　I_0 = 281600 cm⁴
Sectional factor　Z_0 = 5130 cm³

Corrosion margin　t_1 = 1.00 mm (riverside)　t_2 = 1.00 mm (landside)

Corrosion rate (to I_0)　η = 0.83
Corrosion rate (to Z_0)　η = 0.85
Section efficiency (to I_0)　μ = 1.00
Section efficiency (to Z_0)　μ = 1.00

Round unit of SSP length　0.50 m

Allowable stress　σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

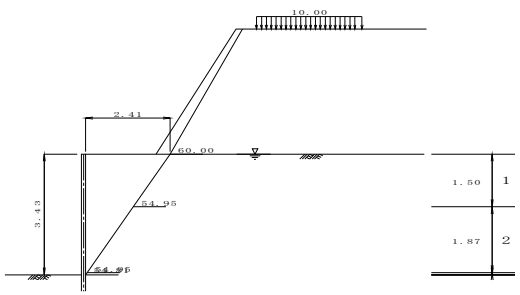
Allowable displacement　δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam　calculated as distributed load of each layer

Reduction of material modulus　Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	3.43 ~ 3.37	Sand	27.0	15.0	0.0	26.41	8.27	33.61	54.81
2	3.37 ~ 1.50	Sand	27.2	15.0	0.0	25.95	8.27	33.03	54.95
3	1.50 ~ 0.00	Sand	27.2	15.0	0.0	11.55	8.27	14.70	54.95
4		embankment	30.0	——	0.0	67.64	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,

ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	54.81	0.06	0.00	0.00	0.04	0.06
2	54.95	1.87	0.04	0.06	1.35	1.93
3	54.95	1.50	1.35	1.93	2.41	3.43
4	60.00	3.56	2.41	3.43	4.46	6.99

From the above table, the loading width (L) on the ground surface is 2.41 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	1.05	19.89
Σ			19.89

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

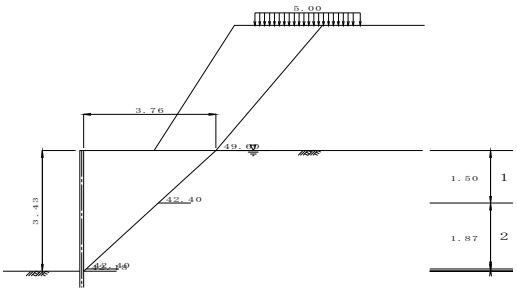
2.1.4 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{19.89 + 0.00 + 0.00}{2.41}$$

$$= 8.27\ \text{kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	3.43 ~ 3.37	Sand	27.0	15.0	0.0	26.41	40.94	33.61	0.200	11.31	42.18
2	3.37 ~ 1.50	Sand	27.2	15.0	0.0	25.95	40.94	33.03	0.200	11.31	42.40
3	1.50 ~ 0.00	Sand	27.2	15.0	0.0	11.55	40.94	14.70	0.200	11.31	42.40
4		embankment	30.0	——	0.0	67.64	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h+Q}$$

Where,

ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	42.18	0.06	0.00	0.00	0.07	0.06
2	42.40	1.87	0.07	0.06	2.11	1.93
3	42.40	1.50	2.11	1.93	3.76	3.43
4	49.60	3.56	3.76	3.43	6.79	6.99

From the above table, the loading width (L) on the ground surface is 3.76 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	7.59	144.17
Σ			144.17

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qsl kN/m
1	5.0	1.93	9.63
Σ			9.63

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

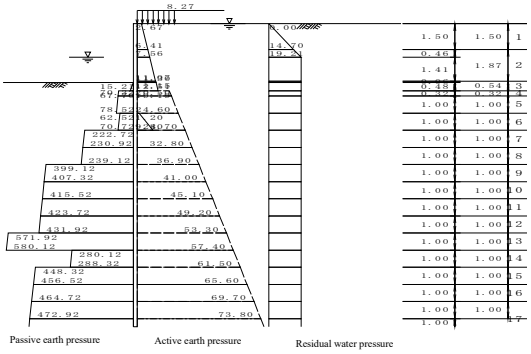
$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{144.17 + 9.63 + 0.00}{3.76}$$

$$= 40.94\ \text{kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



The dotted line in the figure shows the main earth pressure strength Pa2 using the consolidation equilibrium coefficient.

3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cosδ
1	0.00~ 1.50	Sand	7.7	27.2	——— ———	8.267 19.817	0.33489 0.33489	0.32348 0.32348
2	1.50~ 1.96	Sand	7.7	27.2	——— ———	19.817 23.359	0.33489 0.33489	0.32348 0.32348
3	1.96~ 3.37	Sand	7.7	27.2	——— ———	23.359 34.216	0.33489 0.33489	0.32348 0.32348
4	3.37~ 3.43	Sand	7.7	27.0	——— ———	34.216 34.678	0.33738 0.33738	0.32589 0.32589
5	3.43~ 3.91	Sand	7.7	27.0	——— ———	34.678 38.374	0.33738 0.33738	0.32589 0.32589
6	3.91~ 4.23	Clay	8.2	———	32.0 32.0	38.374 40.998	——— ———	——— ———
7	4.23~ 5.23	Clay	8.2	———	32.0 32.0	40.998 49.198	——— ———	——— ———
8	5.23~ 6.23	Clay	8.2	———	24.0 24.0	49.198 57.398	——— ———	——— ———
9	6.23~ 7.23	Clay	8.2	———	100.0 100.0	57.398 65.598	——— ———	——— ———
10	7.23~ 8.23	Clay	8.2	———	100.0 100.0	65.598 73.798	——— ———	——— ———
11	8.23~ 9.23	Clay	8.2	———	180.0 180.0	73.798 81.998	——— ———	——— ———
12	9.23~ 10.23	Clay	8.2	———	180.0 180.0	81.998 90.198	——— ———	——— ———
13	10.23~ 11.23	Clay	8.2	———	180.0 180.0	90.198 98.398	——— ———	——— ———
14	11.23~ 12.23	Clay	8.2	———	180.0 180.0	98.398 106.598	——— ———	——— ———
15	12.23~ 13.23	Clay	8.2	———	250.0 250.0	106.598 114.798	——— ———	——— ———
16	13.23~ 14.23	Clay	8.2	———	100.0 100.0	114.798 122.998	——— ———	——— ———
17	14.23~ 15.23	Clay	8.2	———	180.0 180.0	122.998 131.198	——— ———	——— ———
18	15.23~ 16.23	Clay	8.2	———	180.0 180.0	131.198 139.398	——— ———	——— ———
19	16.23~ 17.23	Clay	8.2	———	180.0 180.0	139.398 147.598	——— ———	——— ———
20	17.23~ 18.23	Clay	8.2	———	180.0 180.0	147.598 155.798	——— ———	——— ———
21	18.23~ 19.23	Clay	8.2	———	100.0 100.0	155.798 163.998	——— ———	——— ———
22	19.23~ 20.23	Clay	8.2	———	180.0 180.0	163.998 172.198	——— ———	——— ———
23	20.23~ 20.64	Clay	8.2	———	250.0 250.0	172.198 175.560	——— ———	——— ———
24	20.64~ 22.73	Clay	6.7	———	200.0 200.0	175.560 189.563	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

δ= 15.00、β= 0.00、θ= 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cosδ
5	3.43~ 3.91	Sand	7.7	27.0	——— ———	0.000 3.696	4.26080 4.26080	4.11561 4.11561
6	3.91~ 4.23	Clay	8.2	0.0	32.0 32.0	3.696 6.320	——— ———	——— ———
7	4.23~ 5.23	Clay	8.2	0.0	32.0 32.0	6.320 14.520	——— ———	——— ———
8	5.23~ 6.23	Clay	8.2	0.0	24.0 24.0	14.520 22.720	——— ———	——— ———
9	6.23~ 7.23	Clay	8.2	0.0	100.0 100.0	22.720 30.920	——— ———	——— ———
10	7.23~ 8.23	Clay	8.2	0.0	100.0 100.0	30.920 39.120	——— ———	——— ———
11	8.23~ 9.23	Clay	8.2	0.0	180.0 180.0	39.120 47.320	——— ———	——— ———
12	9.23~ 10.23	Clay	8.2	0.0	180.0 180.0	47.320 55.520	——— ———	——— ———
13	10.23~ 11.23	Clay	8.2	0.0	180.0 180.0	55.520 63.720	——— ———	——— ———
14	11.23~ 12.23	Clay	8.2	0.0	180.0 180.0	63.720 71.920	——— ———	——— ———
15	12.23~ 13.23	Clay	8.2	0.0	250.0 250.0	71.920 80.120	——— ———	——— ———
16	13.23~ 14.23	Clay	8.2	0.0	100.0 100.0	80.120 88.320	——— ———	——— ———
17	14.23~ 15.23	Clay	8.2	0.0	180.0 180.0	88.320 96.520	——— ———	——— ———
18	15.23~ 16.23	Clay	8.2	0.0	180.0 180.0	96.520 104.720	——— ———	——— ———
19	16.23~ 17.23	Clay	8.2	0.0	180.0 180.0	104.720 112.920	——— ———	——— ———
20	17.23~ 18.23	Clay	8.2	0.0	180.0 180.0	112.920 121.120	——— ———	——— ———
21	18.23~ 19.23	Clay	8.2	0.0	100.0 100.0	121.120 129.320	——— ———	——— ———
22	19.23~ 20.23	Clay	8.2	0.0	180.0 180.0	129.320 137.520	——— ———	——— ———
23	20.23~ 20.64	Clay	8.2	0.0	250.0 250.0	137.520 140.882	——— ———	——— ———
24	20.64~ 22.73	Clay	6.7	20.0	200.0 200.0	140.882 154.885	——— ———	——— ———

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β= 0.00、θ= 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 1.50	2.67 6.41	——— ———	2.67 6.41	0.00 14.70	——— ———
2	1.50~ 1.96	6.41 7.56	——— ———	6.41 7.56	14.70 19.21	——— ———
3	1.96~ 3.37	7.56 11.07	——— ———	7.56 11.07	19.21 19.21	——— ———
4	3.37~ 3.43	11.15 11.30	——— ———	11.15 11.30	19.21 19.21	——— ———
5	3.43~ 3.91	11.30 12.51	——— ———	11.30 12.51	19.21 19.21	0.00 15.21
6	3.91~ 4.23	-25.63 -23.00	19.19 20.50	19.19 20.50	19.21 19.21	67.70 70.32
7	4.23~ 5.23	-23.00 -14.80	20.50 24.60	20.50 24.60	19.21 19.21	70.32 78.52
8	5.23~ 6.23	1.20 9.40	24.60 28.70	24.60 28.70	19.21 19.21	62.52 70.72
9	6.23~ 7.23	-142.60 -134.40	28.70 32.80	28.70 32.80	19.21 19.21	222.72 230.92
10	7.23~ 8.23	-134.40 -126.20	32.80 36.90	32.80 36.90	19.21 19.21	230.92 239.12
11	8.23~ 9.23	-286.20 -278.00	36.90 41.00	36.90 41.00	19.21 19.21	399.12 407.32
12	9.23~ 10.23	-278.00 -269.80	41.00 45.10	41.00 45.10	19.21 19.21	407.32 415.52
13	10.23~ 11.23	-269.80 -261.60	45.10 49.20	45.10 49.20	19.21 19.21	415.52 423.72
14	11.23~ 12.23	-261.60 -253.40	49.20 53.30	49.20 53.30	19.21 19.21	423.72 431.92
15	12.23~ 13.23	-393.40 -385.20	53.30 57.40	53.30 57.40	19.21 19.21	571.92 580.12
16	13.23~ 14.23	-85.20 -77.00	57.40 61.50	57.40 61.50	19.21 19.21	280.12 288.32
17	14.23~ 15.23	-237.00 -228.80	61.50 65.60	61.50 65.60	19.21 19.21	448.32 456.52
18	15.23~ 16.23	-228.80 -220.60	65.60 69.70	65.60 69.70	19.21 19.21	456.52 464.72
19	16.23~ 17.23	-220.60 -212.40	69.70 73.80	69.70 73.80	19.21 19.21	464.72 472.92
20	17.23~ 18.23	-212.40 -204.20	73.80 77.90	73.80 77.90	19.21 19.21	472.92 481.12
21	18.23~ 19.23	-44.20 -36.00	77.90 82.00	77.90 82.00	19.21 19.21	321.12 329.32
22	19.23~ 20.23	-196.00 -187.80	82.00 86.10	82.00 86.10	19.21 19.21	489.32 497.52
23	20.23~ 20.64	-327.80 -324.44	86.10 87.78	86.10 87.78	19.21 19.21	637.52 640.88
24	20.64~ 22.73	-224.44 -210.44	87.78 94.78	87.78 94.78	19.21 19.21	540.88 554.89

- Formula for active earth pressure

Sand $P_{a1}=K_a\cdot\left[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_{a1}=\Sigma\gamma h+Q-2C$
$P_{a2}=K_a\cdot(\Sigma\gamma h+Q)$
K_a : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1}=\left[K_a(\Sigma\gamma h+Q)-2C\sqrt{K_a}\right]\cdot\cos\delta$

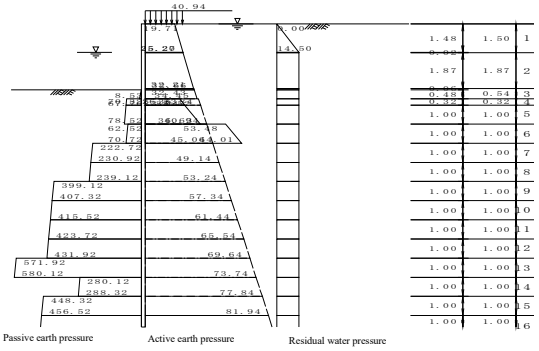
- Formula for passive earth pressure

Sand $P_p=K_p\cdot\left[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_p=\Sigma\gamma h+Q+2C$

Mixed soil $P_p=\left[K_p(\Sigma\gamma h+Q)+2C\sqrt{K_p}\right]\cdot\cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 1.48	Sand	7.7	27.2	——— ———	40.94 52.34	0.00 14.50	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
2	1.48~ 1.50	Sand	7.7	27.2	——— ———	52.34 52.49	14.50 14.70	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
3	1.50~ 3.37	Sand	7.7	27.2	——— ———	52.49 66.89	14.70 33.03	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
4	3.37~ 3.43	Sand	7.7	27.0	——— ———	66.89 67.35	33.03 33.61	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
5	3.43~ 3.91	Sand	7.7	27.0	——— ———	67.35 71.05	33.61 38.32	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
6	3.91~ 4.23	Clay	8.2	———	32.0 32.0	71.05 73.67	38.32 41.45	0.200 0.200	11.31 11.31	——— ———	——— ———	39.77 39.61
7	4.23~ 5.23	Clay	8.2	———	32.0 32.0	73.67 81.87	41.45 51.25	0.200 0.200	11.31 11.31	——— ———	——— ———	39.61 39.12
8	5.23~ 6.23	Clay	8.2	———	24.0 24.0	81.87 90.07	51.25 61.05	0.200 0.200	11.31 11.31	——— ———	——— ———	37.63 37.08
9	6.23~ 7.23	Clay	8.2	———	100.0 100.0	90.07 98.27	61.05 70.85	0.200 0.200	11.31 11.31	——— ———	——— ———	42.63 42.43
10	7.23~ 8.23	Clay	8.2	———	100.0 100.0	98.27 106.47	70.85 80.65	0.200 0.200	11.31 11.31	——— ———	——— ———	42.43 42.24
11	8.23~ 9.23	Clay	8.2	———	180.0 180.0	106.47 114.67	80.65 90.45	0.200 0.200	11.31 11.31	——— ———	——— ———	43.40 43.28
12	9.23~ 10.23	Clay	8.2	———	180.0 180.0	114.67 122.87	90.45 100.25	0.200 0.200	11.31 11.31	——— ———	——— ———	43.28 43.17
13	10.23~ 11.23	Clay	8.2	———	180.0 180.0	122.87 131.07	100.25 110.05	0.200 0.200	11.31 11.31	——— ———	——— ———	43.17 43.05
14	11.23~ 12.23	Clay	8.2	———	180.0 180.0	131.07 139.27	110.05 119.85	0.200 0.200	11.31 11.31	——— ———	——— ———	43.05 42.94
15	12.23~ 13.23	Clay	8.2	———	250.0 250.0	139.27 147.47	119.85 129.65	0.200 0.200	11.31 11.31	——— ———	——— ———	43.49 43.40
16	13.23~ 14.23	Clay	8.2	———	100.0 100.0	147.47 155.67	129.65 139.45	0.200 0.200	11.31 11.31	——— ———	——— ———	41.31 41.13
17	14.23~ 15.23	Clay	8.2	———	180.0 180.0	155.67 163.87	139.45 149.25	0.200 0.200	11.31 11.31	——— ———	——— ———	42.72 42.61
18	15.23~ 16.23	Clay	8.2	———	180.0 180.0	163.87 172.07	149.25 159.05	0.200 0.200	11.31 11.31	——— ———	——— ———	42.61 42.50
19	16.23~ 17.23	Clay	8.2	———	180.0 180.0	172.07 180.27	159.05 168.85	0.200 0.200	11.31 11.31	——— ———	——— ———	42.50 42.39
20	17.23~ 18.23	Clay	8.2	———	180.0 180.0	180.27 188.47	168.85 178.65	0.200 0.200	11.31 11.31	——— ———	——— ———	42.39 42.28
21	18.23~ 19.23	Clay	8.2	———	100.0 100.0	188.47 196.67	178.65 188.45	0.200 0.200	11.31 11.31	——— ———	——— ———	40.44 40.27
22	19.23~ 20.23	Clay	8.2	———	180.0 180.0	196.67 204.87	188.45 198.25	0.200 0.200	11.31 11.31	——— ———	——— ———	42.17 42.07
23	20.23~ 20.64	Clay	8.2	———	250.0 250.0	204.87 208.23	198.25 202.27	0.200 0.200	11.31 11.31	——— ———	——— ———	42.83 42.80
24	20.64~ 22.73	Clay	6.7	———	200.0 200.0	208.23 222.24	202.27 222.75	0.200 0.200	11.31 11.31	——— ———	——— ———	42.29 42.13

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

$\delta = 15.00$、$\beta = 0.00$、$\theta = 0.00$

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h+Q}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
5	3.43~ 3.91	Sand	7.70	27.0	——— ———	0.000 3.696	0.00 4.70	0.200 0.200	11.31 11.31	2.30874 2.30874	2.30874 2.30874
6	3.91~ 4.23	Clay	8.20	0.0	32.0 32.0	3.696 6.320	4.70 7.84	0.200 0.200	11.31 11.31	——— ———	——— ———
7	4.23~ 5.23	Clay	8.20	0.0	32.0 32.0	6.320 14.520	7.84 17.64	0.200 0.200	11.31 11.31	——— ———	——— ———
8	5.23~ 6.23	Clay	8.20	0.0	24.0 24.0	14.520 22.720	17.64 27.44	0.200 0.200	11.31 11.31	——— ———	——— ———
9	6.23~ 7.23	Clay	8.20	0.0	100.0 100.0	22.720 30.920	27.44 37.24	0.200 0.200	11.31 11.31	——— ———	——— ———
10	7.23~ 8.23	Clay	8.20	0.0	100.0 100.0	30.920 39.120	37.24 47.04	0.200 0.200	11.31 11.31	——— ———	——— ———
11	8.23~ 9.23	Clay	8.20	0.0	180.0 180.0	39.120 47.320	47.04 56.84	0.200 0.200	11.31 11.31	——— ———	——— ———
12	9.23~ 10.23	Clay	8.20	0.0	180.0 180.0	47.320 55.520	56.84 66.64	0.200 0.200	11.31 11.31	——— ———	——— ———
13	10.23~ 11.23	Clay	8.20	0.0	180.0 180.0	55.520 63.720	66.64 76.44	0.200 0.200	11.31 11.31	——— ———	——— ———
14	11.23~ 12.23	Clay	8.20	0.0	180.0 180.0	63.720 71.920	76.44 86.24	0.200 0.200	11.31 11.31	——— ———	——— ———
15	12.23~ 13.23	Clay	8.20	0.0	250.0 250.0	71.920 80.120	86.24 96.04	0.200 0.200	11.31 11.31	——— ———	——— ———
16	13.23~ 14.23	Clay	8.20	0.0	100.0 100.0	80.120 88.320	96.04 105.84	0.200 0.200	11.31 11.31	——— ———	——— ———
17	14.23~ 15.23	Clay	8.20	0.0	180.0 180.0	88.320 96.520	105.84 115.64	0.200 0.200	11.31 11.31	——— ———	——— ———
18	15.23~ 16.23	Clay	8.20	0.0	180.0 180.0	96.520 104.720	115.64 125.44	0.200 0.200	11.31 11.31	——— ———	——— ———
19	16.23~ 17.23	Clay	8.20	0.0	180.0 180.0	104.720 112.920	125.44 135.24	0.200 0.200	11.31 11.31	——— ———	——— ———
20	17.23~ 18.23	Clay	8.20	0.0	180.0 180.0	112.920 121.120	135.24 145.04	0.200 0.200	11.31 11.31	——— ———	——— ———
21	18.23~ 19.23	Clay	8.20	0.0	100.0 100.0	121.120 129.320	145.04 154.84	0.200 0.200	11.31 11.31	——— ———	——— ———
22	19.23~ 20.23	Clay	8.20	0.0	180.0 180.0	129.320 137.520	154.84 164.64	0.200 0.200	11.31 11.31	——— ———	——— ———
23	20.23~ 20.64	Clay	8.20	0.0	250.0 250.0	137.520 140.882	164.64 168.66	0.200 0.200	11.31 11.31	——— ———	——— ———
24	20.64~ 22.73	Clay	6.70	20.0	200.0 200.0	140.882 154.885	168.66 189.14	0.200 0.200	11.31 11.31	——— ———	——— ———

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.
$\delta = 0.00$ degrees, $\beta = 0.00$ degrees
Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 1.48	19.71 25.20	——— ———	19.71 25.20	0.00 14.50	——— ———
2	1.48~ 1.50	25.20 25.27	——— ———	25.20 25.27	14.50 14.50	——— ———
3	1.50~ 3.37	25.27 32.21	——— ———	25.27 32.21	14.50 14.50	——— ———
4	3.37~ 3.43	32.43 32.66	——— ———	32.43 32.66	14.50 14.50	——— ———
5	3.43~ 3.91	32.66 34.45	——— ———	32.66 34.45	14.50 14.50	0.00 8.53
6	3.91~ 4.23	23.04 26.33	35.52 36.84	35.52 36.84	14.50 14.50	67.70 70.32
7	4.23~ 5.23	26.33 36.63	36.84 40.94	36.84 40.94	14.50 14.50	70.32 78.52
8	5.23~ 6.23	53.48 64.01	40.94 45.04	53.48 64.01	14.50 14.50	62.52 70.72
9	6.23~ 7.23	-91.05 -81.04	45.04 49.14	45.04 49.14	14.50 14.50	222.72 230.92
10	7.23~ 8.23	-81.04 -71.01	49.14 53.24	49.14 53.24	14.50 14.50	230.92 239.12
11	8.23~ 9.23	-231.57 -221.63	53.24 57.34	53.24 57.34	14.50 14.50	399.12 407.32
12	9.23~ 10.23	-221.63 -211.67	57.34 61.44	57.34 61.44	14.50 14.50	407.32 415.52
13	10.23~ 11.23	-211.67 -201.70	61.44 65.54	61.44 65.54	14.50 14.50	415.52 423.72
14	11.23~ 12.23	-201.70 -191.73	65.54 69.64	65.54 69.64	14.50 14.50	423.72 431.92
15	12.23~ 13.23	-332.06 -322.12	69.64 73.74	69.64 73.74	14.50 14.50	571.92 580.12
16	13.23~ 14.23	-20.64 -10.52	73.74 77.84	73.74 77.84	14.50 14.50	280.12 288.32
17	14.23~ 15.23	-171.76 -161.76	77.84 81.94	77.84 81.94	14.50 14.50	448.32 456.52
18	15.23~ 16.23	-161.76 -151.75	81.94 86.04	81.94 86.04	14.50 14.50	456.52 464.72
19	16.23~ 17.23	-151.75 -141.73	86.04 90.14	86.04 90.14	14.50 14.50	464.72 472.92
20	17.23~ 18.23	-141.73 -131.70	90.14 94.24	90.14 94.24	14.50 14.50	472.92 481.12
21	18.23~ 19.23	30.14 40.34	94.24 98.34	94.24 98.34	14.50 14.50	321.12 329.32
22	19.23~ 20.23	-121.67 -111.63	98.34 102.44	98.34 102.44	14.50 14.50	489.32 497.52
23	20.23~ 20.64	-252.37 -248.27	102.44 104.12	102.44 104.12	14.50 14.50	637.52 640.88
24	20.64~ 22.73	-147.78 -130.64	104.12 111.12	104.12 111.12	14.50 14.50	540.88 554.89

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

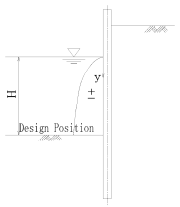
3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.48	0.00	0.00
2	2.48	1.00	2.39
3	3.43	1.95	3.34

$$p_{dw} = \pm\frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

Where,

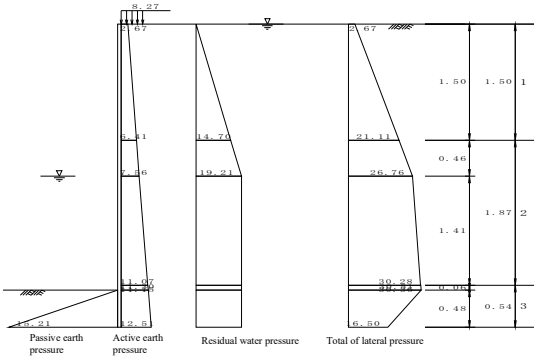
k_{hs}: design seismic coefficient
γ_w : unit weight of water
H : water depth of riverside
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	2.67 6.41	0.00 14.70	——— ———	2.67 21.11
2	1.50~ 1.96	6.41 7.56	14.70 19.21	——— ———	21.11 26.76
3	1.96~ 3.37	7.56 11.07	19.21 19.21	——— ———	26.76 30.28
4	3.37~ 3.43	11.15 11.30	19.21 19.21	——— ———	30.36 30.51

Imaginary riverbed L_k: 0.48 m (GL -3.91 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name		10 H _ H 700 -200 - 12-16-18	
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.83
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	281600 cm^4(original condition)
	I	=	233728 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 233728 \times 10^{-8} = 4.675 \times 10^5$

No	Depth m	N Value
1	1.00	10
2	2.00	10
3	3.00	10
4	3.73	4
5	4.73	4
6	5.73	3
7	6.73	12
8	7.73	11
9	8.73	16
10	9.73	16

No	Depth m	N Value
11	10.73	21
12	11.73	19
13	12.73	38
14	13.73	14
15	14.73	28
16	15.73	28
17	16.73	28
18	17.73	16
19	18.73	13
20	19.73	19

No	Depth m	N Value
21	20.73	50
22	21.73	50
23	22.73	50

5.2 Normal Condition

Assuming Kh = 5036 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.228 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 4.39 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -3.91 m) to 4.39 m depth (GL -8.30 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	3.91	0.82	4.0	4.0	3.28
2	4.73	1.00	4.0	3.0	3.50
3	5.73	1.00	3.0	12.0	7.50
4	6.73	1.00	12.0	11.0	11.50
5	7.73	0.57	11.0	13.8	7.08
	L = Σh = 4.39		Σ A =	32.86	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{32.86}{4.39} = 7.49$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 7.49 = 20959 \text{ kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 20959 = 69864 \text{ kN/m}^3 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 69864(10.00/0.3)^{-3/4} = 5036 \text{ kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 5036 kN/m3.

5.3 Seismic Condition

Assuming Kh = 9039 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.264 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 3.79 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -3.91 m) and 3.79 m depth (GL -7.70 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	3.91	0.82	4.0	4.0	3.28
2	4.73	1.00	4.0	3.0	3.50
3	5.73	1.00	3.0	12.0	7.50
4	6.73	0.97	12.0	11.0	11.20
	L = Σh = 3.79		Σ A =	25.48	

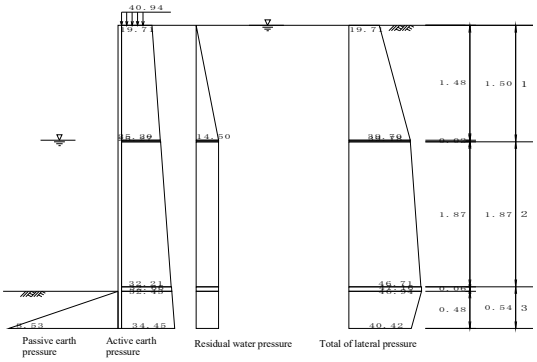
A: (upper N-value + lower N-value) × h/2

5	3.43~ 3.91	11.30 12.51	19.21 19.21	0.00 15.21	30.51 16.50
6	3.91~ 4.23	19.19 20.50	19.21 19.21	67.70 70.32	-29.30 -30.61

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.48 m (GL -3.91 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.48	19.71 25.20	0.00 14.50	——— ———	19.71 39.70
2	1.48~ 1.50	25.20 25.27	14.50 14.50	——— ———	39.70 39.78
3	1.50~ 3.37	25.27 32.21	14.50 14.50	——— ———	39.78 46.71
4	3.37~ 3.43	32.43 32.66	14.50 14.50	——— ———	46.94 47.16
5	3.43~ 3.91	32.66 34.45	14.50 14.50	0.00 8.53	47.16 40.42
6	3.91~ 4.23	35.52 36.84	14.50 14.50	67.70 70.32	-17.67 -18.98

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Average N-value $N' = \frac{\Sigma A}{L} = \frac{25.48}{3.79} = 6.72$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 6.72 = 18809$ kN/m²

$K_{h0} = \frac{1}{0.3} \times \alpha \times 18809 = 125391$ kN/m³ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_h/0.3)^{-3/4} = 125391(10.00/0.3)^{-3/4} = 9039$ kN/m³

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 9039 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	2.67 21.11	2.01 15.83	3.41 2.91	6.84 46.07
2	1.50~ 1.96	0.46	21.11 26.76	4.86 6.16	2.26 2.10	10.96 12.95
3	1.96~ 3.37	1.41	26.76 30.28	18.87 21.34	1.48 1.01	27.93 21.56
4	3.37~ 3.43	0.06	30.36 30.51	0.91 0.92	0.52 0.50	0.47 0.46
5	3.43~ 3.91	0.48	30.51 16.50	7.32 3.96	0.32 0.16	2.34 0.63
				ΣP= 82.17	ΣM= 130.21	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load		P_t	=	44.8 kN/m
	depth to acting position	H_t	=	0.0 m
	moment	M_m	=	11.9 kN・m/m
	depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping		H	=	3.43 m
Depth of Imaginary riverbed from riverbed		L_k	=	0.00 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m = 187.07$ kN・m

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{317.28}{126.97} = 2.50$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 126.97}{3.91} = 64.95$ kN/m

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.48	1.48	19.71 39.70	14.59 29.38	3.42 2.92	49.84 85.89
2	1.48~ 1.50	0.02	39.70 39.78	0.40 0.40	2.42 2.42	0.96 0.96
3	1.50~ 3.37	1.87	39.78 46.71	37.19 43.68	1.79 1.16	66.45 50.81
4	3.37~ 3.43	0.06	46.94 47.16	1.41 1.41	0.52 0.50	0.73 0.71
5	3.43~ 3.91	0.48	47.16 40.42	11.32 9.70	0.32 0.16	3.62 1.55
				ΣP= 149.48	ΣM= 261.53	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load		P_t	=	105.5 kN/m
	depth to acting position	H_t	=	0.00 m
	moment	M_m	=	122.9 kN・m/m
	depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping		H	=	3.43 m
Depth of Imaginary riverbed from riverbed		L_k	=	0.00 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m = 535.41$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	1.48~ 2.48	1.00	0.0 2.4	0.00 1.20	2.10 1.76	0.00 2.11
2	2.48~ 3.43	0.95	2.4 3.3	1.14 1.59	1.11 0.80	1.27 1.27
				ΣPdw= 3.92	ΣMdw= 4.64	

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{801.58}{258.90} = 3.10$ m

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 258.90}{3.91} = 132.43$ kN/m

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name		10 H _ H 700 -200 - 12-16-18		
Unit width	B	=	1.0000 m	
Corrosion margin	t_1	=	1.00 mm (active side)	t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.83	
Section efficiency	μ	=	1.00	
Young's modulus	E	=	200000 N/mm²	
Inertia sectional moment	I_0	=	281600 cm⁴ (original condition)	
	I	=	233728 cm⁴ (after reduction by corrosion and section)	

$EI = 200000 \times 10^3 \times 233728 \times 10^{-8} = 4.675 \times 10^5$

$\beta = 4\sqrt{\frac{K_h \cdot B}{4EI}}$

$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp(-\tan^{-1}\frac{1}{1+2\beta h_0})$

$M_{max} = M_0 \cdot \phi_m$

$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$

$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$

$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	5036	kN/m³
calculated value	β	=	0.22781	m⁻¹
resultant earth force (lateral)	P_0	=	126.97	kN/m
height of acting position of load	h_0	=	2.50	m
moment	M_0	=	317.28	kN・m/m
in consideration of ψ_m = 1.339, maximum moment	M_{max}	=	424.81	kN・m/m
depth of generated position of M_{max}	l_m	=	1.920	m
depth of 1st fixed point	l_i	=	5.368	m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	9039	kN/m³
calculated value	β	=	0.26368	m⁻¹
resultant earth force (lateral)	P_0	=	258.90	kN/m
height of acting position of load	h_0	=	3.10	m
moment	M_0	=	801.58	kN・m/m
in consideration of ψ_m = 1.200, maximum moment	M_{max}	=	961.73	kN・m/m
depth of generated position of M_{max}	l_m	=	1.377	m
depth of 1st fixed point	l_i	=	4.355	m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 700 -200 - 12-16-18			
Corrosion margin	t_1	=	1.00 mm (active side)	t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.85	
Section efficiency	μ	=	1.00	
Module of section	Z_0	=	5130 cm³ (original condition)	
	Z	=	4361 cm³ (after reduction by corrosion and section)	

6.3.1 Normal Condition

$\sigma = \frac{M_{max}}{Z} = \frac{424.81 \times 10^6}{4361 \times 10^3} = 97$ N/mm² ≦ $\sigma_a = 180$ N/mm²

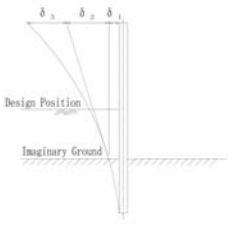
6.3.2 Seismic Condition

$\sigma = \frac{M_{max}}{Z} = \frac{961.73 \times 10^6}{4361 \times 10^3} = 221$ N/mm² ≦ $\sigma_a = 270$ N/mm²

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation

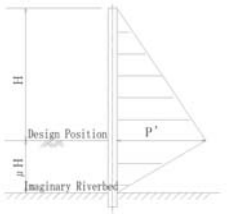


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2278\times 2.50)\times 126.97}{2\times 2.00\times 10^8\times 233728\times 10^{-8}\times 0.2278^3} = 0.01803 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.2278\times 2.50)\times 126.97}{2\times 2.00\times 10^8\times 233728\times 10^{-8}\times 0.2278^2}\times(3.43+0.48) = 0.02188 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.48}{3.43} = 0.140$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{64.95\times 3.43^4}{120\times 2.00\times 10^8\times 233728\times 10^{-8}}(4+20\times 0.140+40\times 0.140^2+35\times 0.140^3+11\times 0.140^4)$$

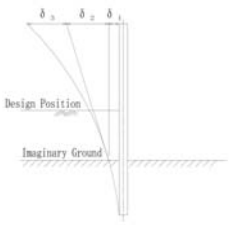
$$= 0.00123 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
$= 0.01803 + 0.02188 + 0.00123$
$= 0.04114$ m
Size = 41.14 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

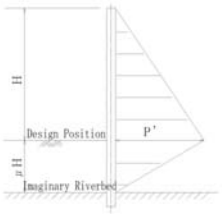


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2637\times 3.10)\times 258.90}{2\times 2.00\times 10^8\times 233728\times 10^{-8}\times 0.2637^3} = 0.02744 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.2637\times 3.10)\times 258.90}{2\times 2.00\times 10^8\times 233728\times 10^{-8}\times 0.2637^2}\times(3.43+0.48) = 0.04100 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.48}{3.43} = 0.140$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{132.43\times 3.43^4}{120\times 2.00\times 10^8\times 233728\times 10^{-8}}(4+20\times 0.140+40\times 0.140^2+35\times 0.140^3+11\times 0.140^4)$$

$$= 0.00251 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
$= 0.02744 + 0.04100 + 0.00251$
$= 0.07095$ m
Size = 70.95 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name			10 H _ H 700 -200 - 12-16-18
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	281600 cm^4 (original condition)
	I	=	281600 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 281600 × 10^{-8}		=	5.632 × 10^6

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_k + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 5036 kN/m^3
Calculated value β = 0.21744 m^{-1}

Penetration length of SSP $D = 0.48 + \frac{3}{0.217} = 14.28$ m
Whole length of SSP $L = 3.43 - 0.40 + 14.28 = 17.31$ m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction K_h = 9039 kN/m^3
Calculated value β = 0.25168 m^{-1}

Penetration length of SSP $D = 0.48 + \frac{3}{0.252} = 12.40$ m
Whole length of SSP $L = 3.43 - 0.40 + 12.40 = 15.43$ m

Therefore, the total length of the sheet pile is 17.50 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 10 H _ H 700 -200 - 12-16-18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	281600		
Sectional Modulus	Z (cm3)	5130		
Maximum bending moment	Mmax (kN・m・m)		424.81	961.73
Stress intensity	σ (N/mm2)		97 (180)	221 (270)
Lateral displacement	δ (mm)		41.14 (50.0)	70.95 (75.0)
Penetration depths	D (m)		14.28	12.40
Whole length of SSP	L (m)	17.50		

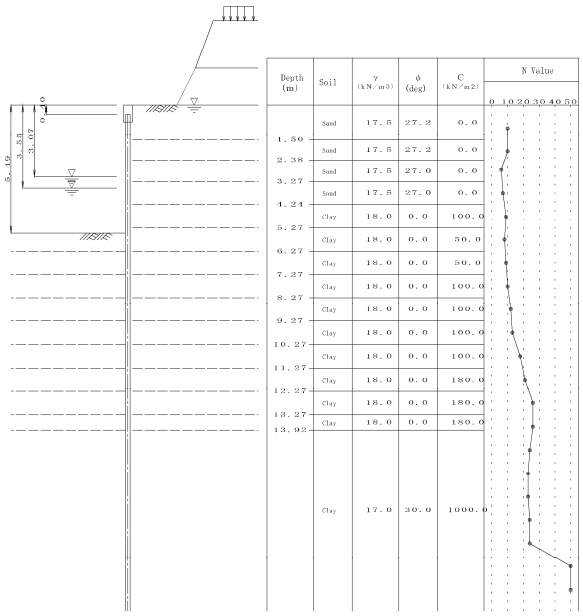
Block No. : R-12
Sta. : 7+900~8+240

Design Cross Section : Sta 8+020
Boring Name : BDM-10

Specification : SSP SP-10H
（Combined） : H 1000-250-16-32-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



Depth (m)	Soil	γ (kN/m3)	φ (deg)	C (kN/m2)
1.50	Sand	17.5	27.2	0.0
2.38	Sand	17.5	27.2	0.0
3.27	Sand	17.5	27.0	0.0
4.24	Sand	17.5	27.0	0.0
5.27	Clay	18.0	0.0	100.0
6.27	Clay	18.0	0.0	50.0
7.27	Clay	18.0	0.0	50.0
8.27	Clay	18.0	0.0	100.0
9.27	Clay	18.0	0.0	100.0
10.27	Clay	18.0	0.0	100.0
11.27	Clay	18.0	0.0	100.0
12.27	Clay	18.0	0.0	180.0
13.27	Clay	18.0	0.0	180.0
13.92	Clay	18.0	0.0	180.0
	Clay	17.0	30.0	1000.0

N Value: 0 10 20 30 40 50

1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.49 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_{it}	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.55 m (Normal Condition)
	L_{wp}'	=	3.07 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress : Chang's formula

Penetration depths : $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water : γ_w = 9.8 kN/m^3

Type of water pressure : trapezoidal water pressure

Lateral pressure : calculated in consideration of site conditions

Study case : - Normal Condition
- Seismic Condition

Design earthquake intensity : k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt =	23.4 kN/m	(Normal Condition)
		Pt' =	62.8 kN/m	(Seismic Condition)
	Depth of acting point	Ht =	0.0 m	(Normal Condition)
		Ht' =	0.0 m	(Seismic Condition)
	Moment	Mm =	0.0 kN･m/m	(Normal Condition)
		Mm' =	33.9 kN･m/m	(Seismic Condition)
	Depth of acting point	Hm' =	0.00 m	(Seismic Condition)
		Hm =	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load : not considered

Minimum angle of rupture : ζ_0 = 10 degrees

Rear side angle of slope : not considered

Angle of rupture (clayey soil) : $\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$

Equilibrium factor of compression : K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_{it}}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_{it} = 10.00 m

E_0 = 2800N

Average N-value : calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value
1	1.00	10
2	2.00	10
3	2.77	6
4	3.77	7
5	4.77	9
6	5.77	8
7	6.77	9
8	7.77	10
9	8.77	12
10	9.77	13
11	10.77	18
12	11.77	21
13	12.77	26
14	13.77	26
15	14.77	24
16	15.77	23
17	16.77	23
18	17.77	24
19	18.77	24
20	19.77	50
21	20.77	50
22	21.77	50

1.6 Vertical Load

Vertical load on landside : calculated in consideration of embankment shape on landside

Vertical load on riverside : not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	1.50	1.50
2	2.38	0.88
3	3.27	0.89
4	4.24	0.97
5	5.27	1.03
6	6.27	1.00
7	7.27	1.00
8	8.27	1.00
9	9.27	1.00
10	10.27	1.00
11	11.27	1.00
12	12.27	1.00
13	13.27	1.00
14	13.92	0.65
15	20.77	6.85

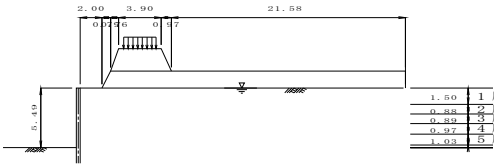
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition	Kh (kN/m3) Normal Condition	Kh (kN/m3) Seismic Condition
1	1.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto		
2	2.38	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto		
3	3.27	S	6.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto		
4	4.24	S	7.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto		
5	5.27	C	9.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto		
6	6.27	C	8.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto		
7	7.27	C	8.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto		
8	8.27	C	9.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto		
9	9.27	C	10.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto		
10	10.27	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto		
11	11.27	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto		
12	12.27	C	18.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
13	13.27	C	21.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
14	13.92	C	26.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto		
15	20.77	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto		

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate				Thickness	soil single weight γ		internal friction angle	stickiness	decay angle ζ	
		Bottom Left m	Top Left m	Top Right m	Bottom Right m	h m	Normal Condition kN/m3	Seismic Condition kN/m3	φ degree	C kN/m2	Normal Condition degree	Seismic Condition degree
1	Sand	2.00	2.79	30.00	30.00	1.58	19.0	19.0	30.0	0.0	Auto	Auto
2	Sand	2.79	3.55	7.45	8.42	2.05	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area		load strength	
	From m	End point m	Normal Condition kN/m2	Seismic Condition kN/m2
1	4.00	7.00	10.0	5.0

Angle of rapture in embankment calculated in consideration of embankment conditions

2	5.27～4.24	Clay	0.0	15.0	100.0	41.09	45.38	51.65	45.00
3	4.24～3.27	Sand	27.0	15.0	0.0	32.65	45.38	41.55	54.81
4	3.27～2.38	Sand	27.0	15.0	0.0	25.18	45.38	32.05	54.81
5	2.38～1.50	Sand	27.2	15.0	0.0	18.33	45.38	23.32	54.95
6	1.50～0.00	Sand	27.2	15.0	0.0	11.55	45.38	14.70	54.95
7		embankment	30.0	——	0.0	68.97	10.00	0.00	60.00
8		embankment	30.0	——	0.0	38.95	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- φ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = $\tan^{-1}$k or θ = $\tan^{-1}$k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C : cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.00	0.22	0.00	0.00	0.22	0.22
2	45.00	1.03	0.22	0.22	1.25	1.25
3	54.81	0.97	1.25	1.25	1.93	2.22
4	54.81	0.89	1.93	2.22	2.56	3.11
5	54.95	0.88	2.56	3.11	3.18	3.99
6	54.95	1.50	3.18	3.99	4.23	5.49
7	60.00	1.58	4.23	5.49	5.14	7.07
8	60.00	2.05	5.14	7.07	6.33	9.12

From the above table, the loading width (L) on the ground surface is 4.23 m.

1.9 Steel Sheet Pile (SSP)

Material name 10 H _ H 1000 -250 -16 -32 -18
Young's modulus E = 200000 N/mm²
Inertia sectional moment I_0 = 896800 cm⁴
Sectional factor Z_0 = 13590 cm³

Corrosion margin t_1 = 1.00 mm (riverside) t_2 = 1.00 mm (landside)

Corrosion rate (to I_0) η = 0.88
Corrosion rate (to Z_0) η = 0.90
Section efficiency (to I_0) μ = 1.00
Section efficiency (to Z_0) μ = 1.00

Round unit of SSP length 0.50 m

Allowable stress σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

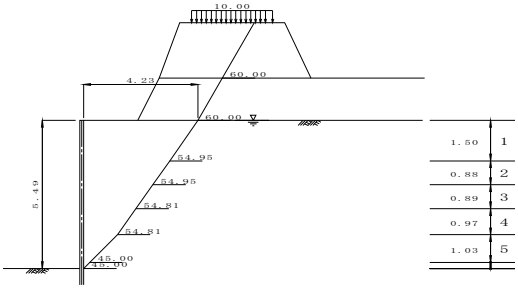
Allowable displacement δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam calculated as distributed load of each layer

Reduction of material modulus Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σ γ h kN/m2	Q kN/m2	γ wtw kN/m2	Angle of Rupture ζ degree
1	5.49～5.27	Clay	0.0	15.0	50.0	42.90	45.38	53.80	45.00

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	3.62	68.82
2	19.0	5.26	99.92
Σ			168.73

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qsl kN/m
1	10.0	2.33	23.27
Σ			23.27

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

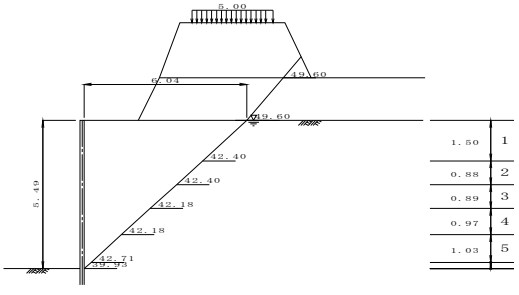
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{168.73 + 23.27 + 0.00}{4.23}$$

$$= 45.38\ \text{kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.49～5.27	Clay	0.0	15.0	50.0	42.90	53.40	53.80	0.200	11.31	39.93
2	5.27～4.24	Clay	0.0	15.0	100.0	41.09	53.40	51.65	0.200	11.31	42.71
3	4.24～3.27	Sand	27.0	15.0	0.0	32.65	53.40	41.55	0.200	11.31	42.18
4	3.27～2.38	Sand	27.0	15.0	0.0	25.18	53.40	32.05	0.200	11.31	42.18
5	2.38～1.50	Sand	27.2	15.0	0.0	18.33	53.40	23.32	0.200	11.31	42.40
6	1.50～0.00	Sand	27.2	15.0	0.0	11.55	53.40	14.70	0.200	11.31	42.40
7		embankment	30.0	——	0.0	68.97	5.00	0.00	0.200	11.31	49.60
8		embankment	30.0	——	0.0	38.95	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	39.93	0.22	0.00	0.00	0.26	0.22
2	42.71	1.03	0.26	0.22	1.38	1.25
3	42.18	0.97	1.38	1.25	2.45	2.22
4	42.18	0.89	2.45	2.22	3.43	3.11
5	42.40	0.88	3.43	3.11	4.40	3.99
6	42.40	1.50	4.40	3.99	6.04	5.49
7	49.60	1.58	6.04	5.49	7.38	7.07
8	49.60	0.78	7.38	7.07	8.05	7.85

From the above table, the loading width (L) on the ground surface is 6.04 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	6.82	129.54
2	19.0	9.36	177.87
Σ			307.41

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.00	15.00
Σ			15.00

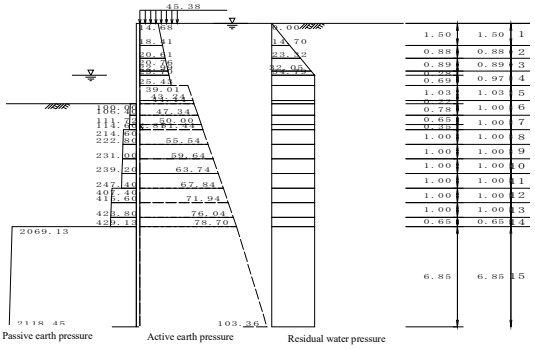
Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times l)+\Sigma P}{L} = \frac{307.41 + 15.00 + 0.00}{6.04} = 53.40\ \text{kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



The dotted line in the figure shows the main earth pressure strength Pa2 using the consolidation equilibrium coefficient.

3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00～1.50	Sand	7.7	27.2	——	45.377 56.927	0.33489 0.33489	0.32348 0.32348
2	1.50～2.38	Sand	7.7	27.2	—— ——	56.927 63.703	0.33489 0.33489	0.32348 0.32348
3	2.38～3.27	Sand	7.7	27.0	—— ——	63.703 70.556	0.33738 0.33738	0.32589 0.32589
4	3.27～3.55	Sand	7.7	27.0	—— ——	70.556 72.712	0.33738 0.33738	0.32589 0.32589
5	3.55～4.24	Sand	7.7	27.0	—— ——	72.712 78.025	0.33738 0.33738	0.32589 0.32589
6	4.24～5.27	Clay	8.2	——	100.0 100.0	78.025 86.471	—— ——	—— ——
7	5.27～5.49	Clay	8.2	——	50.0 50.0	86.471 88.275	—— ——	—— ——
8	5.49～6.27	Clay	8.2	——	50.0 50.0	88.275 94.671	—— ——	—— ——
9	6.27～6.92	Clay	8.2	——	50.0 50.0	94.671 100.000	—— ——	—— ——
10	6.92～7.27	Clay	8.2	——	50.0 50.0	100.000 102.871	—— ——	—— ——
11	7.27～8.27	Clay	8.2	——	100.0 100.0	102.871 111.071	—— ——	—— ——
12	8.27～9.27	Clay	8.2	——	100.0 100.0	111.071 119.271	—— ——	—— ——
13	9.27～10.27	Clay	8.2	——	100.0 100.0	119.271 127.471	—— ——	—— ——
14	10.27～11.27	Clay	8.2	——	100.0 100.0	127.471 135.671	—— ——	—— ——
15	11.27～12.27	Clay	8.2	——	180.0 180.0	135.671 143.871	—— ——	—— ——
16	12.27～13.27	Clay	8.2	——	180.0 180.0	143.871 152.071	—— ——	—— ——
17	13.27～13.92	Clay	8.2	——	180.0 180.0	152.071 157.401	—— ——	—— ——
18	13.92～20.77	Clay	7.2	——	1000.0 1000.0	157.401 206.721	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β= 0.00、θ= 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
8	5.49～6.27	Clay	8.2	0.0	50.0 50.0	0.000 6.396	—— ——	—— ——
9	6.27～6.92	Clay	8.2	0.0	50.0 50.0	6.396 11.725	—— ——	—— ——
10	6.92～7.27	Clay	8.2	0.0	50.0 50.0	11.725 14.596	—— ——	—— ——
11	7.27～8.27	Clay	8.2	0.0	100.0 100.0	14.596 22.796	—— ——	—— ——
12	8.27～9.27	Clay	8.2	0.0	100.0 100.0	22.796 30.996	—— ——	—— ——
13	9.27～10.27	Clay	8.2	0.0	100.0 100.0	30.996 39.196	—— ——	—— ——
14	10.27～11.27	Clay	8.2	0.0	100.0 100.0	39.196 47.396	—— ——	—— ——
15	11.27～12.27	Clay	8.2	0.0	180.0 180.0	47.396 55.596	—— ——	—— ——
16	12.27～13.27	Clay	8.2	0.0	180.0 180.0	55.596 63.796	—— ——	—— ——
17	13.27～13.92	Clay	8.2	0.0	180.0 180.0	63.796 69.126	—— ——	—— ——
18	13.92～20.77	Clay	7.2	30.0	1000.0 1000.0	69.126 118.446	—— ——	—— ——

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β= 0.00、θ= 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.50	14.68 18.41	—— ——	14.68 18.41	0.00 14.70	—— ——
2	1.50~ 2.38	18.41 20.61	—— ——	18.41 20.61	14.70 23.32	—— ——
3	2.38~ 3.27	20.76 22.99	—— ——	20.76 22.99	23.32 32.05	—— ——
4	3.27~ 3.55	22.99 23.70	—— ——	22.99 23.70	32.05 34.79	—— ——
5	3.55~ 4.24	23.70 25.43	—— ——	23.70 25.43	34.79 34.79	—— ——
6	4.24~ 5.27	-121.97 -113.53	39.01 43.24	39.01 43.24	34.79 34.79	—— ——
7	5.27~ 5.49	-113.53 -111.72	43.24 44.14	43.24 44.14	34.79 34.79	—— ——
8	5.49~ 6.27	-111.72 -5.33	44.14 47.34	44.14 47.34	34.79 34.79	100.00 106.40
9	6.27~ 6.92	-5.33 0.00	47.34 50.00	47.34 50.00	34.79 34.79	106.40 111.72
10	6.92~ 7.27	0.00 2.87	50.00 51.44	50.00 51.44	34.79 34.79	111.72 114.60
11	7.27~ 8.27	-97.13 -88.93	51.44 55.54	51.44 55.54	34.79 34.79	214.60 222.80
12	8.27~ 9.27	-88.93 -80.73	55.54 59.64	55.54 59.64	34.79 34.79	222.80 231.00
13	9.27~ 10.27	-80.73 -72.53	59.64 63.74	59.64 63.74	34.79 34.79	231.00 239.20
14	10.27~ 11.27	-72.53 -64.33	63.74 67.84	63.74 67.84	34.79 34.79	239.20 247.40
15	11.27~ 12.27	-224.33 -216.13	67.84 71.94	67.84 71.94	34.79 34.79	407.40 415.60
16	12.27~ 13.27	-216.13 -207.93	71.94 76.04	71.94 76.04	34.79 34.79	415.60 423.80
17	13.27~ 13.92	-207.93 -202.60	76.04 78.70	76.04 78.70	34.79 34.79	423.80 429.13
18	13.92~ 20.77	-1842.60 -1793.28	78.70 103.36	78.70 103.36	34.79 34.79	2069.13 2118.45

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

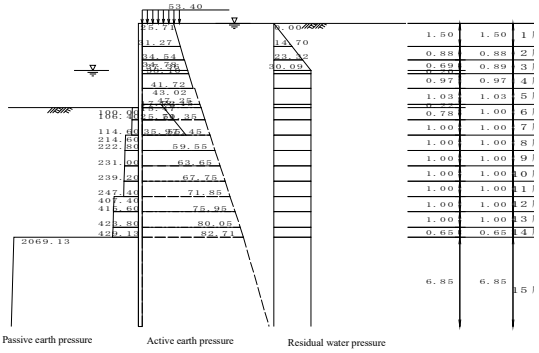
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 1.50	Sand	7.7	27.2	—— ——	53.40 64.95	0.00 14.70	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	—— ——
2	1.50~ 2.38	Sand	7.7	27.2	—— ——	64.95 71.72	14.70 23.32	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	—— ——
3	2.38~ 3.07	Sand	7.7	27.0	—— ——	71.72 77.04	23.32 30.09	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
4	3.07~ 3.27	Sand	7.7	27.0	—— ——	77.04 78.58	30.09 32.05	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——
5	3.27~ 4.24	Sand	7.7	27.0	—— ——	78.58 86.05	32.05 41.55	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	—— ——

6	4.24~ 5.27	Clay	8.2	——	100.0 100.0	86.05 94.49	41.55 51.65	0.200 0.200	11.31 11.31	—— ——	—— ——	42.85 42.71
7	5.27~ 5.49	Clay	8.2	——	50.0 50.0	94.49 96.30	51.65 53.80	0.200 0.200	11.31 11.31	—— ——	—— ——	40.00 39.93
8	5.49~ 6.27	Clay	8.2	——	50.0 50.0	96.30 102.69	53.80 61.45	0.200 0.200	11.31 11.31	—— ——	—— ——	39.93 39.67
9	6.27~ 7.27	Clay	8.2	——	50.0 50.0	102.69 110.89	61.45 71.25	0.200 0.200	11.31 11.31	—— ——	—— ——	39.67 39.33
10	7.27~ 8.27	Clay	8.2	——	100.0 100.0	110.89 119.09	71.25 81.05	0.200 0.200	11.31 11.31	—— ——	—— ——	42.43 42.29
11	8.27~ 9.27	Clay	8.2	——	100.0 100.0	119.09 127.29	81.05 90.85	0.200 0.200	11.31 11.31	—— ——	—— ——	42.29 42.15
12	9.27~ 10.27	Clay	8.2	——	100.0 100.0	127.29 135.49	90.85 100.65	0.200 0.200	11.31 11.31	—— ——	—— ——	42.15 42.01
13	10.27~ 11.27	Clay	8.2	——	100.0 100.0	135.49 143.69	100.65 110.45	0.200 0.200	11.31 11.31	—— ——	—— ——	42.01 41.86
14	11.27~ 12.27	Clay	8.2	——	180.0 180.0	143.69 151.89	110.45 120.25	0.200 0.200	11.31 11.31	—— ——	—— ——	43.34 43.27
15	12.27~ 13.27	Clay	8.2	——	180.0 180.0	151.89 160.09	120.25 130.05	0.200 0.200	11.31 11.31	—— ——	—— ——	43.27 43.19
16	13.27~ 13.92	Clay	8.2	——	180.0 180.0	160.09 165.42	130.05 136.42	0.200 0.200	11.31 11.31	—— ——	—— ——	43.19 43.14
17	13.92~ 20.77	Clay	7.2	——	1000.0 1000.0	165.42 214.74	136.42 203.55	0.200 0.200	11.31 11.31	—— ——	—— ——	44.68 44.61

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h + 2Q}{2C}\cdot\tan\theta}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
8	5.49~ 6.27	Clay	8.20	0.0	50.0 50.0	0.000 6.396	0.00 7.64	0.200 0.200	11.31 11.31	—— ——	—— ——
9	6.27~ 7.27	Clay	8.20	0.0	50.0 50.0	6.396 14.596	7.64 17.44	0.200 0.200	11.31 11.31	—— ——	—— ——
10	7.27~ 8.27	Clay	8.20	0.0	100.0 100.0	14.596 22.796	17.44 27.24	0.200 0.200	11.31 11.31	—— ——	—— ——
11	8.27~ 9.27	Clay	8.20	0.0	100.0 100.0	22.796 30.996	27.24 37.04	0.200 0.200	11.31 11.31	—— ——	—— ——
12	9.27~ 10.27	Clay	8.20	0.0	100.0 100.0	30.996 39.196	37.04 46.84	0.200 0.200	11.31 11.31	—— ——	—— ——
13	10.27~ 11.27	Clay	8.20	0.0	100.0 100.0	39.196 47.396	46.84 56.64	0.200 0.200	11.31 11.31	—— ——	—— ——
14	11.27~ 12.27	Clay	8.20	0.0	180.0 180.0	47.396 55.596	56.64 66.44	0.200 0.200	11.31 11.31	—— ——	—— ——
15	12.27~ 13.27	Clay	8.20	0.0	180.0 180.0	55.596 63.796	66.44 76.24	0.200 0.200	11.31 11.31	—— ——	—— ——
16	13.27~ 13.92	Clay	8.20	0.0	180.0 180.0	63.796 69.126	76.24 82.61	0.200 0.200	11.31 11.31	—— ——	—— ——
17	13.92~ 20.77	Clay	7.20	30.0	1000.0 1000.0	69.126 118.446	82.61 149.74	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.50	25.71 31.27	—— ——	25.71 31.27	0.00 14.70	—— ——
2	1.50~ 2.38	31.27 34.54	—— ——	31.27 34.54	14.70 23.32	—— ——
3	2.38~ 3.07	34.78 37.36	—— ——	34.78 37.36	23.32 30.09	—— ——
4	3.07~ 3.27	37.36 38.10	—— ——	37.36 38.10	30.09 30.09	—— ——
5	3.27~ 4.24	38.10 41.72	—— ——	38.10 41.72	30.09 30.09	—— ——
6	4.24~ 5.27	-95.97 -85.68	43.02 47.25	43.02 47.25	30.09 30.09	—— ——
7	5.27~ 5.49	15.47 17.72	47.25 48.15	47.25 48.15	30.09 30.09	—— ——
8	5.49~ 6.27	17.72 25.70	48.15 51.35	48.15 51.35	30.09 30.09	100.00 106.40
9	6.27~ 7.27	25.70 35.97	51.35 55.45	51.35 55.45	30.09 30.09	106.40 114.60
10	7.27~ 8.27	-65.65 -55.62	55.45 59.55	55.45 59.55	30.09 30.09	214.60 222.80
11	8.27~ 9.27	-55.62 -45.58	59.55 63.65	59.55 63.65	30.09 30.09	222.80 231.00
12	9.27~ 10.27	-45.58 -35.52	63.65 67.75	63.65 67.75	30.09 30.09	231.00 239.20
13	10.27~ 11.27	-35.52 -25.44	67.75 71.85	67.75 71.85	30.09 30.09	239.20 247.40
14	11.27~ 12.27	-186.46 -176.49	71.85 75.95	71.85 75.95	30.09 30.09	407.40 415.60
15	12.27~ 13.27	-176.49 -166.52	75.95 80.05	75.95 80.05	30.09 30.09	415.60 423.80
16	13.27~ 13.92	-166.52 -160.03	80.05 82.71	80.05 82.71	30.09 30.09	423.80 429.13

17	13.92~ 20.77	-1801.25 -1741.91	82.71 107.37	82.71 107.37	30.09 30.09	2069.13 2118.45

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma \gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	3.07	0.00	0.00
2	4.07	1.00	2.67
3	5.07	2.00	3.77
4	5.49	2.42	4.15

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

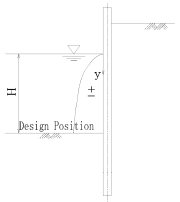
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

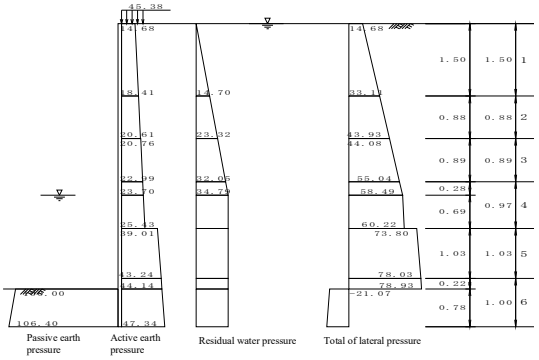
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	14.68 18.41	0.00 14.70	——— ———	14.68 33.11
2	1.50~ 2.38	18.41 20.61	14.70 23.32	——— ———	33.11 43.93
3	2.38~ 3.27	20.76 22.99	23.32 32.05	——— ———	44.08 55.04
4	3.27~ 3.55	22.99 23.70	32.05 34.79	——— ———	55.04 58.49
5	3.55~ 4.24	23.70 25.43	34.79 34.79	——— ———	58.49 60.22
6	4.24~ 5.27	39.01 43.24	34.79 34.79	——— ———	73.80 78.03
7	5.27~ 5.49	43.24 44.14	34.79 34.79	——— ———	78.03 78.93
8	5.49~ 6.27	44.14 47.34	34.79 34.79	100.00 106.40	-21.07 -24.27

P_a : Active earth pressure

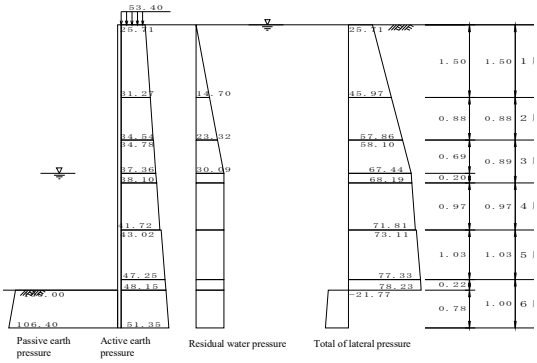
P_w : Residual water pressure

P_p : Passive earth pressure

P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.49 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	25.71 31.27	0.00 14.70	——— ———	25.71 45.97
2	1.50~ 2.38	31.27 34.54	14.70 23.32	——— ———	45.97 57.86
3	2.38~ 3.07	34.78 37.36	23.32 30.09	——— ———	58.10 67.44
4	3.07~ 3.27	37.36 38.10	30.09 30.09	——— ———	67.44 68.19
5	3.27~ 4.24	38.10 41.72	30.09 30.09	——— ———	68.19 71.81
6	4.24~ 5.27	43.02 47.25	30.09 30.09	——— ———	73.11 77.33
7	5.27~ 5.49	47.25 48.15	30.09 30.09	——— ———	77.33 78.23
8	5.49~ 6.27	48.15 51.35	30.09 30.09	100.00 106.40	-21.77 -24.96

P_a : Active earth pressure

P_w : Residual water pressure

P_p : Passive earth pressure

P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.49 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \quad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name		10 H _ H 1000 -250 -16 -32 -18	
Unit width	B	= 1.0000 m	
Corrosion margin	t_1	= 1.00 mm (active side)	t_2 = 1.00 mm (passive side)
Corrosion rate	η	= 0.88	
Section efficiency	μ	= 1.00	
Young's modulus	E	= 200000 N/mm^2	
Inertia sectional moment	I_0	= 896800 cm^4(original condition)	
	I	= 789184 cm^4(after reduction by corrosion and section)	
Inertia sectional moment	EI	= $200000 \times 10^3 \times 789184 \times 10^{-8} = 1.578 \times 10^6$	

No	Depth m	N Value
1	1.00	10
2	2.00	10
3	2.77	6
4	3.77	7
5	4.77	9
6	5.77	8
7	6.77	9
8	7.77	10
9	8.77	12
10	9.77	13

No	Depth m	N Value
11	10.77	18
12	11.77	21
13	12.77	26
14	13.77	26
15	14.77	24
16	15.77	23
17	16.77	23
18	17.77	24
19	18.77	24
20	19.77	50

No	Depth m	N Value
21	20.77	50
22	21.77	50

5.2 Normal Condition

Assuming Kh = 7626 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.186\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 5.36\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.49 m) to 5.36 m depth (GL -10.85 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.49	0.28	8.3	8.0	2.28
2	5.77	1.00	8.0	9.0	8.50
3	6.77	1.00	9.0	10.0	9.50
4	7.77	1.00	10.0	12.0	11.00
5	8.77	1.00	12.0	13.0	12.50
6	9.77	1.00	13.0	18.0	15.50
7	10.77	0.08	18.0	18.3	1.52
		L = Σh = 5.36		Σ A =	60.80

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{60.80}{5.36} = 11.33$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 11.33 = 31738\ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 31738 = 105792\ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 105792(10.00/0.3)^{-3/4} = 7626\ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 7626 kN/m3.

5.3 Seismic Condition

Assuming Kh = 14099 kN/m3,

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.217\ m^{-1}$

$L = \frac{1}{\beta} = 4.60\ m$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.49 m) and 4.60 m depth (GL -10.09 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.49	0.28	8.3	8.0	2.28
2	5.77	1.00	8.0	9.0	8.50
3	6.77	1.00	9.0	10.0	9.50
4	7.77	1.00	10.0	12.0	11.00
5	8.77	1.00	12.0	13.0	12.50
6	9.77	0.32	13.0	14.6	4.42
		L = Σh = 4.60		Σ A =	48.20

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{48.20}{4.60} = 10.48$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 10.48 = 29338\ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 29338 = 195584\ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 195584(10.00/0.3)^{-3/4} = 14099\ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 14099 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	14.68 33.11	11.01 24.84	4.99 4.49	54.93 111.51
2	1.50~ 2.38	0.88	33.11 43.93	14.57 19.33	3.70 3.40	53.86 65.78
3	2.38~ 3.27	0.89	44.08 55.04	19.62 24.49	2.81 2.52	55.19 61.64
4	3.27~ 3.55	0.28	55.04 58.49	7.71 8.19	2.13 2.03	16.39 16.65
5	3.55~ 4.24	0.69	58.49 60.22	20.18 20.78	1.71 1.48	34.50 30.75
6	4.24~ 5.27	1.03	73.80 78.03	38.01 40.18	0.91 0.56	34.46 22.64
7	5.27~ 5.49	0.22	78.03 78.93	8.58 8.68	0.15 0.07	1.26 0.64
				Σ P = 266.16	Σ M =	560.21

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 23.4 kN/m
depth to acting position H_t = 0.0 m
moment M_m = 0.0 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 5.49 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 128.47$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{688.67}{289.56} = 2.38\ m$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 289.56}{5.49} = 105.49\ kN/m$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	25.71 45.97	19.28 34.48	4.99 4.49	96.23 154.82
2	1.50~ 2.38	0.88	45.97 57.86	20.23 25.46	3.70 3.40	74.78 86.64
3	2.38~ 3.07	0.69	58.10 67.44	20.05 23.27	2.88 2.65	57.73 61.66
4	3.07~ 3.27	0.20	67.44 68.19	6.74 6.82	2.35 2.29	15.87 15.59
5	3.27~ 4.24	0.97	68.19 71.81	33.07 34.83	1.90 1.57	62.73 54.80
6	4.24~ 5.27	1.03	73.11 77.33	37.65 39.83	0.91 0.56	34.14 22.44
7	5.27~ 5.49	0.22	77.33 78.23	8.51 8.61	0.15 0.07	1.25 0.63
				Σ P = 318.82	Σ M =	739.29

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 62.8 kN/m
depth to acting position H_t = 0.00 m
moment M_m = 33.9 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 5.49 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 378.67$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	3.07~ 4.07	1.00	0.0 2.7	0.00 1.33	2.09 1.75	0.00 2.34
2	4.07~ 5.07	1.00	2.7 3.8	1.33 1.89	1.09 0.75	1.45 1.42
3	5.07~ 5.49	0.42	3.8 4.2	0.79 0.87	0.28 0.14	0.22 0.12
				Σ Pdw = 6.22	Σ Mdw =	5.55

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1123.52}{387.83} = 2.90\ m$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 387.83}{5.49} = 141.29\ kN/m$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name 10 H _ H 1000 -250 -16 -32 -18
Unit width B = 1.0000 m
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.88
Section efficiency μ = 1.00
Young's modulus E = 200000 N/mm^2
Inertia sectional moment I_0 = 896800 cm^4 (original condition)
I = 789184 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 789184 × 10^{-8} = 1.578 × 10^6

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$

$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp(-\tan^{-1}\frac{1}{1+2\beta h_0})$

$M_{max} = M_0 \cdot \phi_m$

$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$

$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$

$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	7626 kN/m³
calculated value	β	=	0.18643 m⁻¹
resultant earth force (lateral)	P_0	=	289.56 kN/m
height of acting position of load	h_0	=	2.38 m
moment	M_0	=	688.67 kN･m/m
in consideration of ψ_m = 1.479,			
maximum moment	M_{max}	=	1018.64 kN･m/m
depth of generated position of M_{max}	l_m	=	2.614 m
depth of 1st fixed point	l_i	=	6.827 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	14099 kN/m³
calculated value	β	=	0.21738 m⁻¹
resultant earth force (lateral)	P_0	=	387.83 kN/m
height of acting position of load	h_0	=	2.90 m
moment	M_0	=	1123.52 kN･m/m
in consideration of ψ_m = 1.293,			
maximum moment	M_{max}	=	1453.07 kN･m/m
depth of generated position of M_{max}	l_m	=	1.917 m
depth of 1st fixed point	l_i	=	5.530 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 1000 -250 -16 -32 -18		
Corrosion margin	t_1 = 1.00 mm (active side)	t_2 = 1.00 mm (passive side)	
Corrosion rate	η	=	0.90
Section efficiency	μ	=	1.00
Module of section	Z_0	=	13590 cm³ (original condition)
	Z	=	12231 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1018.64\times10^6}{12231\times10^3} = 83\ N/mm^2 \leqq \sigma_a = 180\ N/mm^2$$

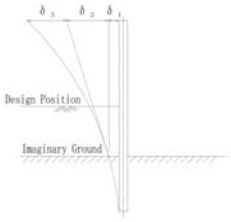
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1453.07\times10^6}{12231\times10^3} = 119\ N/mm^2 \leqq \sigma_a = 270\ N/mm^2$$

6.4 Displacement Calculation

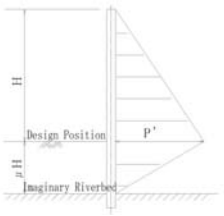
6.4.1 Normal Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.1864\times2.38)\times289.56}{2\times2.00\times10^8\times789184\times10^{-8}\times0.1864^3} = 0.02043\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.1864\times2.38)\times289.56}{2\times2.00\times10^8\times789184\times10^{-8}\times0.1864^2}\times(5.49+0.00) = 0.02734\ m$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.49} = 0.000$$

$$\delta_3 = \frac{P'H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{105.49\times5.49^4}{120\times2.00\times10^8\times789184\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4) = 0.00202\ m$$

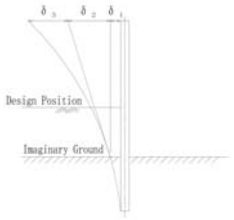
$\delta = \delta1 + \delta2 + \delta3$
= 0.02043 + 0.02734 + 0.00202
= 0.04980 m
Size = 49.80 ≦ δa = 50.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

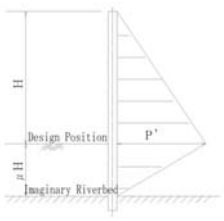
6.4.2 Seismic Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.2174\times2.90)\times387.83}{2\times2.00\times10^8\times789184\times10^{-8}\times0.2174^3} = 0.01949\ m$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.2174\times2.90)\times387.83}{2\times2.00\times10^8\times789184\times10^{-8}\times0.2174^2}\times(5.49+0.00) = 0.03225\ m$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.49} = 0.000$$

$$\delta_3 = \frac{P'H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{141.29\times5.49^4}{120\times2.00\times10^8\times789184\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4) = 0.00271\ m$$

$\delta = \delta1 + \delta2 + \delta3$
= 0.01949 + 0.03225 + 0.00271
= 0.05445 m
Size = 54.45 ≦ δa = 75.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name	10 H _ H 1000 -250 -16 -32 -18		
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	896800 cm⁴ (original condition)
	I	=	896800 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 896800 × 10⁻⁸		=	1.794 × 10⁶

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h\cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction	K_h	=	7626 kN/m³
Calculated value	β	=	0.18056 m⁻¹
Penetration length of SSP	D	=	$0.00 + \frac{3}{0.181}$ = 16.61 m
Whole length of SSP	L	=	5.49 − 0.40 + 16.61 = 21.70 m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction $K_h = 14099\ kN/m^3$
Calculated value $\beta = 0.21055\ m^{-1}$

Penetration length of SSP $D = 0.00 + \frac{3}{0.211} = 14.25\ m$
Whole length of SSP $L = 5.49 - 0.40 + 14.25 = 19.34\ m$

Therefore, the total length of the sheet pile is 22.00 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 10 H _ H 1000 -250 -16 -32 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	896800		
Sectional Modulus	Z (cm3)	13590		
Maximum bending moment	Mmax (kN・m・m)		1018.64	1453.07
Stress intensity	σ (N/mm2)		83 (180)	119 (270)
Lateral displacement	δ (mm)		49.80 (50.0)	54.45 (75.0)
Penetration depths	D (m)		16.61	14.25
Whole length of SSP	L (m)	22.00		

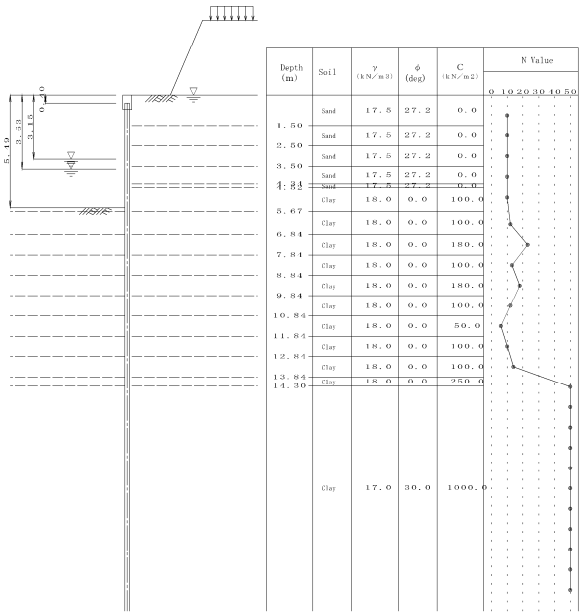
Block No. : R-13
Sta. : 8+240~8+500

Design Cross Section : Sta 8+320
Boring Name : DD-BH-R08

Specification : SSP SP-10H
(Combined) : H 950-250-16-22-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



Depth (m)	Soil	γ (kN/m3)	φ (deg)	C (kN/m2)	N Value
1.50	Sand	17.5	27.2	0.0	
2.50	Sand	17.5	27.2	0.0	
3.50	Sand	17.5	27.2	0.0	
4.84	Sand	17.5	27.2	0.0	
5.67	Clay	18.0	0.0	100.0	
6.84	Clay	18.0	0.0	100.0	
7.84	Clay	18.0	0.0	180.0	
8.84	Clay	18.0	0.0	100.0	
9.84	Clay	18.0	0.0	180.0	
10.84	Clay	18.0	0.0	100.0	
11.84	Clay	18.0	0.0	50.0	
12.84	Clay	18.0	0.0	100.0	
13.84	Clay	18.0	0.0	100.0	
14.30	Clay	18.0	0.0	250.0	
	Clay	17.0	30.0	1000.0	

N Value: 0 10 20 30 40 50

1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.49 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_B	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.63 m (Normal Condition)
	L_{wp}'	=	3.15 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress Chang's formula
Penetration depths $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water $\gamma_w = 9.8\ kN/m^3$

Type of water pressure trapezoidal water pressure

Lateral pressure calculated in consideration of site conditions

Study case
- Normal Condition
- Seismic Condition

Design earthquake intensity k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	23.4 kN/m	(Normal Condition)
		Pt'	=	62.8 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	M_m	=	0.0 kN・m/m	(Normal Condition)
		M_m'	=	33.9 kN・m/m	(Seismic Condition)
	Depth of acting point	H_m'	=	0.00 m	(Seismic Condition)
		H_m	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load not considered

Minimum angle of rupture $\zeta_0 = 10$ degrees

Rear side angle of slope not considered

Angle of rupture (clayey soil) $\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C} \cdot \tan\theta}$

Equilibrium factor of compression $K_c = 0.50$ (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula
$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$
$K_{h0} = \frac{1}{0.3}\alpha E_0$ (α :Normal Condition =1, Seismi Condition =2)
$B_H = 10.00$ m
$E_0 = 2800N$

Average N-value calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value
1	1.00	10	11	11.34	6	21	21.34	50
2	2.00	10	12	12.34	10	22	22.34	50
3	3.00	10	13	13.34	14	23	23.34	50
4	4.00	10	14	14.34	50	24	24.34	50
5	5.00	10	15	15.34	50			
6	6.34	12	16	16.34	50			
7	7.34	23	17	17.34	50			
8	8.34	13	18	18.34	50			
9	9.34	18	19	19.34	50			
10	10.34	12	20	20.34	50			

1.6 Vertical Load

Vertical load on landside　　calculated in consideration of embankment shape on landside

Vertical load on riverside　　not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	1.50	1.50
2	2.50	1.00
3	3.50	1.00
4	4.34	0.84
5	4.52	0.18
6	5.67	1.15
7	6.84	1.17
8	7.84	1.00
9	8.84	1.00
10	9.84	1.00
11	10.84	1.00
12	11.84	1.00
13	12.84	1.00
14	13.84	1.00
15	14.30	0.46
16	24.34	10.04

No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	1.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
2	2.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
3	3.50	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
4	4.34	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
5	4.52	S	9.9	17.50	7.70	27.2	0.0	0.0	0.200	Auto	Auto
6	5.67	C	9.9	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
7	6.84	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
8	7.84	C	23.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
9	8.84	C	13.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
10	9.84	C	18.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
11	10.84	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
12	11.84	C	6.0	18.00	8.20	0.0	50.0	0.0	0.200	Auto	Auto
13	12.84	C	10.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
14	13.84	C	14.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
15	14.30	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
16	24.34	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note)　depth : from top of coping to bottom of the layer　　C_a : soil adhesion
soil : sandy(S), clayey(C), mixed (M)　　a : slope of soil adhesion
N-value : average N-value in the layer　　k' : design seismic coefficient (underwater)
γ : wet unit weight of soil　　ζ : angle of active rupture
γ' : saturated unit weight of soil　　kh : modulus of subgrade reaction
φ : internal friction angle of soil

1.9 Steel Sheet Pile (SSP)

Material name　10 H _ H 950 -250 -16 -22 -18
Young's modulus　E = 200000 N/mm²
Inertia sectional moment　I_0 = 688700 cm⁴
Sectional factor　Z_0 = 10570 cm³

Corrosion margin　t_1 = 1.00 mm (riverside)　　t_2 = 1.00 mm (landside)

Corrosion rate (to I_0)　η = 0.86
Corrosion rate (to Z_0)　η = 0.88
Section efficiency (to I_0)　μ = 1.00
Section efficiency (to Z_0)　μ = 1.00

Round unit of SSP length　0.50 m

Allowable stress　σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

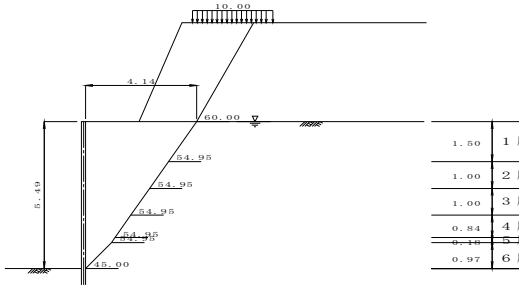
Allowable displacement　δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam　calculated as distributed load of each layer

Reduction of material modulus　Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



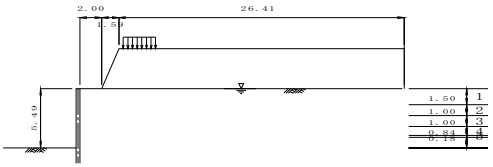
2.1.1 Angle of Active Rupture

No	Depth. m	Soil	δ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	5.49 ~ 4.52	Clay	0.0	15.0	100.0	42.76	46.33	53.80	45.00

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	2.00	3.59	30.00	30.00	3.69	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	End point m	load strength Normal Condition kN/m2	Seismic Condition kN/m2
1	3.99	6.99	10.0	5.0

Angle of rapture in embankment　　calculated in consideration of embankment conditions

2	4.52 ~ 4.34	Sand	27.2	15.0	0.0	34.80	46.33	44.30	54.95
3	4.34 ~ 3.50	Sand	27.2	15.0	0.0	33.42	46.33	42.53	54.95
4	3.50 ~ 2.50	Sand	27.2	15.0	0.0	26.95	46.33	34.30	54.95
5	2.50 ~ 1.50	Sand	27.2	15.0	0.0	19.25	46.33	24.50	54.95
6	1.50 ~ 0.00	Sand	27.2	15.0	0.0	11.55	46.33	14.70	54.95
7		embankment	30.0	——	0.0	70.11	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°
Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C : cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	45.00	0.97	0.00	0.00	0.97	0.97
2	54.95	0.18	0.97	0.97	1.10	1.15
3	54.95	0.84	1.10	1.15	1.69	1.99
4	54.95	1.00	1.69	1.99	2.39	2.99
5	54.95	1.00	2.39	2.99	3.09	3.99
6	54.95	1.50	3.09	3.99	4.14	5.49
7	60.00	3.69	4.14	5.49	6.27	9.18

From the above table, the loading width (L) on the ground surface is 4.14 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	8.90	169.04
Σ			169.04

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	2.28	22.81
Σ			22.81

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

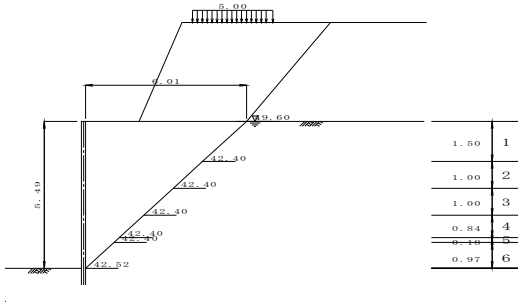
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{169.04 + 22.81 + 0.00}{4.14}$$

$$= 46.33 \ kN/m^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.49～4.52	Clay	0.0	15.0	100.0	42.76	58.31	53.80	0.200	11.31	42.52
2	4.52～4.34	Sand	27.2	15.0	0.0	34.80	58.31	44.30	0.200	11.31	42.40
3	4.34～3.50	Sand	27.2	15.0	0.0	33.42	58.31	42.53	0.200	11.31	42.40
4	3.50～2.50	Sand	27.2	15.0	0.0	26.95	58.31	34.30	0.200	11.31	42.40
5	2.50～1.50	Sand	27.2	15.0	0.0	19.25	58.31	24.50	0.200	11.31	42.40
6	1.50～0.00	Sand	27.2	15.0	0.0	11.55	58.31	14.70	0.200	11.31	42.40
7		embankment	30.0	——	0.0	70.11	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	42.52	0.97	0.00	0.00	1.06	0.97
2	42.40	0.18	1.06	0.97	1.26	1.15
3	42.40	0.84	1.26	1.15	2.17	1.99
4	42.40	1.00	2.17	1.99	3.27	2.99
5	42.40	1.00	3.27	2.99	4.37	3.99
6	42.40	1.50	4.37	3.99	6.01	5.49
7	49.60	3.69	6.01	5.49	9.15	9.18

From the above table, the loading width (L) on the ground surface is 6.01 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	17.65	335.33
Σ			335.33

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.00	15.00
Σ			15.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

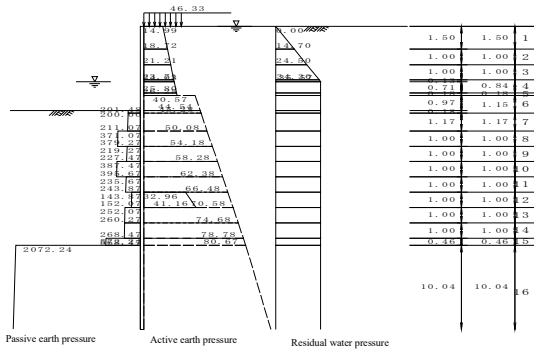
$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{335.33 + 15.00 + 0.00}{6.01}$$

$$= 58.31 \ kN/m^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00～1.50	Sand	7.7	27.2	——	46.332 57.882	0.33489 0.33489	0.32348 0.32348
2	1.50～2.50	Sand	7.7	27.2	——	57.882 65.582	0.33489 0.33489	0.32348 0.32348
3	2.50～3.50	Sand	7.7	27.2	——	65.582 73.282	0.33489 0.33489	0.32348 0.32348
4	3.50～3.63	Sand	7.7	27.2	——	73.282 74.283	0.33489 0.33489	0.32348 0.32348
5	3.63～4.34	Sand	7.7	27.2	——	74.283 79.750	0.33489 0.33489	0.32348 0.32348
6	4.34～4.52	Sand	7.7	27.2	——	79.750 81.136	0.33489 0.33489	0.32348 0.32348
7	4.52～5.49	Clay	8.2	——	100.0 100.0	81.136 89.090	——	——
8	5.49～5.67	Clay	8.2	——	100.0 100.0	89.090 90.566	——	——
9	5.67～6.84	Clay	8.2	——	100.0 100.0	90.566 100.160	——	——
10	6.84～7.84	Clay	8.2	——	180.0 180.0	100.160 108.360	——	——
11	7.84～8.84	Clay	8.2	——	100.0 100.0	108.360 116.560	——	——
12	8.84～9.84	Clay	8.2	——	180.0 180.0	116.560 124.760	——	——
13	9.84～10.84	Clay	8.2	——	100.0 100.0	124.760 132.960	——	——
14	10.84～11.84	Clay	8.2	——	50.0 50.0	132.960 141.160	——	——
15	11.84～12.84	Clay	8.2	——	100.0 100.0	141.160 149.360	——	——
16	12.84～13.84	Clay	8.2	——	100.0 100.0	149.360 157.560	——	——
17	13.84～14.30	Clay	8.2	——	250.0 250.0	157.560 161.332	——	——
18	14.30～24.34	Clay	7.2	——	1000.0 1000.0	161.332 233.620	——	——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ = 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
8	5.49～5.67	Clay	8.2	0.0	100.0 100.0	0.000 1.476	——	——
9	5.67～6.84	Clay	8.2	0.0	100.0 100.0	1.476 11.070	——	——
10	6.84～7.84	Clay	8.2	0.0	180.0 180.0	11.070 19.270	——	——
11	7.84～8.84	Clay	8.2	0.0	100.0 100.0	19.270 27.470	——	——
12	8.84～9.84	Clay	8.2	0.0	180.0 180.0	27.470 35.670	——	——

13	9.84~ 10.84	Clay	8.2	0.0	100.0 100.0	35.670 43.870	———	———
14	10.84~ 11.84	Clay	8.2	0.0	50.0 50.0	43.870 52.070	———	———
15	11.84~ 12.84	Clay	8.2	0.0	100.0 100.0	52.070 60.270	———	———
16	12.84~ 13.84	Clay	8.2	0.0	100.0 100.0	60.270 68.470	———	———
17	13.84~ 14.30	Clay	8.2	0.0	250.0 250.0	68.470 72.242	———	———
18	14.30~ 24.34	Clay	7.2	30.0	1000.0 1000.0	72.242 144.530	———	———

Coefficient of passive earth pressure of sandy soil Kp is calculated by the formula below;
δ= -15.00、β = 0.00、θ = 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.50	14.99 18.72	———	14.99 18.72	0.00 14.70	———
2	1.50~ 2.50	18.72 21.21	———	18.72 21.21	14.70 24.50	———
3	2.50~ 3.50	21.21 23.71	———	21.21 23.71	24.50 34.30	———
4	3.50~ 3.63	23.71 24.03	———	23.71 24.03	34.30 35.57	———
5	3.63~ 4.34	24.03 25.80	———	24.03 25.80	35.57 35.57	———
6	4.34~ 4.52	25.80 26.25	———	25.80 26.25	35.57 35.57	———
7	4.52~ 5.49	-118.86 -110.91	40.57 44.54	40.57 44.54	35.57 35.57	———
8	5.49~ 5.67	-110.91 -109.43	44.54 45.28	44.54 45.28	35.57 35.57	200.00 201.48
9	5.67~ 6.84	-109.43 -99.84	45.28 50.08	45.28 50.08	35.57 35.57	201.48 211.07
10	6.84~ 7.84	-259.84 -251.64	50.08 54.18	50.08 54.18	35.57 35.57	371.07 379.27
11	7.84~ 8.84	-91.64 -83.44	54.18 58.28	54.18 58.28	35.57 35.57	219.27 227.47
12	8.84~ 9.84	-243.44 -235.24	58.28 62.38	58.28 62.38	35.57 35.57	387.47 395.67
13	9.84~ 10.84	-75.24 -67.04	62.38 66.48	62.38 66.48	35.57 35.57	235.67 243.87
14	10.84~ 11.84	32.96 41.16	66.48 70.58	66.48 70.58	35.57 35.57	143.87 152.07
15	11.84~ 12.84	-58.84 -50.64	70.58 74.68	70.58 74.68	35.57 35.57	252.07 260.27
16	12.84~ 13.84	-50.64 -42.44	74.68 78.78	74.68 78.78	35.57 35.57	260.27 268.47
17	13.84~ 14.30	-342.44 -338.67	78.78 80.67	78.78 80.67	35.57 35.57	568.47 572.24
18	14.30~ 24.34	-1838.67 -1766.38	80.67 116.81	80.67 116.81	35.57 35.57	2072.24 2144.53

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_a \cdot (\Sigma\gamma h + Q)$
K_a : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

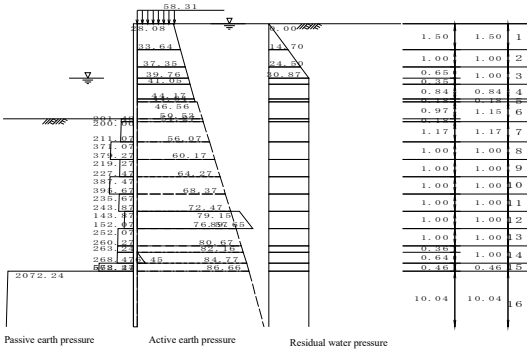
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	$\Sigma\gamma h+Q$ kN/m2	γ whw kN/m2	k (k')	θ degree	Ka	Ka × cos δ	ζ degree
1	0.00~ 1.50	Sand	7.7	27.2	——— ———	58.31 69.86	0.00 14.70	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
2	1.50~ 2.50	Sand	7.7	27.2	——— ———	69.86 77.56	14.70 24.50	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
3	2.50~ 3.15	Sand	7.7	27.2	——— ———	77.56 82.57	24.50 30.87	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
4	3.15~ 3.50	Sand	7.7	27.2	——— ———	82.57 85.26	30.87 34.30	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
5	3.50~ 4.34	Sand	7.7	27.2	——— ———	85.26 91.73	34.30 42.53	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
6	4.34~ 4.52	Sand	7.7	27.2	——— ———	91.73 93.12	42.53 44.30	0.200 0.200	11.31 11.31	0.49850 0.49850	0.48152 0.48152	——— ———
7	4.52~ 5.49	Clay	8.2	———	100.0 100.0	93.12 101.07	44.30 53.80	0.200 0.200	11.31 11.31	——— ———	——— ———	42.65 42.52
8	5.49~ 5.67	Clay	8.2	———	100.0 100.0	101.07 102.55	53.80 55.57	0.200 0.200	11.31 11.31	——— ———	——— ———	42.52 42.49
9	5.67~ 6.84	Clay	8.2	———	100.0 100.0	102.55 112.14	55.57 67.03	0.200 0.200	11.31 11.31	——— ———	——— ———	42.49 42.33
10	6.84~ 7.84	Clay	8.2	———	180.0 180.0	112.14 120.34	67.03 76.83	0.200 0.200	11.31 11.31	——— ———	——— ———	43.58 43.50
11	7.84~ 8.84	Clay	8.2	———	100.0 100.0	120.34 128.54	76.83 86.63	0.200 0.200	11.31 11.31	——— ———	——— ———	42.19 42.04
12	8.84~ 9.84	Clay	8.2	———	180.0 180.0	128.54 136.74	86.63 96.43	0.200 0.200	11.31 11.31	——— ———	——— ———	43.43 43.36
13	9.84~ 10.84	Clay	8.2	———	100.0 100.0	136.74 144.94	96.43 106.23	0.200 0.200	11.31 11.31	——— ———	——— ———	41.90 41.75
14	10.84~ 11.84	Clay	8.2	———	50.0 50.0	144.94 153.14	106.23 116.03	0.200 0.200	11.31 11.31	——— ———	——— ———	37.61 37.22
15	11.84~ 12.84	Clay	8.2	———	100.0 100.0	153.14 161.34	116.03 125.83	0.200 0.200	11.31 11.31	——— ———	——— ———	41.61 41.46
16	12.84~ 13.20	Clay	8.2	———	100.0 100.0	161.34 164.31	125.83 ———	0.200 ———	11.31 ———	——— ———	——— ———	41.46 ———
17	13.20~ 13.84	Clay	8.2	———	100.0 100.0	164.31 169.54	——— 135.63	——— 0.200	——— 11.31	——— ———	——— ———	——— 41.31
18	13.84~ 14.30	Clay	8.20	0.0	250.0 250.0	68.470 72.242	81.83 86.34	0.200 0.200	11.31 11.31	——— ———	——— ———	——— ———
19	14.30~ 24.34	Clay	7.20	30.0	1000.0 1000.0	72.242 144.530	86.34 184.73	0.200 0.200	11.31 11.31	——— ———	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	$\Sigma\gamma h+Qp$ kN/m2	γ whw kN/m2	k (k')	θ degree	Kp	Kp × cos δ
8	5.49~ 5.67	Clay	8.20	0.0	100.0 100.0	0.000 1.476	0.00 1.76	0.200 0.200	11.31 11.31	——— ———	——— ———
9	5.67~ 6.84	Clay	8.20	0.0	100.0 100.0	1.476 11.070	1.76 13.23	0.200 0.200	11.31 11.31	——— ———	——— ———
10	6.84~ 7.84	Clay	8.20	0.0	180.0 180.0	11.070 19.270	13.23 23.03	0.200 0.200	11.31 11.31	——— ———	——— ———

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.
δ = 0.00 degrees, β = 0.00 degrees
Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.50	28.08 33.64	———	28.08 33.64	0.00 14.70	———
2	1.50~ 2.50	33.64 37.35	———	33.64 37.35	14.70 24.50	———
3	2.50~ 3.15	37.35 39.76	———	37.35 39.76	24.50 30.87	———
4	3.15~ 3.50	39.76 41.05	———	39.76 41.05	30.87 30.87	———
5	3.50~ 4.34	41.05 44.17	———	41.05 44.17	30.87 30.87	———
6	4.34~ 4.52	44.17 44.84	———	44.17 44.84	30.87 30.87	———
7	4.52~ 5.49	-87.34 -77.64	46.56 50.53	46.56 50.53	30.87 30.87	———
8	5.49~ 5.67	-77.64 -75.84	50.53 51.27	50.53 51.27	30.87 30.87	200.00 201.48
9	5.67~ 6.84	-75.84 -64.11	51.27 56.07	51.27 56.07	30.87 30.87	201.48 211.07
10	6.84~ 7.84	-224.73 -214.79	56.07 60.17	56.07 60.17	30.87 30.87	371.07 379.27

11	7.84~ 8.84	-54.07 -44.02	60.17 64.27	60.17 64.27	30.87 30.87	219.27 227.47
12	8.84~ 9.84	-204.85 -194.89	64.27 68.37	64.27 68.37	30.87 30.87	387.47 395.67
13	9.84~ 10.84	-33.96 -23.88	68.37 72.47	68.37 72.47	30.87 30.87	235.67 243.87
14	10.84~ 11.84	79.15 89.65	72.47 76.57	79.15 89.65	30.87 30.87	143.87 152.07
15	11.84~ 12.84	-13.78 -3.67	76.57 80.67	76.57 80.67	30.87 30.87	252.07 260.27
16	12.84~ 13.20	-3.67 0.00	80.67 82.16	80.67 82.16	30.87 30.87	260.27 263.24
17	13.20~ 13.84	0.00 6.45	82.16 84.77	82.16 84.77	30.87 30.87	263.24 268.47
18	13.84~ 14.30	-295.46 -290.89	84.77 86.66	84.77 86.66	30.87 30.87	568.47 572.24
19	14.30~ 24.34	-1791.76 -1704.76	86.66 122.80	86.66 122.80	30.87 30.87	2072.24 2144.53

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma \gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	3.15	0.00	0.00
2	4.15	1.00	2.62
3	5.15	2.00	3.71
4	5.49	2.34	4.01

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

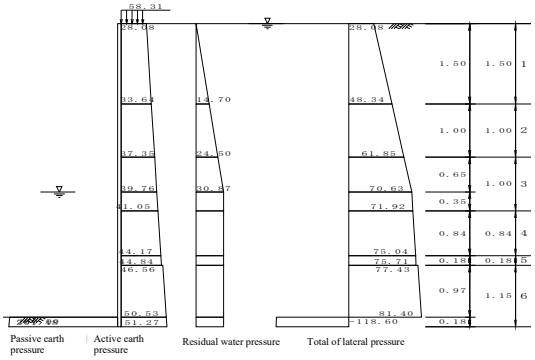
Where,
k_{hs}: design seismic coefficient
γ_w : unit weight of water
H : water depth of riverside
y : depth from water surface to the point where active water pressure is calculated

5	3.63~ 4.34	24.03 25.80	35.57 35.57	——— ———	59.60 61.37
6	4.34~ 4.52	25.80 26.25	35.57 35.57	——— ———	61.37 61.82
7	4.52~ 5.49	40.57 44.54	35.57 35.57	——— ———	76.14 80.12
8	5.49~ 5.67	44.54 45.28	35.57 35.57	200.00 201.48	-119.88 -120.62

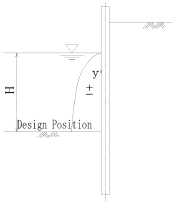
P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.49 m)

4.2 Seismic Condition



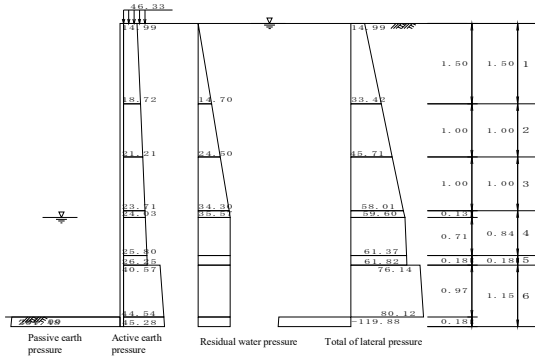
No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	28.08 33.64	0.00 14.70	——— ———	28.08 48.34
2	1.50~ 2.50	33.64 37.35	14.70 24.50	——— ———	48.34 61.85
3	2.50~ 3.15	37.35 39.76	24.50 30.87	——— ———	61.85 70.63
4	3.15~ 3.50	39.76 41.05	30.87 30.87	——— ———	70.63 71.92
5	3.50~ 4.34	41.05 44.17	30.87 30.87	——— ———	71.92 75.04
6	4.34~ 4.52	44.17 44.84	30.87 30.87	——— ———	75.04 75.71



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	14.99 18.72	0.00 14.70	——— ———	14.99 33.42
2	1.50~ 2.50	18.72 21.21	14.70 24.50	——— ———	33.42 45.71
3	2.50~ 3.50	21.21 23.71	24.50 34.30	——— ———	45.71 58.01
4	3.50~ 3.63	23.71 24.03	34.30 35.57	——— ———	58.01 59.60

7	4.52~ 5.49	46.56 50.53	30.87 30.87	——— ———	77.43 81.40
8	5.49~ 5.67	50.53 51.27	30.87 30.87	200.00 201.48	-118.60 -119.33

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.49 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$K_h = K_{h0}(\frac{B_{II}}{0.3})^{-3/4}$ (B_{II}=10.00m)

$K_{h0} = \frac{1}{0.3}\alpha E_0$ (α :Normal Condition =1, Seismi Condition =2)

$E_h = 2800N'$

where:

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$

Material Name		10 H _ H 950 -250 -16 -22 -18	
Unit width	B	= 1.0000 m	
Corrosion margin	t_1	= 1.00 mm (active side)	t_2 = 1.00 mm (passive side)
Corrosion rate	η	= 0.86	
Section efficiency	μ	= 1.00	
Young's modulus	E	= 200000 N/mm^2	
Inertia sectional moment	I_0	= 688700 cm^4(original condition)	
	I	= 592282 cm^4(after reduction by corrosion and section)	
Inertia sectional moment	EI	= $200000 \times 10^3 \times 592282 \times 10^{-8} = 1.185 \times 10^5$	

No	Depth m	N Value
1	1.00	10
2	2.00	10
3	3.00	10
4	4.00	10
5	5.00	10
6	6.34	12
7	7.34	23
8	8.34	13
9	9.34	18
10	10.34	12

No	Depth m	N Value
11	11.34	6
12	12.34	10
13	13.34	14
14	14.34	50
15	15.34	50
16	16.34	50
17	17.34	50
18	18.34	50
19	19.34	50
20	20.34	50

No	Depth m	N Value
21	21.34	50
22	22.34	50
23	23.34	50
24	24.34	50

5.2 Normal Condition

Assuming Kh = 10600 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}} = 0.217 \ m^{-1}$$

$$L = \frac{1}{\beta} = 4.60 \ m$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.49 m) to 4.60 m depth (GL -10.09 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.49	0.85	10.7	12.0	9.66
2	6.34	1.00	12.0	23.0	17.50
3	7.34	1.00	23.0	13.0	18.00
4	8.34	1.00	13.0	18.0	15.50
5	9.34	0.75	18.0	13.5	11.79
	L = Σh = 4.60		Σ A =	72.45	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{72.45}{4.60} = 15.76$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 15.76 = 44117 \ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 44117 = 147057 \ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 147057(10.00/0.3)^{-3/4} = 10600 \ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 10600 kN/m3.

5.3 Seismic Condition

Assuming Kh = 21213 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}} = 0.259 \ m^{-1}$$

$$L = \frac{1}{\beta} = 3.87 \ m$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.49 m) and 3.87 m depth (GL -9.36 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.49	0.85	10.7	12.0	9.66
2	6.34	1.00	12.0	23.0	17.50
3	7.34	1.00	23.0	13.0	18.00
4	8.34	1.00	13.0	18.0	15.50
5	9.34	0.02	18.0	17.9	0.29
	L = Σh = 3.87		Σ A =	60.95	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{60.95}{3.87} = 15.77$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 15.77 = 44143 \ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 44143 = 294283 \ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 294283(10.00/0.3)^{-3/4} = 21213 \ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 21213 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	14.99 33.42	11.24 25.07	4.99 4.49	56.09 112.55
2	1.50~ 2.50	1.00	33.42 45.71	16.71 22.86	3.66 3.32	61.11 75.96
3	2.50~ 3.50	1.00	45.71 58.01	22.86 29.00	2.66 2.32	60.72 67.38
4	3.50~ 3.63	0.13	58.01 59.60	3.77 3.87	1.95 1.90	7.34 7.37
5	3.63~ 4.34	0.71	59.60 61.37	21.16 21.79	1.62 1.39	34.35 30.21
6	4.34~ 4.52	0.18	61.37 61.82	5.52 5.56	1.09 1.03	6.02 5.73
7	4.52~ 5.49	0.97	76.14 80.12	36.93 38.86	0.65 0.32	23.88 12.56
	Σ P = 265.20		Σ M = 561.29			

Ps : active earth pressure + residual water pressure - passive earth pressure
P : load Ps x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 23.4 kN/m
depth to acting position H_t = 0.0 m
moment M_m = 0.0 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 5.49 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m$ = 128.47 kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{689.76}{288.60} = 2.39 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 288.60}{5.49} = 105.14 \ kN/m$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.50	1.50	28.08 48.34	21.06 36.25	4.99 4.49	105.08 162.78
2	1.50~ 2.50	1.00	48.34 61.85	24.17 30.92	3.66 3.32	88.38 102.77
3	2.50~ 3.15	0.65	61.85 70.63	20.10 22.95	2.77 2.56	55.74 58.69
4	3.15~ 3.50	0.35	70.63 71.92	12.36 12.59	2.22 2.11	27.48 26.52
5	3.50~ 4.34	0.84	71.92 75.04	30.21 31.52	1.71 1.43	51.66 45.07
6	4.34~ 4.52	0.18	75.04 75.71	6.75 6.81	1.09 1.03	7.36 7.02
7	4.52~ 5.49	0.97	77.43 81.40	37.55 39.48	0.65 0.32	24.28 12.77
	Σ P = 332.73		Σ M = 775.59			

Ps : active earth pressure + residual water pressure - passive earth pressure
P : load Ps x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 62.8 kN/m
depth to acting position H_t = 0.00 m
moment M_m = 33.9 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 5.49 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m$ = 378.69 kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	3.15~ 4.15	1.00	0.0 2.6	0.00 1.31	2.01 1.67	0.00 2.19
2	4.15~ 5.15	1.00	2.6 3.7	1.31 1.86	1.01 0.67	1.32 1.25
3	5.15~ 5.49	0.34	3.7 4.0	0.63 0.68	0.23 0.11	0.14 0.08
			Σ Pdw = 5.79	Σ Mdw = 4.98		

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1159.25}{401.32} = 2.89 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 401.32}{5.49} = 146.20 \ kN/m$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name 10 H _ H 950 -250 -16 -22 -18
Unit width B = 1.0000 m
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.86
Section efficiency μ = 1.00
Young's modulus E = 200000 N/mm²
Inertia sectional moment I_0 = 688700 cm⁴ (original condition)
I = 592282 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10^3 × 592282 × 10^{-8} = 1.185 × 10^6

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} \left(\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x\right)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	10600 kN/m³
calculated value	β	=	0.21748 m⁻¹
resultant earth force (lateral)	P_0	=	288.60 kN/m
height of acting position of load	h_0	=	2.39 m
Moment	M_0	=	689.76 kN·m/m
in consideration of ψ_m = 1.385,			
maximum moment	M_{max}	=	955.40 kN·m/m
depth of generated position of M_{max}	l_m	=	2.096 m
depth of 1st fixed point	l_i	=	5.707 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	21213 kN/m³
calculated value	β	=	0.25867 m⁻¹
resultant earth force (lateral)	P_0	=	401.32 kN/m
height of acting position of load	h_0	=	2.89 m
moment	M_0	=	1159.25 kN·m/m
in consideration of ψ_m = 1.228,			
maximum moment	M_{max}	=	1423.82 kN·m/m
depth of generated position of M_{max}	l_m	=	1.474 m
depth of 1st fixed point	l_i	=	4.510 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 950 -250 -16 -22 -18		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.88
Section efficiency	μ	=	1.00
Module of section	Z_0	=	10570 cm³ (original condition)
	Z	=	9302 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{955.40\times10^6}{9302\times10^3} = 103 \text{ N/mm}^2 \leqq \sigma_a = 180 \text{ N/mm}^2$$

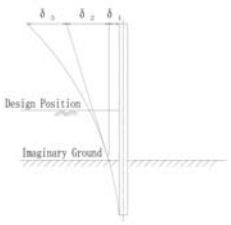
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1423.82\times10^6}{9302\times10^3} = 153 \text{ N/mm}^2 \leqq \sigma_a = 270 \text{ N/mm}^2$$

6.4 Displacement Calculation

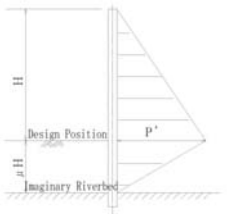
6.4.1 Normal Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.2175\times2.39)\times288.60}{2\times2.00\times10^8\times592282\times10^{-8}\times0.2175^3} = 0.01800 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.2175\times2.39)\times288.60}{2\times2.00\times10^8\times592282\times10^{-8}\times0.2175^2}\times(5.49+0.00) = 0.02884 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.49} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{105.14\times5.49^4}{120\times2.00\times10^8\times592282\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4)$$

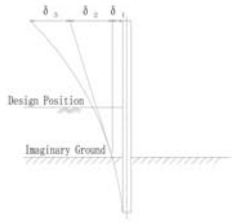
$$= 0.00269 \text{ m}$$

$\delta = \delta1 + \delta2 + \delta3$
$= 0.01800 + 0.02884 + 0.00269$
$= 0.04952$ m
Size = 49.52 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

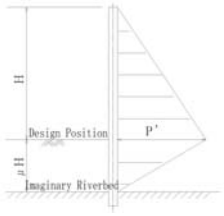
6.4.2 Seismic Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.2587\times2.89)\times401.32}{2\times2.00\times10^8\times592282\times10^{-8}\times0.2587^3} = 0.01710 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k) = \frac{(1+2\times0.2587\times2.89)\times401.32}{2\times2.00\times10^8\times592282\times10^{-8}\times0.2587^2}\times(5.49+0.00) = 0.03467 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.49} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{146.20\times5.49^4}{120\times2.00\times10^8\times592282\times10^{-8}}(4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4)$$

$$= 0.00374 \text{ m}$$

$\delta = \delta1 + \delta2 + \delta3$
$= 0.01710 + 0.03467 + 0.00374$
$= 0.05551$ m
Size = 55.51 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name	10 H _ H 950 -250 -16 -22 -18		
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²

Inertia sectional moment I_0 = 688700 cm^4 (original condition)
I = 688700 cm^4 (after reduction by corrosion and section)
$EI = 200000 \times 10^3 \times 688700 \times 10^{-8}$ = 1.377×10^6

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$
$$L = H - H_{ls} + D$$
$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 10600 kN/m^3
Calculated value β = 0.20944 m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.209} = 14.32$ m
Whole length of SSP $L = 5.49 - 0.40 + 14.32 = 19.41$ m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction K_h = 21213 kN/m^3
Calculated value β = 0.24910 m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.249} = 12.04$ m
Whole length of SSP $L = 5.49 - 0.40 + 12.04 = 17.13$ m

Therefore, the total length of the sheet pile is 19.50 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 10 H _ H 950 -250 -16 -22 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	688700		
Sectional Modulus	Z (cm3)	10570		
Maximum bending moment	Mmax (kN・m・m)		955.40	1423.82
Stress intensity	σ (N/mm2)		103 (180)	153 (270)
Lateral displacement	δ (mm)		49.52 (50.0)	55.51 (75.0)
Penetration depths	D (m)		14.32	12.04
Whole length of SSP	L (m)	19.50		

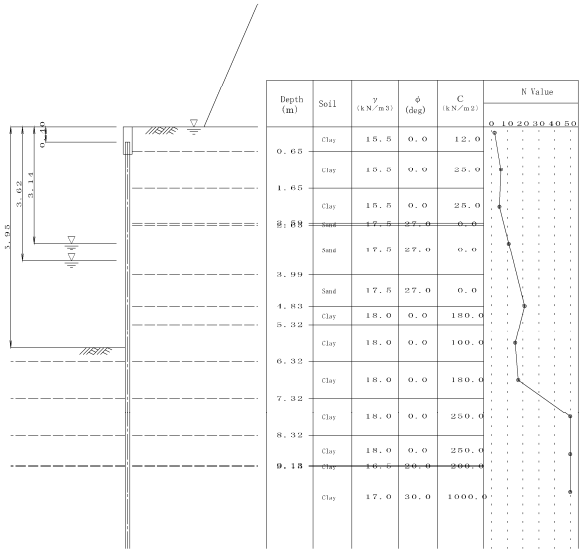
Block No. : R-14
Sta. : 8+500~8+620

Design Cross Section : Sta 8+500
Boring Name : DD-BH-R09

Specification : SSP SP-10H
(Combined) : H 950-250-16-22-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	5.95 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_{ls}	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	3.62 m (Normal Condition)
	L_{wp}'	=	3.14 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress Chang's formula

Penetration depths $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water γ_w = 9.8 kN/m^3

Type of water pressure trapezoidal water pressure

Lateral pressure calculated in consideration of site conditions

Study case
- Normal Condition
- Seismic Condition

Design earthquake intensity k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt =	23.4 kN/m	(Normal Condition)
		Pt' =	62.8 kN/m	(Seismic Condition)
	Depth of acting point	Ht =	0.0 m	(Normal Condition)
		Ht' =	0.0 m	(Seismic Condition)
	Moment	M_m =	0.0 kN・m/m	(Normal Condition)
		M_m' =	33.9 kN・m/m	(Seismic Condition)
	Depth of acting point	H_m' =	0.00 m	(Seismic Condition)
		H_m =	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load not considered

Minimum angle of rupture ζ_0 = 10 degrees

Rear side angle of slope not considered

Angle of rupture (clayey soil)
$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2 - a^2}}$$
$$a = \sin\theta$$
$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h + Q}$$

Equilibrium factor of compression K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula
$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$
$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$
B_H = 10.00 m
E_0 = 2800N

Average N-value calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value
1	0.15	2
2	1.15	6
3	2.15	5
4	3.15	11
5	4.82	21
6	5.82	15
7	6.82	17
8	7.82	50
9	8.82	50
10	9.82	50
11	10.82	50

1.6 Vertical Load

Vertical load on landside　　calculated in consideration of embankment shape on landside

Vertical load on riverside　　not considered

1.7 Soil Modulus

Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	0.65	0.65
2	1.65	1.00
3	2.59	0.94
4	2.65	0.06
5	3.99	1.34
6	4.83	0.84
7	5.32	0.49
8	6.32	1.00
9	7.32	1.00
10	8.32	1.00
11	9.13	0.81
12	9.15	0.02
13	10.82	1.67

No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	0.65	C	2.0	15.50	5.70	0.0	12.0	0.0	0.200	Auto	Auto
2	1.65	C	6.0	15.50	5.70	0.0	25.0	0.0	0.200	Auto	Auto
3	2.59	C	5.0	15.50	5.70	0.0	25.0	0.0	0.200	Auto	Auto
4	2.65	S	5.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
5	3.99	S	5.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
6	4.83	S	5.0	17.50	7.70	27.0	0.0	0.0	0.200	Auto	Auto
7	5.32	C	21.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
8	6.32	C	15.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
9	7.32	C	17.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
10	8.32	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
11	9.13	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
12	9.15	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto
13	10.82	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note)　depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

1.9 Steel Sheet Pile (SSP)

Material name　10 H _ H 950 -250 -16 -22 -18
Young's modulus　E = 200000 N/mm²
Inertia sectional moment　I_0 = 688700 cm⁴
Sectional factor　Z_0 = 10570 cm³

Corrosion margin　t_1 = 1.00 mm (riverside)　t_2 = 1.00 mm (landside)

Corrosion rate (to I_0)　η = 0.86
Corrosion rate (to Z_0)　η = 0.88
Section efficiency (to I_0)　μ = 1.00
Section efficiency (to Z_0)　μ = 1.00

Round unit of SSP length　0.50 m

Allowable stress　σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

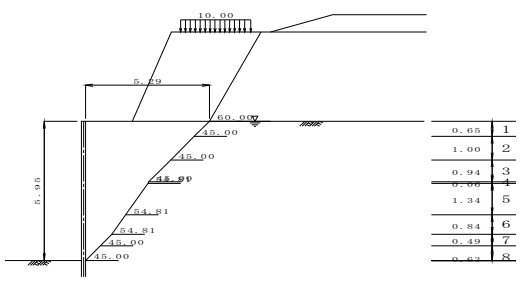
Allowable displacement　δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam　calculated as distributed load of each layer

Reduction of material modulus　Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

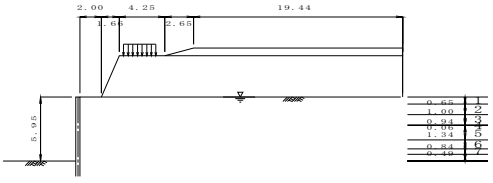
2.1 Normal Condition



Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	2.00	3.66	30.00	30.00	3.82	19.0	19.0	30.0	0.0	Auto	Auto
2	Sand	7.91	10.56	30.00	30.00	0.74	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	End point m	load strength Normal Condition kN/m2	Seismic Condition kN/m2
1	4.06	7.06	10.0	5.0

Angle of rapture in embankment　　calculated in consideration of embankment conditions

2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	5.95 ~ 5.32	Clay	0.0	15.0	100.0	41.19	54.55	58.31	45.00
2	5.32 ~ 4.83	Clay	0.0	15.0	180.0	36.03	54.55	52.14	45.00
3	4.83 ~ 3.99	Sand	27.0	15.0	0.0	32.01	54.55	47.33	54.81
4	3.99 ~ 2.65	Sand	27.0	15.0	0.0	25.54	54.55	39.10	54.81
5	2.65 ~ 2.59	Sand	27.0	15.0	0.0	15.23	54.55	25.97	54.81
6	2.59 ~ 1.65	Clay	0.0	15.0	25.0	14.76	54.55	25.38	45.00
7	1.65 ~ 0.65	Clay	0.0	15.0	25.0	9.40	54.55	16.17	45.00
8	0.65 ~ 0.00	Clay	0.0	15.0	12.0	3.70	54.55	6.37	45.00
9		embankment	30.0	———	0.0	86.64	0.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = $\tan^{-1}$k or θ = $\tan^{-1}$k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C : cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	45.00	0.63	0.00	0.00	0.63	0.63
2	45.00	0.49	0.63	0.63	1.12	1.12
3	54.81	0.84	1.12	1.12	1.71	1.96
4	54.81	1.34	1.71	1.96	2.66	3.30
5	54.81	0.06	2.66	3.30	2.70	3.36
6	45.00	0.94	2.70	3.36	3.64	4.30
7	45.00	1.00	3.64	4.30	4.64	5.30
8	45.00	0.65	4.64	5.30	5.29	5.95
9	60.00	3.82	5.29	5.95	7.50	9.77

From the above table, the loading width (L) on the ground surface is 5.29 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	13.61	258.55
Σ			258.55

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	10.0	3.00	30.00
Σ			30.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

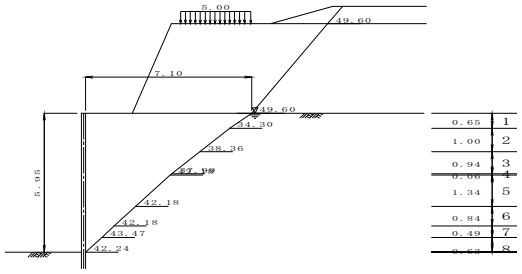
2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{258.55 + 30.00 + 0.00}{5.29}$$

$$= 54.55 \ kN/m^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	5.95 ~ 5.32	Clay	0.0	15.0	100.0	41.19	65.22	58.31	0.200	11.31	42.24
2	5.32 ~ 4.83	Clay	0.0	15.0	180.0	36.03	65.22	52.14	0.200	11.31	43.47
3	4.83 ~ 3.99	Sand	27.0	15.0	0.0	32.01	65.22	47.33	0.200	11.31	42.18
4	3.99 ~ 2.65	Sand	27.0	15.0	0.0	25.54	65.22	39.10	0.200	11.31	42.18
5	2.65 ~ 2.59	Sand	27.0	15.0	0.0	15.23	65.22	25.97	0.200	11.31	42.18
6	2.59 ~ 1.65	Clay	0.0	15.0	25.0	14.76	65.22	25.38	0.200	11.31	37.99
7	1.65 ~ 0.65	Clay	0.0	15.0	25.0	9.40	65.22	16.17	0.200	11.31	38.36
8	0.65 ~ 0.00	Clay	0.0	15.0	12.0	3.70	65.22	6.37	0.200	11.31	34.30
9		embankment	30.0	——	0.0	86.64	0.00	0.00	0.200	11.31	49.60
10		embankment	30.0	——	0.0	14.06	0.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h + Q}$$

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- φ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	42.24	0.63	0.00	0.00	0.69	0.63
2	43.47	0.49	0.69	0.63	1.21	1.12
3	42.18	0.84	1.21	1.12	2.14	1.96
4	42.18	1.34	2.14	1.96	3.62	3.30
5	42.18	0.06	3.62	3.30	3.68	3.36
6	37.99	0.94	3.68	3.36	4.89	4.30
7	38.36	1.00	4.89	4.30	6.15	5.30
8	34.30	0.65	6.15	5.30	7.10	5.95
9	49.60	3.82	7.10	5.95	10.35	9.77
10	49.60	0.74	10.35	9.77	10.98	10.51

From the above table, the loading width (L) on the ground surface is 7.10 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	22.53	428.10
2	19.0	1.06	20.15
Σ			448.26

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	5.0	3.00	15.00
Σ			15.00

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

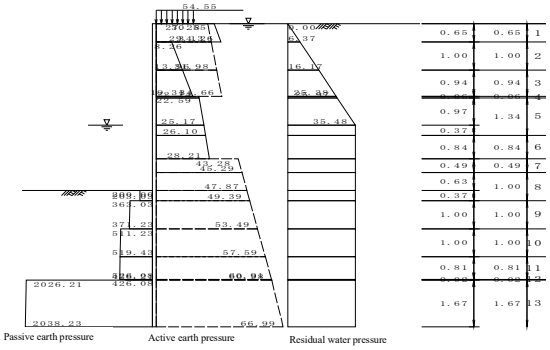
$$Q = \frac{\Sigma(\gamma \times A)+\Sigma(Q \times l)+\Sigma P}{L}$$

$$= \frac{448.26 + 15.00 + 0.00}{7.10}$$

$$= 65.22 \ kN/m^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh + Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 0.65	Clay	5.7	——	12.0 12.0	54.551 58.256	—— ——	—— ——
2	0.65~ 1.65	Clay	5.7	——	25.0 25.0	58.256 63.956	—— ——	—— ——
3	1.65~ 2.59	Clay	5.7	——	25.0 25.0	63.956 69.314	—— ——	—— ——
4	2.59~ 2.65	Sand	7.7	27.0	—— ——	69.314 69.776	0.33738 0.33738	0.32589 0.32589
5	2.65~ 3.62	Sand	7.7	27.0	—— ——	69.776 77.245	0.33738 0.33738	0.32589 0.32589
6	3.62~ 3.99	Sand	7.7	27.0	—— ——	77.245 80.094	0.33738 0.33738	0.32589 0.32589
7	3.99~ 4.83	Sand	7.7	27.0	—— ——	80.094 86.562	0.33738 0.33738	0.32589 0.32589
8	4.83~ 5.32	Clay	8.2	——	180.0 180.0	86.562 90.580	—— ——	—— ——
9	5.32~ 5.95	Clay	8.2	——	100.0 100.0	90.580 95.746	—— ——	—— ——
10	5.95~ 6.32	Clay	8.2	——	100.0 100.0	95.746 98.780	—— ——	—— ——
11	6.32~ 7.32	Clay	8.2	——	180.0 180.0	98.780 106.980	—— ——	—— ——
12	7.32~ 8.32	Clay	8.2	——	250.0 250.0	106.980 115.180	—— ——	—— ——

13	8.32~ 9.13	Clay	8.2	——	250.0 250.0	115.180 121.822	—— ——	—— ——
14	9.13~ 9.15	Clay	6.7	——	200.0 200.0	121.822 121.956	—— ——	—— ——
15	9.15~ 10.82	Clay	7.2	——	1000.0 1000.0	121.956 133.980	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cosδ
10	5.95~ 6.32	Clay	8.2	0.0	100.0 100.0	0.000 3.034	—— ——	—— ——
11	6.32~ 7.32	Clay	8.2	0.0	180.0 180.0	3.034 11.234	—— ——	—— ——
12	7.32~ 8.32	Clay	8.2	0.0	250.0 250.0	11.234 19.434	—— ——	—— ——
13	8.32~ 9.13	Clay	8.2	0.0	250.0 250.0	19.434 26.076	—— ——	—— ——
14	9.13~ 9.15	Clay	6.7	20.0	200.0 200.0	26.076 26.210	—— ——	—— ——
15	9.15~ 10.82	Clay	7.2	30.0	1000.0 1000.0	26.210 38.234	—— ——	—— ——

Coefficient of passive earth pressure of sandy soil Kp is calculated by the formula below;
δ= -15.00、β = 0.00、θ = 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.65	30.55 34.26	27.28 29.13	30.55 34.26	0.00 6.37	——
2	0.65~ 1.65	8.26 13.96	29.13 31.98	29.13 31.98	6.37 16.17	——
3	1.65~ 2.59	13.96 19.31	31.98 34.66	31.98 34.66	16.17 25.38	——
4	2.59~ 2.65	22.59 22.74	——	22.59 22.74	25.38 25.97	——
5	2.65~ 3.62	22.74 25.17	——	22.74 25.17	25.97 35.48	——
6	3.62~ 3.99	25.17 26.10	——	25.17 26.10	35.48 35.48	——
7	3.99~ 4.83	26.10 28.21	——	26.10 28.21	35.48 35.48	——
8	4.83~ 5.32	-273.44 -269.42	43.28 45.29	43.28 45.29	35.48 35.48	——
9	5.32~ 5.95	-109.42 -104.25	45.29 47.87	45.29 47.87	35.48 35.48	——
10	5.95~ 6.32	-104.25 -101.22	47.87 49.39	47.87 49.39	35.48 35.48	200.00 203.03
11	6.32~ 7.32	-261.22 -253.02	49.39 53.49	49.39 53.49	35.48 35.48	363.03 371.23
12	7.32~ 8.32	-393.02 -384.82	53.49 57.59	53.49 57.59	35.48 35.48	511.23 519.43
13	8.32~ 9.13	-384.82 -378.18	57.59 60.91	57.59 60.91	35.48 35.48	519.43 526.08
14	9.13~ 9.15	-278.18 -278.04	60.91 60.98	60.91 60.98	35.48 35.48	426.08 426.21
15	9.15~ 10.82	-1878.04 -1866.02	60.98 66.99	60.98 66.99	35.48 35.48	2026.21 2038.23

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

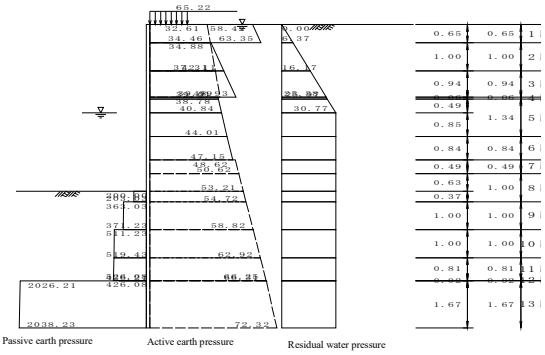
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 0.65	Clay	5.7	——	12.0 12.0	65.22 68.92	0.00 6.37	0.200 0.200	11.31 11.31	—— ——	—— ——	34.69 34.30
2	0.65~ 1.65	Clay	5.7	——	25.0 25.0	68.92 74.62	6.37 16.17	0.200 0.200	11.31 11.31	—— ——	—— ——	38.76 38.36
3	1.65~ 2.59	Clay	5.7	——	25.0 25.0	74.62 79.98	16.17 25.38	0.200 0.200	11.31 11.31	—— ——	—— ——	38.36 37.99
4	2.59~ 2.65	Sand	7.7	27.0	—— ——	79.98 80.44	25.38 25.97	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
5	2.65~ 3.14	Sand	7.7	27.0	—— ——	80.44 84.22	25.97 30.77	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
6	3.14~ 3.99	Sand	7.7	27.0	—— ——	84.22 90.76	30.77 39.10	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
7	3.99~ 4.83	Sand	7.7	27.0	—— ——	90.76 97.23	39.10 47.33	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——
8	4.83~ 5.32	Clay	8.2	——	180.0 180.0	97.23 101.25	47.33 52.14	0.200 0.200	11.31 11.31	—— ——	—— ——	43.53 43.47
9	5.32~ 5.95	Clay	8.2	——	100.0 100.0	101.25 106.41	52.14 58.31	0.200 0.200	11.31 11.31	—— ——	—— ——	42.36 42.24
10	5.95~ 6.32	Clay	8.2	——	100.0 100.0	106.41 109.45	58.31 61.94	0.200 0.200	11.31 11.31	—— ——	—— ——	42.24 42.17
11	6.32~ 7.32	Clay	8.2	——	180.0 180.0	109.45 117.65	61.94 71.74	0.200 0.200	11.31 11.31	—— ——	—— ——	43.36 43.24
12	7.32~ 8.32	Clay	8.2	——	250.0 250.0	117.65 125.85	71.74 81.54	0.200 0.200	11.31 11.31	—— ——	—— ——	43.71 43.63
13	8.32~ 9.13	Clay	8.2	——	250.0 250.0	125.85 132.49	81.54 89.47	0.200 0.200	11.31 11.31	—— ——	—— ——	43.63 43.56
14	9.13~ 9.15	Clay	6.7	——	200.0 200.0	132.49 132.62	89.47 89.67	0.200 0.200	11.31 11.31	—— ——	—— ——	43.22 43.22
15	9.15~ 10.82	Clay	7.2	——	1000.0 1000.0	132.62 144.65	89.67 106.04	0.200 0.200	11.31 11.31	—— ——	—— ——	44.63 44.59

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$
$$a = \sin\theta$$
$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h + Q}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
10	5.95~ 6.32	Clay	8.20	0.0	100.0 100.0	0.000 3.034	0.00 3.63	0.200 0.200	11.31 11.31	—— ——	—— ——
11	6.32~ 7.32	Clay	8.20	0.0	180.0 180.0	3.034 11.234	3.63 13.43	0.200 0.200	11.31 11.31	—— ——	—— ——
12	7.32~ 8.32	Clay	8.20	0.0	250.0 250.0	11.234 19.434	13.43 23.23	0.200 0.200	11.31 11.31	—— ——	—— ——
13	8.32~ 9.13	Clay	8.20	0.0	250.0 250.0	19.434 26.076	23.23 31.16	0.200 0.200	11.31 11.31	—— ——	—— ——
14	9.13~ 9.15	Clay	6.70	20.0	200.0 200.0	26.076 26.210	31.16 31.36	0.200 0.200	11.31 11.31	—— ——	—— ——
15	9.15~ 10.82	Clay	7.20	30.0	1000.0 1000.0	26.210 38.234	31.36 47.73	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.
δ = 0.00 degrees, β = 0.00 degrees
Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.65	58.42 63.35	32.61 34.46	58.42 63.35	0.00 6.37	——
2	0.65~ 1.65	34.88 42.11	34.46 37.31	34.88 42.11	6.37 16.17	——

3	1.65~ 2.59	42.11 48.93	37.31 39.99	42.11 48.93	16.17 25.38	———
4	2.59~ 2.65	38.78 39.01	———	38.78 39.01	25.38 25.97	———
5	2.65~ 3.14	39.01 40.84	———	39.01 40.84	25.97 30.77	———
6	3.14~ 3.99	40.84 44.01	———	40.84 44.01	30.77 30.77	———
7	3.99~ 4.83	44.01 47.15	———	44.01 47.15	30.77 30.77	———
8	4.83~ 5.32	-242.77 -237.90	48.62 50.62	48.62 50.62	30.77 30.77	———
9	5.32~ 5.95	-77.40 -71.08	50.62 53.21	50.62 53.21	30.77 30.77	———
10	5.95~ 6.32	-71.08 -67.36	53.21 54.72	53.21 54.72	30.77 30.77	200.00 203.03
11	6.32~ 7.32	-227.96 -218.01	54.72 58.82	54.72 58.82	30.77 30.77	363.03 371.23
12	7.32~ 8.32	-358.25 -348.32	58.82 62.92	58.82 62.92	30.77 30.77	511.23 519.43
13	8.32~ 9.13	-348.32 -340.28	62.92 66.25	62.92 66.25	30.77 30.77	519.43 526.08
14	9.13~ 9.15	-240.09 -239.92	66.25 66.31	66.25 66.31	30.77 30.77	426.08 426.21
15	9.15~ 10.82	-1840.67 -1826.21	66.31 72.32	66.31 72.32	30.77 30.77	2026.21 2038.23

- Formula for active earth pressure

Sand $P_{a1}=K_a\cdot[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}]\cdot\cos\delta$

Clay $P_{a1}=\Sigma\gamma h+Q-2C$

$P_{a2}=K_c\cdot(\Sigma\gamma h+Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1}=[K_a(\Sigma\gamma h+Q)-2C\sqrt{K_a}]\cdot\cos\delta$

- Formula for passive earth pressure

Sand $P_p=K_p\cdot[\Sigma\gamma h+\frac{Q}{\cos(-\beta)}]\cdot\cos\delta$

Clay $P_p=\Sigma\gamma h+Q+2C$

Mixed soil $P_p=[K_p(\Sigma\gamma h+Q)+2C\sqrt{K_p}]\cdot\cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	3.14	0.00	0.00
2	4.14	1.00	2.87
3	5.14	2.00	4.07
4	5.95	2.81	4.82

$$p_{dw}=\pm\frac{7}{8}k_{hs}\cdot\gamma_w\cdot\sqrt{H\cdot y}$$

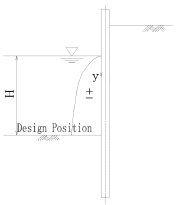
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

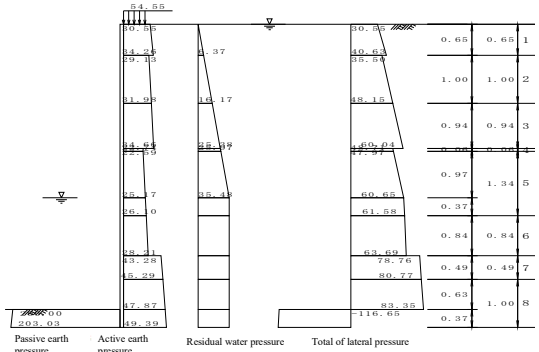
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.65	30.55 34.26	0.00 6.37	———	30.55 40.63
2	0.65~ 1.65	29.13 31.98	6.37 16.17	———	35.50 48.15
3	1.65~ 2.59	31.98 34.66	16.17 25.38	———	48.15 60.04
4	2.59~ 2.65	22.59 22.74	25.38 25.97	———	47.97 48.71
5	2.65~ 3.62	22.74 25.17	25.97 35.48	———	48.71 60.65
6	3.62~ 3.99	25.17 26.10	35.48 35.48	———	60.65 61.58
7	3.99~ 4.83	26.10 28.21	35.48 35.48	———	61.58 63.69
8	4.83~ 5.32	43.28 45.29	35.48 35.48	———	78.76 80.77
9	5.32~ 5.95	45.29 47.87	35.48 35.48	———	80.77 83.35
10	5.95~ 6.32	47.87 49.39	35.48 35.48	200.00 203.03	-116.65 -118.17

P_a : Active earth pressure

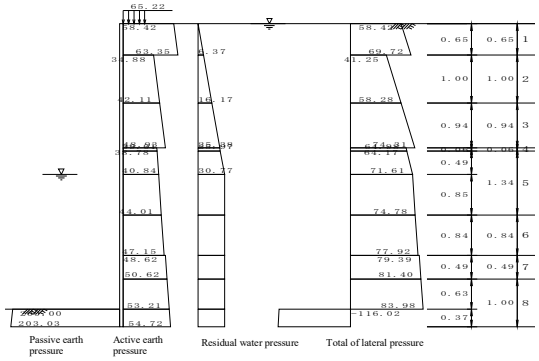
P_w : Residual water pressure

P_p : Passive earth pressure

P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.95 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.65	58.42 63.35	0.00 6.37	———	58.42 69.72
2	0.65~ 1.65	34.88 42.11	6.37 16.17	———	41.25 58.28
3	1.65~ 2.59	42.11 48.93	16.17 25.38	———	58.28 74.31
4	2.59~ 2.65	38.78 39.01	25.38 25.97	———	64.17 64.98
5	2.65~ 3.14	39.01 40.84	25.97 30.77	———	64.98 71.61
6	3.14~ 3.99	40.84 44.01	30.77 30.77	———	71.61 74.78
7	3.99~ 4.83	44.01 47.15	30.77 30.77	———	74.78 77.92
8	4.83~ 5.32	48.62 50.62	30.77 30.77	———	79.39 81.40
9	5.32~ 5.95	50.62 53.21	30.77 30.77	———	81.40 83.98
10	5.95~ 6.32	53.21 54.72	30.77 30.77	200.00 203.03	-116.02 -117.54

P_a : Active earth pressure

P_w : Residual water pressure

P_p : Passive earth pressure

P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -5.95 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$K_h = K_{h0}(\frac{B_{ll}}{0.3})^{-3/4}$ (B_{ll}=10.00m)

$K_{h0}=\frac{1}{0.3}\alpha E_0$ (α :Normal Condition =1, Seismi Condition =2)

$E_h = 2800N'$

where:

$$\beta=\sqrt[4]{\frac{K_h\cdot B}{4EI}}$$

Material Name	10 H _ H 950 -250 -16 -22 -18				
Unit width	B	=	1.0000 m		
Corrosion margin	t_1	=	1.00 mm (active side)	t_2 =	1.00 mm (passive side)
Corrosion rate	η	=	0.86		
Section efficiency	μ	=	1.00		
Young's modulus	E	=	200000 N/mm^2		
Inertia sectional moment	I_0	=	688700 cm^4(original condition)		
	I	=	592282 cm^4(after reduction by corrosion and section)		
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 592282 \times 10^{-8} = 1.185 \times 10^5$		

No	Depth m	N Value
1	0.15	2
2	1.15	6
3	2.15	5
4	3.15	11
5	4.82	21
6	5.82	15
7	6.82	17
8	7.82	50
9	8.82	50
10	9.82	50
11	10.82	50

5.2 Normal Condition

Assuming Kh = 25281 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}} = 0.270 \ m^{-1}$$

$$L = \frac{1}{\beta} = 3.70 \ m$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.95 m) to 3.70 m depth (GL -9.65 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.95	0.87	15.3	17.0	14.03
2	6.82	1.00	17.0	50.0	33.50
3	7.82	1.00	50.0	50.0	50.00
4	8.82	0.83	50.0	50.0	41.50
	L = Σh = 3.70		ΣA = 139.03		

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{139.03}{3.70} = 37.58$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 37.58 = 105215 \ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 105215 = 350718 \ kN/m^3$ (α :Normal Condition =1, Seismic Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 350718(10.00/0.3)^{-3/4} = 25281 \ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 25281 kN/m3.

5.3 Seismic Condition

Assuming Kh = 47688 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}} = 0.317 \ m^{-1}$$

$$L = \frac{1}{\beta} = 3.16 \ m$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -5.95 m) and 3.16 m depth (GL -9.11 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	5.95	0.87	15.3	17.0	14.03
2	6.82	1.00	17.0	50.0	33.50
3	7.82	1.00	50.0	50.0	50.00
4	8.82	0.29	50.0	50.0	14.36
	L = Σh = 3.16		ΣA = 111.89		

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{111.89}{3.16} = 35.44$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 35.44 = 99233 \ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 99233 = 661556 \ kN/m^3$ (α :Normal Condition =1, Seismic Condition =2)

$K_h = K_{h0}(B_H/0.3)^{-3/4} = 661556(10.00/0.3)^{-3/4} = 47688 \ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 47688 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.65	0.65	30.55 40.63	9.93 13.20	5.73 5.52	56.93 72.84
2	0.65~ 1.65	1.00	35.50 48.15	17.75 24.07	4.97 4.63	88.15 111.54
3	1.65~ 2.59	0.94	48.15 60.04	22.63 28.22	3.99 3.67	90.22 103.66
4	2.59~ 2.65	0.06	47.97 48.71	1.44 1.46	3.34 3.32	4.81 4.85
5	2.65~ 3.62	0.97	48.71 60.65	23.62 29.41	2.98 2.65	70.32 78.05
6	3.62~ 3.99	0.37	60.65 61.58	11.22 11.39	2.21 2.08	24.76 23.73
7	3.99~ 4.83	0.84	61.58 63.69	25.86 26.75	1.68 1.40	43.45 37.45
8	4.83~ 5.32	0.49	78.76 80.77	19.30 19.79	0.96 0.79	18.46 15.70
9	5.32~ 5.95	0.63	80.77 83.35	25.44 26.25	0.42 0.21	10.69 5.51
			ΣP = 337.75		ΣM = 861.11	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	23.4 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.95 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 139.23 \ kN \cdot m$
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{1000.34}{361.15} = 2.77 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 361.15}{5.95} = 121.39 \ kN/m$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.65	0.65	58.42 69.72	18.99 22.66	5.73 5.52	108.86 125.01
2	0.65~ 1.65	1.00	41.25 58.28	20.63 29.14	4.97 4.63	102.45 135.01
3	1.65~ 2.59	0.94	58.28 74.31	27.39 34.93	3.99 3.67	109.20 128.30
4	2.59~ 2.65	0.06	64.17 64.98	1.92 1.95	3.34 3.32	6.43 6.47
5	2.65~ 3.14	0.49	64.98 71.61	15.92 17.54	3.14 2.97	49.93 52.17
6	3.14~ 3.99	0.85	71.61 74.78	30.43 31.78	2.53 2.24	76.90 71.30
7	3.99~ 4.83	0.84	74.78 77.92	31.41 32.73	1.68 1.40	52.77 45.82
8	4.83~ 5.32	0.49	79.39 81.40	19.45 19.94	0.96 0.79	18.61 15.82
9	5.32~ 5.95	0.63	81.40 83.98	25.64 26.45	0.42 0.21	10.77 5.56
			ΣP = 408.91		ΣM = 1121.36	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	62.8 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	33.9 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	5.95 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 407.56 \ kN \cdot m$

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	3.14~ 4.14	1.00	0.0 2.9	0.00 1.44	2.48 2.14	0.00 3.08
2	4.14~ 5.14	1.00	2.9 4.1	1.44 2.03	1.48 1.14	2.12 2.32
3	5.14~ 5.95	0.81	4.1 4.8	1.65 1.95	0.54 0.27	0.89 0.53
			ΣPdw = 8.51		Σ Mdw = 8.94	

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1537.86}{480.21} = 3.20 \text{ m}$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 480.21}{5.95} = 161.42 \text{ kN/m}$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name	10 H _ H 950 -250 -16 -22 -18		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.86
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	688700 cm^4 (original condition)
	I	=	592282 cm^4 (after reduction by corrosion and section)

$EI = 200000 \times 10^3 \times 592282 \times 10^{-8} = 1.185 \times 10^6$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

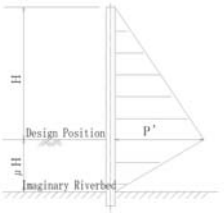
$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	25281 kN/m^3
calculated value	β	=	0.27027 m^{-1}
resultant earth force (lateral)	P_0	=	361.15 kN/m
height of acting position of load	h_0	=	2.77 m
Moment	M_0	=	1000.34 kN·m/m
in consideration of ψ_m = 1.228,			
maximum moment	M_{max}	=	1227.99 kN·m/m
depth of generated position of M_{max}	l_m	=	1.409 m
depth of 1st fixed point	l_i	=	4.315 m

$$\delta_1 = \frac{(1+\beta h_0) \times P_0}{2EI\beta^3} = \frac{(1+0.2703 \times 2.77) \times 361.15}{2 \times 2.00 \times 10^8 \times 592282 \times 10^{-8} \times 0.2703^3} = 0.01350 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0) \times P_0}{2EI\beta^2} \times (H + L_k) = \frac{(1+2 \times 0.2703 \times 2.77) \times 361.15}{2 \times 2.00 \times 10^8 \times 592282 \times 10^{-8} \times 0.2703^2} \times (5.95+0.00) = 0.03101 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.95} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI} (4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{121.39 \times 5.95^4}{120 \times 2.00 \times 10^8 \times 592282 \times 10^{-8}} (4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4) = 0.00428 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
$= 0.01350 + 0.03101 + 0.00428$
$= 0.04879$ m
Size = 48.79 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	47688 kN/m^3
calculated value	β	=	0.31674 m^{-1}
resultant earth force (lateral)	P_0	=	480.21 kN/m
height of acting position of load	h_0	=	3.20 m
moment	M_0	=	1537.86 kN·m/m
in consideration of ψ_m = 1.143,			
maximum moment	M_{max}	=	1757.63 kN·m/m
depth of generated position of M_{max}	l_m	=	1.007 m
depth of 1st fixed point	l_i	=	3.487 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 950 -250 -16 -22 -18		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.88
Section efficiency	μ	=	1.00
Module of section	Z_0	=	10570 cm^3 (original condition)
	Z	=	9302 cm^3 (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1227.99 \times 10^6}{9302 \times 10^3} = 132 \text{ N/mm}^2 \leqq \sigma_a = 180 \text{ N/mm}^2$$

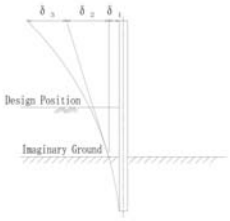
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1757.63 \times 10^6}{9302 \times 10^3} = 189 \text{ N/mm}^2 \leqq \sigma_a = 270 \text{ N/mm}^2$$

6.4 Displacement Calculation

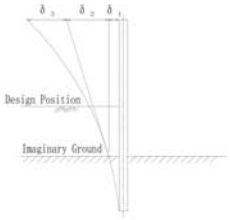
6.4.1 Normal Condition

Displacement Calculation



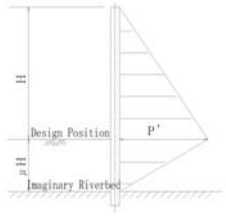
6.4.2 Seismic Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0) \times P_0}{2EI\beta^3} = \frac{(1+0.3167 \times 3.20) \times 480.21}{2 \times 2.00 \times 10^8 \times 592282 \times 10^{-8} \times 0.3167^3} = 0.01285 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0) \times P_0}{2EI\beta^2} \times (H + L_k) = \frac{(1+2 \times 0.3167 \times 3.20) \times 480.21}{2 \times 2.00 \times 10^8 \times 592282 \times 10^{-8} \times 0.3167^2} \times (5.95+0.00) = 0.03641 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.00}{5.95} = 0.000$$

$$\delta_3 = \frac{P' H^4}{120EI} (4+20\mu+40\mu^2+35\mu^3+11\mu^4) = \frac{161.42 \times 5.95^4}{120 \times 2.00 \times 10^8 \times 592282 \times 10^{-8}} (4+20\times0.000+40\times0.000^2+35\times0.000^3+11\times0.000^4) = 0.00569 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
$= 0.01285 + 0.03641 + 0.00569$
$= 0.05495$ m
Size = 54.95 ≦ δa = 75.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name			10 H _ H 950 -250 -16 -22 -18
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	688700 cm^4 (original condition)
	I	=	688700 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 688700 × 10^{-8}		=	1.377 × 10^6

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{it} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 25281 kN/m^3
Calculated value β = 0.26027 m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.260} = 11.53$ m
Whole length of SSP $L = 5.95 - 0.40 + 11.53 = 17.08$ m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction K_h = 47688 kN/m^3
Calculated value β = 0.30502 m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.305} = 9.84$ m
Whole length of SSP $L = 5.95 - 0.40 + 9.84 = 15.39$ m

Therefore, the total length of the sheet pile is 17.50 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 10 H _ H 950 -250 -16 -22 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	688700		
Sectional Modulus	Z (cm3)	10570		
Maximum bending moment	Mmax (kN・m・m)		1227.99	1757.63
Stress intensity	σ (N/mm2)		132 (180)	189 (270)
Lateral displacement	δ (mm)		48.79 (50.0)	54.95 (75.0)
Penetration depths	D (m)		11.53	9.84
Whole length of SSP	L (m)	17.50		

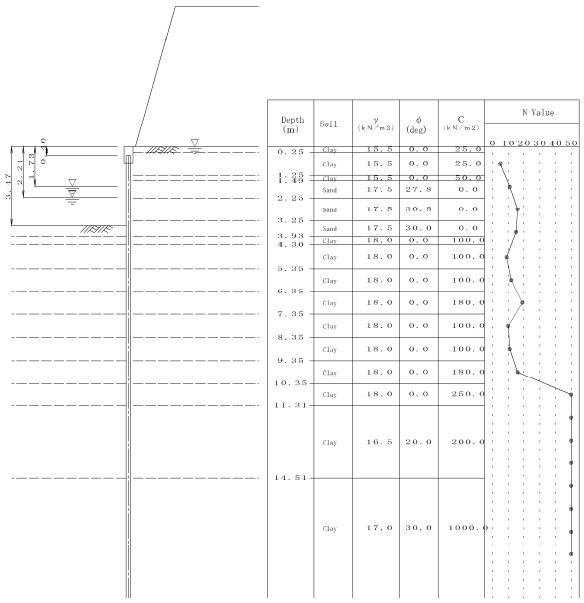
Block No. : R-15
Sta. : 8+620~8+940

Design Cross Section : Sta 8+820
Boring Name : DD-BH-R10

Specification : SSP SP-25H
(Combined) : H 1000-250-16-22-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	3.47 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_k	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	2.21 m (Normal Condition)
	L_{wp}'	=	1.73 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress　Chang's formula

Penetration depths　$L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water　γ_w = 9.8 kN/m³

Type of water pressure　trapezoidal water pressure

Lateral pressure　calculated in consideration of site conditions

Study case　- Normal Condition
- Seismic Condition

Design earthquake intensity　k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	Pt	=	44.8 kN/m	(Normal Condition)
		Pt'	=	105.5 kN/m	(Seismic Condition)
	Depth of acting point	Ht	=	0.0 m	(Normal Condition)
		Ht'	=	0.0 m	(Seismic Condition)
	Moment	Mm	=	11.9 kN･m/m	(Normal Condition)
		Mm'	=	122.9 kN･m/m	(Seismic Condition)
	Depth of acting point	Hm'	=	0.00 m	(Seismic Condition)
		Hm	=	0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

Wind load, Impact load　not considered

Minimum angle of rupture　ζ_0 = 10 degrees

Rear side angle of slope　not considered

Angle of rupture (clayey soil)

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h + Q}$$

Equilibrium factor of compression　K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_u}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_u = 10.00 m

E_0 = 2800N

Average N-value　calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value
1	0.75	5
2	1.75	11
3	2.75	16
4	3.75	15
5	4.85	9
6	5.85	12
7	6.85	19
8	7.85	10
9	8.85	11
10	9.85	16

No	Depth m	N Value
11	10.85	50
12	11.85	50
13	12.85	50
14	13.85	50
15	14.85	50
16	15.85	50
17	16.85	50
18	17.85	50
19	18.85	50

1.6 Vertical Load

Vertical load on landside　calculated in consideration of embankment shape on landside

Vertical load on riverside　not considered

1.7 Soil Modulus

Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	0.25	0.25
2	1.25	1.00
3	1.49	0.24
4	2.25	0.76
5	3.25	1.00
6	3.93	0.68
7	4.30	0.37
8	5.35	1.05
9	6.35	1.00
10	7.35	1.00
11	8.35	1.00
12	9.35	1.00
13	10.35	1.00
14	11.31	0.96
15	14.51	3.20
16	18.85	4.34

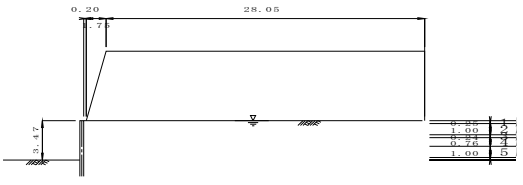
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	0.25	C	6.0	15.50	5.70	0.0	25.0	0.0	0.200	Auto	Auto
2	1.25	C	5.0	15.50	5.70	0.0	25.0	0.0	0.200	Auto	Auto
3	1.49	C	11.0	15.50	5.70	0.0	50.0	0.0	0.200	Auto	Auto
4	2.25	S	11.0	17.50	7.70	27.8	0.0	0.0	0.200	Auto	Auto
5	3.25	S	16.0	17.50	7.70	30.5	0.0	0.0	0.200	Auto	Auto
6	3.93	S	15.0	17.50	7.70	30.0	0.0	0.0	0.200	Auto	Auto
7	4.30	C	15.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
8	5.35	C	9.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
9	6.35	C	12.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
10	7.35	C	19.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
11	8.35	C	10.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
12	9.35	C	11.0	18.00	8.20	0.0	100.0	0.0	0.200	Auto	Auto
13	10.35	C	16.0	18.00	8.20	0.0	180.0	0.0	0.200	Auto	Auto
14	11.31	C	50.0	18.00	8.20	0.0	250.0	0.0	0.200	Auto	Auto
15	14.51	C	63.5	16.50	6.70	20.0	200.0	0.0	0.200	Auto	Auto
16	18.85	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto

Note)　depth : from top of coping to bottom of the layer　C_o :
soil : sandy(S), clayey(C), mixed (M)　a :
N-value : average N-value in the layer　k' :
γ : wet unit weight of soil　ζ :
γ' : saturated unit weight of soil　kh :
φ : internal friction angle of soil

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate				Thickness	soil single weight γ		internal friction angle	stickiness	decay angle ζ	
		Bottom Left m	Top Left m	Top Right m	Bottom Right m	h m	Normal Condition kN/m3	Seismic Condition kN/m3	φ degree	C kN/m2	Normal Condition degree	Seismic Condition degree
1	Sand	0.20	1.95	30.00	30.00	6.11	19.0	19.0	30.0	0.0	Auto	Auto

Angle of rapture in embankment　calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name　25 H_ H 1000 -250 -16 -22 -18
Young's modulus　E = 200000 N/mm²
Inertia sectional moment　I_0 = 892400 cm⁴
Sectional factor　Z_0 = 12240 cm³

Corrosion margin　t_1 = 1.00 mm (riverside)　t_2 = 1.00 mm (landside)

Corrosion rate (to I_0)　η = 0.87
Corrosion rate (to Z_0)　η = 0.88
Section efficiency (to I_0)　μ = 1.00
Section efficiency (to Z_0)　μ = 1.00

Round unit of SSP length　0.50 m

Allowable stress　σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

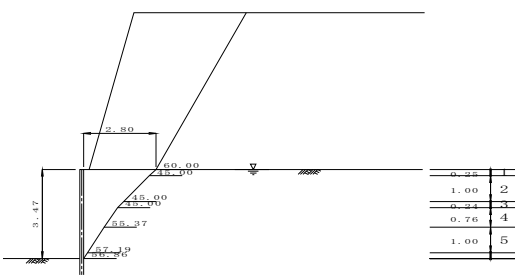
Allowable displacement　δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam　calculated as distributed load of each layer

Reduction of material modulus　Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	3.47 ~ 3.25	Sand	30.0	15.0	0.0	23.74	144.62	34.01	56.86
2	3.25 ~ 2.25	Sand	30.5	15.0	0.0	22.05	144.62	31.85	57.19
3	2.25 ~ 1.49	Sand	27.8	15.0	0.0	14.35	144.62	22.05	55.37
4	1.49 ~ 1.25	Clay	0.0	15.0	50.0	8.49	144.62	14.60	45.00
5	1.25 ~ 0.25	Clay	0.0	15.0	25.0	7.13	144.62	12.25	45.00
6	0.25 ~ 0.00	Clay	0.0	15.0	25.0	1.42	144.62	2.45	45.00
7		embankment	30.0	——	0.0	116.09	0.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,

ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	56.86	0.22	0.00	0.00	0.14	0.22
2	57.19	1.00	0.14	0.22	0.79	1.22
3	55.37	0.76	0.79	1.22	1.31	1.98
4	45.00	0.24	1.31	1.98	1.55	2.22
5	45.00	1.00	1.55	2.22	2.55	3.22
6	45.00	0.25	2.55	3.22	2.80	3.47
7	60.00	6.11	2.80	3.47	6.33	9.58

From the above table, the loading width (L) on the ground surface is 2.80 m.

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h+Q}$$

Where,

ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = tan⁻¹k or θ = tan⁻¹k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	45.32	0.22	0.00	0.00	0.22	0.22
2	45.81	1.00	0.22	0.22	1.19	1.22
3	43.05	0.76	1.19	1.22	2.00	1.98
4	37.76	0.24	2.00	1.98	2.31	2.22
5	33.28	1.00	2.31	2.22	3.84	3.22
6	33.54	0.25	3.84	3.22	4.21	3.47
7	49.60	6.11	4.21	3.47	9.41	9.58

From the above table, the loading width (L) on the ground surface is 4.21 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	35.06	666.19
Σ			666.19

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	21.34	405.39
Σ			405.39

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

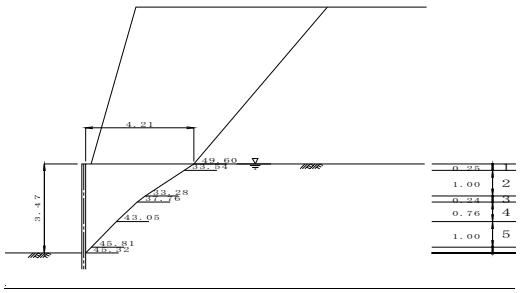
2.1.4 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{405.39 + 0.00 + 0.00}{2.80}$$

$$= 144.62\ \text{kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	3.47 ~ 3.25	Sand	30.0	15.0	0.0	23.74	158.09	34.01	0.200	11.31	45.32
2	3.25 ~ 2.25	Sand	30.5	15.0	0.0	22.05	158.09	31.85	0.200	11.31	45.81
3	2.25 ~ 1.49	Sand	27.8	15.0	0.0	14.35	158.09	22.05	0.200	11.31	43.05
4	1.49 ~ 1.25	Clay	0.0	15.0	50.0	8.49	158.09	14.60	0.200	11.31	37.76
5	1.25 ~ 0.25	Clay	0.0	15.0	25.0	7.13	158.09	12.25	0.200	11.31	33.28
6	0.25 ~ 0.00	Clay	0.0	15.0	25.0	1.42	158.09	2.45	0.200	11.31	33.54
7		embankment	30.0	——	0.0	116.09	0.00	0.00	0.200	11.31	49.60

2.2.4 Calculated Load

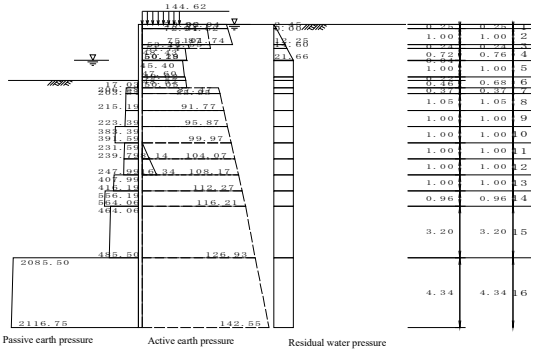
$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{666.19 + 0.00 + 0.00}{4.21}$$

$$= 158.09\ \text{kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 0.25	Clay	5.7	——	25.0 25.0	144.615 146.040	———	———
2	0.25~ 1.25	Clay	5.7	——	25.0 25.0	146.040 151.740	———	———
3	1.25~ 1.49	Clay	5.7	——	50.0 50.0	151.740 153.108	———	———
4	1.49~ 2.21	Sand	7.7	27.8	—— ——	153.108 158.652	0.32749 0.32749	0.31633 0.31633
5	2.21~ 2.25	Sand	7.7	27.8	—— ——	158.652 158.960	0.32749 0.32749	0.31633 0.31633
6	2.25~ 3.25	Sand	7.7	30.5	—— ——	158.960 166.660	0.29571 0.29571	0.28563 0.28563
7	3.25~ 3.47	Sand	7.7	30.0	—— ——	166.660 168.354	0.30142 0.30142	0.29115 0.29115

8	3.47~ 3.93	Sand	7.7	30.0	——— ———	168.354 171.896	0.30142 0.30142	0.29115 0.29115
9	3.93~ 4.30	Clay	8.2	———	100.0 100.0	171.896 174.930	——— ———	——— ———
10	4.30~ 5.35	Clay	8.2	———	100.0 100.0	174.930 183.540	——— ———	——— ———
11	5.35~ 6.35	Clay	8.2	———	100.0 100.0	183.540 191.740	——— ———	——— ———
12	6.35~ 7.35	Clay	8.2	———	180.0 180.0	191.740 199.940	——— ———	——— ———
13	7.35~ 8.35	Clay	8.2	———	100.0 100.0	199.940 208.140	——— ———	——— ———
14	8.35~ 9.35	Clay	8.2	———	100.0 100.0	208.140 216.340	——— ———	——— ———
15	9.35~ 10.35	Clay	8.2	———	180.0 180.0	216.340 224.540	——— ———	——— ———
16	10.35~ 11.31	Clay	8.2	———	250.0 250.0	224.540 232.412	——— ———	——— ———
17	11.31~ 14.51	Clay	6.7	———	200.0 200.0	232.412 253.852	——— ———	——— ———
18	14.51~ 18.85	Clay	7.2	———	1000.0 1000.0	253.852 285.100	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	$\Sigma\gamma h+Qp$ kN/m2	Kp	Kp $\times\cos\delta$
8	3.47~ 3.93	Sand	7.7	30.0	——— ———	0.000 3.542	4.97650 4.97650	4.80693 4.80693
9	3.93~ 4.30	Clay	8.2	0.0	100.0 100.0	3.542 6.576	——— ———	——— ———
10	4.30~ 5.35	Clay	8.2	0.0	100.0 100.0	6.576 15.186	——— ———	——— ———
11	5.35~ 6.35	Clay	8.2	0.0	100.0 100.0	15.186 23.386	——— ———	——— ———
12	6.35~ 7.35	Clay	8.2	0.0	180.0 180.0	23.386 31.586	——— ———	——— ———
13	7.35~ 8.35	Clay	8.2	0.0	100.0 100.0	31.586 39.786	——— ———	——— ———
14	8.35~ 9.35	Clay	8.2	0.0	100.0 100.0	39.786 47.986	——— ———	——— ———
15	9.35~ 10.35	Clay	8.2	0.0	180.0 180.0	47.986 56.186	——— ———	——— ———
16	10.35~ 11.31	Clay	8.2	0.0	250.0 250.0	56.186 64.058	——— ———	——— ———
17	11.31~ 14.51	Clay	6.7	20.0	200.0 200.0	64.058 85.498	——— ———	——— ———
18	14.51~ 18.85	Clay	7.2	30.0	1000.0 1000.0	85.498 116.746	——— ———	——— ———

Coefficient of passive earth pressure of sandy soil Kp is calculated by the formula below;

δ= -15.00、β = 0.00、θ = 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\dfrac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.25	94.62 96.04	72.31 73.02	94.62 96.04	0.00 2.45	——— ———
2	0.25~ 1.25	96.04 101.74	73.02 75.87	96.04 101.74	2.45 12.25	——— ———
3	1.25~ 1.49	51.74 53.11	75.87 76.55	75.87 76.55	12.25 14.60	——— ———
4	1.49~ 2.21	48.43 50.19	——— ———	48.43 50.19	14.60 21.66	——— ———
5	2.21~ 2.25	50.19 50.28	——— ———	50.19 50.28	21.66 21.66	——— ———
6	2.25~ 3.25	45.40 47.60	——— ———	45.40 47.60	21.66 21.66	——— ———
7	3.25~ 3.47	48.52 49.02	——— ———	48.52 49.02	21.66 21.66	——— ———
8	3.47~ 3.93	49.02 50.05	——— ———	49.02 50.05	21.66 21.66	0.00 17.03
9	3.93~ 4.30	-28.10 -25.07	85.95 87.47	85.95 87.47	21.66 21.66	203.54 206.58
10	4.30~ 5.35	-25.07 -16.46	87.47 91.77	87.47 91.77	21.66 21.66	206.58 215.19
11	5.35~ 6.35	-16.46 -8.26	91.77 95.87	91.77 95.87	21.66 21.66	215.19 223.39
12	6.35~ 7.35	-168.26 -160.06	95.87 99.97	95.87 99.97	21.66 21.66	383.39 391.59
13	7.35~ 8.35	-0.06 8.14	99.97 104.07	99.97 104.07	21.66 21.66	231.59 239.79
14	8.35~ 9.35	8.14 16.34	104.07 108.17	104.07 108.17	21.66 21.66	239.79 247.99
15	9.35~ 10.35	-143.66 -135.46	108.17 112.27	108.17 112.27	21.66 21.66	407.99 416.19
16	10.35~ 11.31	-275.46 -267.59	112.27 116.21	112.27 116.21	21.66 21.66	556.19 564.06
17	11.31~ 14.51	-167.59 -146.15	116.21 126.93	116.21 126.93	21.66 21.66	464.06 485.50
18	14.51~ 18.85	-1746.15 -1714.90	126.93 142.55	126.93 142.55	21.66 21.66	2085.50 2116.75

- Formula for active earth pressure

Sand $P_{a1}=K_a\cdot\left[\Sigma\gamma h+\dfrac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_{a1}=\Sigma\gamma h+Q-2C$

$P_{a2}=K_c\cdot(\Sigma\gamma h+Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1}=\left[K_a(\Sigma\gamma h+Q)-2C\sqrt{K_a}\right]\cdot\cos\delta$

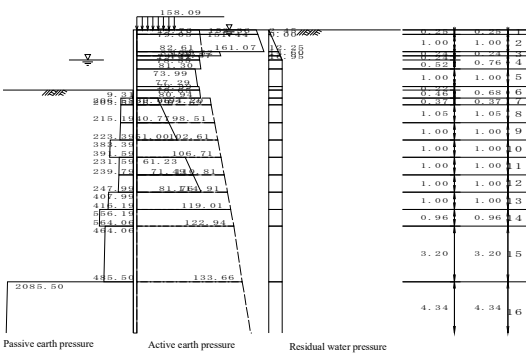
- Formula for passive earth pressure

Sand $P_p=K_p\cdot\left[\Sigma\gamma h+\dfrac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_p=\Sigma\gamma h+Q+2C$

Mixed soil $P_p=\left[K_p(\Sigma\gamma h+Q)+2C\sqrt{K_p}\right]\cdot\cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	$\Sigma\gamma h+Q$ kN/m2	γ whw kN/m2	k (k^{-1})	θ degree	Ka	Ka $\times\cos\delta$	ζ degree
1	0.00~ 0.25	Clay	5.7	———	25.0 25.0	158.09 159.52	0.00 2.45	0.200 0.200	11.31 11.31	——— ———	——— ———	33.60 33.54
2	0.25~ 1.25	Clay	5.7	———	25.0 25.0	159.52 165.22	2.45 12.25	0.200 0.200	11.31 11.31	——— ———	——— ———	33.54 33.28
3	1.25~ 1.49	Clay	5.7	———	50.0 50.0	165.22 166.59	12.25 14.60	0.200 0.200	11.31 11.31	——— ———	——— ———	37.81 37.76
4	1.49~ 1.73	Sand	7.7	27.8	——— ———	166.59 168.43	14.60 16.95	0.200 0.200	11.31 11.31	0.48814 0.48814	0.47151 0.47151	——— ———
5	1.73~ 2.25	Sand	7.7	27.8	——— ———	168.43 172.44	16.95 22.05	0.200 0.200	11.31 11.31	0.48814 0.48814	0.47151 0.47151	——— ———
6	2.25~ 3.25	Sand	7.7	30.5	——— ———	172.44 180.14	22.05 31.85	0.200 0.200	11.31 11.31	0.44421 0.44421	0.42907 0.42907	——— ———
7	3.25~ 3.47	Sand	7.7	30.0	——— ———	180.14 181.83	31.85 34.01	0.200 0.200	11.31 11.31	0.45203 0.45203	0.43663 0.43663	——— ———
8	3.47~ 3.93	Sand	7.7	30.0	——— ———	181.83 185.37	34.01 38.51	0.200 0.200	11.31 11.31	0.45203 0.45203	0.43663 0.43663	——— ———
9	3.93~ 4.30	Clay	8.2	———	100.0 100.0	185.37 188.41	38.51 42.14	0.200 0.200	11.31 11.31	——— ———	——— ———	40.50 40.44
10	4.30~ 5.35	Clay	8.2	———	100.0 100.0	188.41 197.02	42.14 52.43	0.200 0.200	11.31 11.31	——— ———	——— ———	40.44 40.26
11	5.35~ 6.35	Clay	8.2	———	100.0 100.0	197.02 205.22	52.43 62.23	0.200 0.200	11.31 11.31	——— ———	——— ———	40.26 40.10
12	6.35~ 7.35	Clay	8.2	———	180.0 180.0	205.22 213.42	62.23 72.03	0.200 0.200	11.31 11.31	——— ———	——— ———	42.06 41.96
13	7.35~ 8.35	Clay	8.2	———	100.0 100.0	213.42 221.62	72.03 81.83	0.200 0.200	11.31 11.31	——— ———	——— ———	39.94 39.77
14	8.35~ 9.35	Clay	8.2	———	100.0 100.0	221.62 229.82	81.83 91.63	0.200 0.200	11.31 11.31	——— ———	——— ———	39.77 39.61
15	9.35~ 10.35	Clay	8.2	———	180.0 180.0	229.82 238.02	91.63 101.43	0.200 0.200	11.31 11.31	——— ———	——— ———	41.75 41.65
16	10.35~ 11.31	Clay	8.2	———	250.0 250.0	238.02 245.89	101.43 110.84	0.200 0.200	11.31 11.31	——— ———	——— ———	42.51 42.43
17	11.31~ 14.51	Clay	6.7	———	200.0 200.0	245.89 267.33	110.84 142.20	0.200 0.200	11.31 11.31	——— ———	——— ———	41.86 41.61
18	14.51~ 18.85	Clay	7.2	———	1000.0 1000.0	267.33 298.58	142.20 184.73	0.200 0.200	11.31 11.31	——— ———	——— ———	44.25 44.17

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h+Q}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	$\Sigma\gamma h+Qp$ kN/m2	γ whw kN/m2	k (k^{-1})	θ degree	Kp	Kp $\times\cos\delta$
8	3.47~ 3.93	Sand	7.70	30.0	——— ———	0.000 3.542	0.00 4.51	0.200 0.200	11.31 11.31	2.62913 2.62913	2.62913 2.62913
9	3.93~ 4.30	Clay	8.20	0.0	100.0 100.0	3.542 6.576	4.51 8.13	0.200 0.200	11.31 11.31	——— ———	——— ———
10	4.30~ 5.35	Clay	8.20	0.0	100.0 100.0	6.576 15.186	8.13 18.42	0.200 0.200	11.31 11.31	——— ———	——— ———
11	5.35~ 6.35	Clay	8.20	0.0	100.0 100.0	15.186 23.386	18.42 28.22	0.200 0.200	11.31 11.31	——— ———	——— ———
12	6.35~ 7.35	Clay	8.20	0.0	180.0 180.0	23.386 31.586	28.22 38.02	0.200 0.200	11.31 11.31	——— ———	——— ———

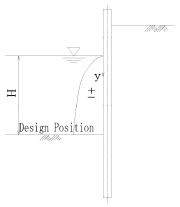
13	7.35~ 8.35	Clay	8.20	0.0	100.0 100.0	31.586 39.786	38.02 47.82	0.200 0.200	11.31 11.31	—— ——	—— ——
14	8.35~ 9.35	Clay	8.20	0.0	100.0 100.0	39.786 47.986	47.82 57.62	0.200 0.200	11.31 11.31	—— ——	—— ——
15	9.35~ 10.35	Clay	8.20	0.0	180.0 180.0	47.986 56.186	57.62 67.42	0.200 0.200	11.31 11.31	—— ——	—— ——
16	10.35~ 11.31	Clay	8.20	0.0	250.0 250.0	56.186 64.058	67.42 76.83	0.200 0.200	11.31 11.31	—— ——	—— ——
17	11.31~ 14.51	Clay	6.70	20.0	200.0 200.0	64.058 85.498	76.83 108.19	0.200 0.200	11.31 11.31	—— ——	—— ——
18	14.51~ 18.85	Clay	7.20	30.0	1000.0 1000.0	85.498 116.746	108.19 150.72	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.
δ = 0.00 degrees, β = 0.00 degrees
Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

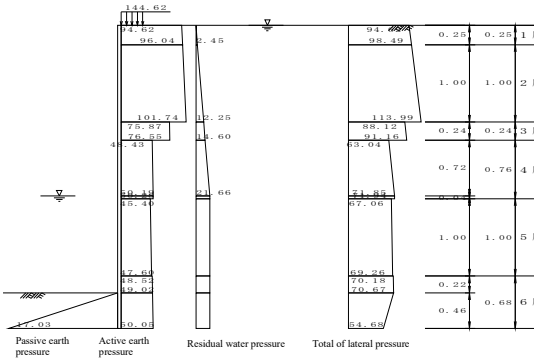
No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.25	151.44 153.36	79.05 79.76	151.44 153.36	0.00 2.45	—— ——
2	0.25~ 1.25	153.36 161.07	79.76 82.61	153.36 161.07	2.45 12.25	—— ——
3	1.25~ 1.49	104.57 106.32	82.61 83.29	104.57 106.32	12.25 14.60	—— ——
4	1.49~ 1.73	78.55 79.42	—— ——	78.55 79.42	14.60 16.95	—— ——
5	1.73~ 2.25	79.42 81.30	—— ——	79.42 81.30	16.95 16.95	—— ——
6	2.25~ 3.25	73.99 77.29	—— ——	73.99 77.29	16.95 16.95	—— ——
7	3.25~ 3.47	78.65 79.39	—— ——	78.65 79.39	16.95 16.95	—— ——
8	3.47~ 3.93	79.39 80.94	—— ——	79.39 80.94	16.95 16.95	0.00 9.31
9	3.93~ 4.30	26.29 30.06	92.69 94.20	92.69 94.20	16.95 16.95	203.54 206.58
10	4.30~ 5.35	30.06 40.77	94.20 98.51	94.20 98.51	16.95 16.95	206.58 215.19
11	5.35~ 6.35	40.77 51.00	98.51 102.61	98.51 102.61	16.95 16.95	215.19 223.39
12	6.35~ 7.35	-111.20 -101.15	102.61 106.71	102.61 106.71	16.95 16.95	383.39 391.59
13	7.35~ 8.35	61.23 71.49	106.71 110.81	106.71 110.81	16.95 16.95	231.59 239.79
14	8.35~ 9.35	71.49 81.76	110.81 114.91	110.81 114.91	16.95 16.95	239.79 247.99



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.25	94.62 96.04	0.00 2.45	—— ——	94.62 98.49
2	0.25~ 1.25	96.04 101.74	2.45 12.25	—— ——	98.49 113.99
3	1.25~ 1.49	75.87 76.55	12.25 14.60	—— ——	88.12 91.16
4	1.49~ 2.21	48.43 50.19	14.60 21.66	—— ——	63.04 71.85
5	2.21~ 2.25	50.19 50.28	21.66 21.66	—— ——	71.85 71.94

No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
15	9.35~ 10.35	-81.01 -70.93	114.91 119.01	114.91 119.01	16.95 16.95	407.99 416.19
16	10.35~ 11.31	-211.95 -202.33	119.01 122.94	119.01 122.94	16.95 16.95	556.19 564.06
17	11.31~ 14.51	-101.64 -75.29	122.94 133.66	122.94 133.66	16.95 16.95	464.06 485.50
18	14.51~ 18.85	-1678.47 -1640.79	133.66 149.29	133.66 149.29	16.95 16.95	2085.50 2116.75

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma \gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma \gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma \gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma \gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma \gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma \gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.73	0.00	0.00
2	2.73	1.00	2.26
3	3.47	1.74	2.98

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

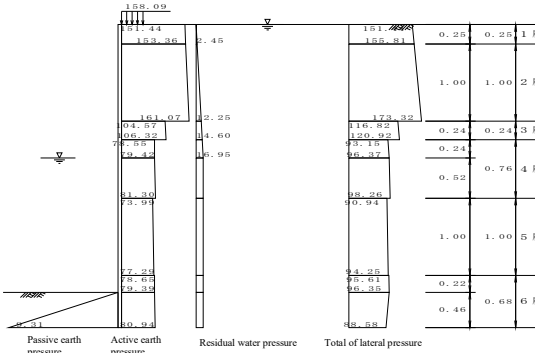
Where,
k_{hs}: design seismic coefficient
γ_w : unit weight of water
H : water depth of riverside
y : depth from water surface to the point where active water pressure is calculated

6	2.25~ 3.25	45.40 47.60	21.66 21.66	—— ——	67.06 69.26
7	3.25~ 3.47	48.52 49.02	21.66 21.66	—— ——	70.18 70.67
8	3.47~ 3.93	49.02 50.05	21.66 21.66	0.00 17.03	70.67 54.68
9	3.93~ 4.30	85.95 87.47	21.66 21.66	203.54 206.58	-95.94 -97.45

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed Lk: 0.46 m (GL -3.93 m)

4.2 Seismic Condition



No	Depth. m	Ps kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.25	151.44 153.36	0.00 2.45	—— ——	151.44 155.81
2	0.25~ 1.25	153.36 161.07	2.45 12.25	—— ——	155.81 173.32
3	1.25~ 1.49	104.57 106.32	12.25 14.60	—— ——	116.82 120.92
4	1.49~ 1.73	78.55 79.42	14.60 16.95	—— ——	93.15 96.37
5	1.73~ 2.25	79.42 81.30	16.95 16.95	—— ——	96.37 98.26
6	2.25~ 3.25	73.99 77.29	16.95 16.95	—— ——	90.94 94.25

7	3.25~ 3.47	78.65 79.39	16.95 16.95	——— ———	95.61 96.35
8	3.47~ 3.93	79.39 80.94	16.95 16.95	0.00 9.31	96.35 88.58
9	3.93~ 4.30	92.69 94.20	16.95 16.95	203.54 206.58	-93.90 -95.42

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.46 m (GL -3.93 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4} \qquad (B_H = 10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\,\alpha\,E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800\,N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4\,E\,I}}$$

Material Name	25 H _ H 1000 -250 -16 -22 -18		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	892400 cm^4(original condition)
	I	=	776388 cm^4(after reduction by corrosion and section)
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 776388 \times 10^{-8} = 1.533 \times 10^6$

No	Depth m	N Value
1	0.75	5
2	1.75	11
3	2.75	16
4	3.75	15
5	4.85	9
6	5.85	12
7	6.85	19
8	7.85	10
9	8.85	11
10	9.85	16

No	Depth m	N Value
11	10.85	50
12	11.85	50
13	12.85	50
14	13.85	50
15	14.85	50
16	15.85	50
17	16.85	50
18	17.85	50
19	18.85	50

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	3.93	0.92	14.0	9.0	10.59
2	4.85	1.00	9.0	12.0	10.50
3	5.85	1.00	12.0	19.0	15.50
4	6.85	1.00	19.0	10.0	14.50
5	7.85	0.44	10.0	10.4	4.52
		L = Σh = 4.36		Σ A =	55.61

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \dfrac{\Sigma A}{L} = \dfrac{55.61}{4.36} = 12.75$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800\,N' = 2800 \times 12.75 = 35694 \text{ kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 35694 = 237958 \text{ kN/m}^3 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 237958\,(10.00/0.3)^{-3/4} = 17153 \text{ kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 17153 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth P_s kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.25	0.25	94.62 98.49	11.83 12.31	3.85 3.76	45.49 46.33
2	0.25~ 1.25	1.00	98.49 113.99	49.25 57.00	3.35 3.01	164.81 171.75
3	1.25~ 1.49	0.24	88.12 91.16	10.57 10.94	2.60 2.52	27.49 27.57
4	1.49~ 2.21	0.72	63.04 71.85	22.69 25.86	2.20 1.96	49.92 50.69
5	2.21~ 2.25	0.04	71.85 71.94	1.44 1.44	1.71 1.69	2.45 2.44
6	2.25~ 3.25	1.00	67.06 69.26	33.53 34.63	1.35 1.01	45.16 35.09
7	3.25~ 3.47	0.22	70.18 70.67	7.72 7.77	0.61 0.53	4.68 4.15
8	3.47~ 3.93	0.46	70.67 54.68	16.25 12.58	0.31 0.15	4.98 1.93

5.2 Normal Condition

Assuming Kh = 8392 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4\,E\,I}} = 0.192 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 5.22 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -3.93 m) to 5.22 m depth (GL -9.15 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	3.93	0.92	14.0	9.0	10.59
2	4.85	1.00	9.0	12.0	10.50
3	5.85	1.00	12.0	19.0	15.50
4	6.85	1.00	19.0	10.0	14.50
5	7.85	1.00	10.0	11.0	10.50
6	8.85	0.30	11.0	12.5	3.47
		L = Σh = 5.22		Σ A =	65.06

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \dfrac{\Sigma A}{L} = \dfrac{65.06}{5.22} = 12.47$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800\,N' = 2800 \times 12.47 = 34928 \text{ kN/m}^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 34928 = 116426 \text{ kN/m}^3 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 116426\,(10.00/0.3)^{-3/4} = 8392 \text{ kN/m}^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 8392 kN/m3.

5.3 Seismic Condition

Assuming Kh = 17153 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4\,E\,I}} = 0.229 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 4.36 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -3.93 m) and 4.36 m depth (GL -8.29 m).

				Σ P = 315.81	Σ M = 684.94

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	44.8 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	11.9 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	3.47 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 187.96$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{872.90}{360.61} = 2.42 \text{ m}$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 360.61}{3.93} = 183.52 \text{ kN/m}$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth P_s kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.25	0.25	151.44 155.81	18.93 19.48	3.85 3.76	72.82 73.30
2	0.25~ 1.25	1.00	155.81 173.32	77.91 86.66	3.35 3.01	260.72 261.13
3	1.25~ 1.49	0.24	116.82 120.92	14.02 14.51	2.60 2.52	36.45 36.57
4	1.49~ 1.73	0.24	93.15 96.37	11.18 11.56	2.36 2.28	26.38 26.37
5	1.73~ 2.25	0.52	96.37 98.26	25.06 25.55	2.03 1.85	50.78 47.35
6	2.25~ 3.25	1.00	90.94 94.25	45.47 47.12	1.35 1.01	61.23 47.75
7	3.25~ 3.47	0.22	95.61 96.35	10.52 10.60	0.61 0.53	6.38 5.65
8	3.47~ 3.93	0.46	96.35 88.58	22.16 20.37	0.31 0.15	6.80 3.12
				Σ P = 461.09	Σ M = 1022.79

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load		P_t	=	105.5 kN/m
	depth to acting position	H_t	=	0.00 m
	moment	M_m	=	122.9 kN･m/m
	depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping		H	=	3.47 m
Depth of Imaginary riverbed from riverbed		L_k	=	0.46 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m$ = 537.52 kN･m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN ・ m
1	1.73~ 2.73	1.00	0.0 2.3	0.00 1.13	1.87 1.53	0.00 1.73
2	2.73~ 3.47	0.74	2.3 3.0	0.84 1.10	0.95 0.71	0.80 0.78
			ΣPdw = 3.07	Σ Mdw = 3.31		

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{1563.62}{569.66} = 2.74 \text{ m}$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 569.66}{3.93} = 289.90 \text{ kN/m}$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name	25 H _ H 1000 -250 -16 -22 -18		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.87
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	892400 cm⁴ (original condition)
	I	=	776388 cm⁴ (after reduction by corrosion and section)

$EI = 200000 \times 10^3 \times 776388 \times 10^{-8}$ = 1.553×10^6

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1 + 2\beta h_0)^2 + 1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1 + 2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1 + 2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1 + \beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1 + \beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	8392 kN/m³
calculated value	β	=	0.19173 m⁻¹
resultant earth force (lateral)	P_0	=	360.61 kN/m
height of acting position of load	h_0	=	2.42 m
Moment	M_0	=	872.90 kN･m/m
in consideration of ψ_m = 1.450,			
maximum moment	M_{max}	=	1265.97 kN･m/m
depth of generated position of M_{max}	l_m	=	2.495 m
depth of 1st fixed point	l_i	=	6.592 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	17153 kN/m³
calculated value	β	=	0.22924 m⁻¹
resultant earth force (lateral)	P_0	=	569.66 kN/m
height of acting position of load	h_0	=	2.74 m
moment	M_0	=	1563.62 kN･m/m
in consideration of ψ_m = 1.294,			
maximum moment	M_{max}	=	2022.79 kN･m/m
depth of generated position of M_{max}	l_m	=	1.818 m
depth of 1st fixed point	l_i	=	5.244 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	25 H _ H 1000 -250 -16 -22 -18		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.88
Section efficiency	μ	=	1.00
Module of section	Z_0	=	12240 cm³ (original condition)
	Z	=	10771 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{1265.97 \times 10^6}{10771 \times 10^3} = 118 \text{ N/mm}^2 \leqq \sigma_a = 180 \text{ N/mm}^2$$

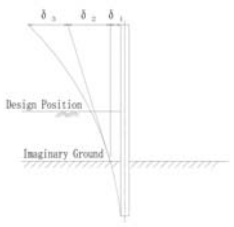
6.3.2 Seismic Condition

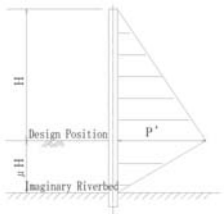
$$\sigma = \frac{M_{max}}{Z} = \frac{2022.79 \times 10^6}{10771 \times 10^3} = 188 \text{ N/mm}^2 \leqq \sigma_a = 270 \text{ N/mm}^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation





$$\delta_1 = \frac{(1 + \beta h_0) \times P_0}{2EI\beta^3} = \frac{(1 + 0.1917 \times 2.42) \times 360.61}{2 \times 2.00 \times 10^8 \times 776388 \times 10^{-8} \times 0.1917^3} = 0.02412 \text{ m}$$

$$\delta_2 = \frac{(1 + 2\beta h_0) \times P_0}{2EI\beta^2} \times (H + L_k) = \frac{(1 + 2 \times 0.1917 \times 2.42) \times 360.61}{2 \times 2.00 \times 10^8 \times 776388 \times 10^{-8} \times 0.1917^2} \times (3.47 + 0.46) = 0.02394 \text{ m}$$

$$\mu = \frac{L_k}{H} = \frac{0.46}{3.47} = 0.133$$

$$\delta_3 = \frac{P' H^4}{120EI}(4 + 20\mu + 40\mu^2 + 35\mu^3 + 11\mu^4) = \frac{183.52 \times 3.47^4}{120 \times 2.00 \times 10^8 \times 776388 \times 10^{-8}}(4 + 20 \times 0.133 + 40 \times 0.133^2 + 35 \times 0.133^3 + 11 \times 0.133^4) = 0.00106 \text{ m}$$

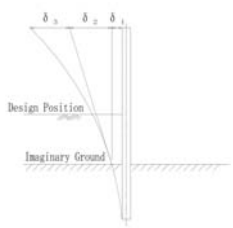
$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.02412 + 0.02394 + 0.00106
= 0.04912 m
Size = 49.12 ≦ δ_a = 50.00 mm

Where,

δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

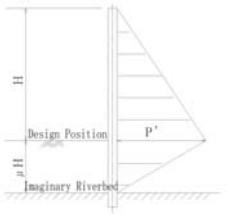


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2292\times 2.74)\times 569.66}{2\times 2.00\times 10^8\times 776388\times 10^{-8}\times 0.2292^3} = 0.02481 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.2292\times 2.74)\times 569.66}{2\times 2.00\times 10^8\times 776388\times 10^{-8}\times 0.2292^2}\times(3.47+0.46) = 0.03098 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.46}{3.47} = 0.133$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{289.90\times 3.47^4}{120\times 2.00\times 10^8\times 776388\times 10^{-8}}(4+20\times 0.133+40\times 0.133^2+35\times 0.133^3+11\times 0.133^4)$$

$$= 0.00168 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.02481 + 0.03098 + 0.00168
= 0.05747 m
Size = 57.47 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name			25 H _ H 1000 -250 -16 -22 -18
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	892400 cm^4 (original condition)
	I	=	892400 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 892400 × 10^{-8}		=	1.785 × 10^6

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction	K_h	=	8392 kN/m^3
Calculated value	β	=	0.18517 m^{-1}
Penetration length of SSP	D	=	$0.46+\frac{3}{0.185}$ = 16.66 m
Whole length of SSP	L	=	3.47−0.40+16.66 = 19.73 m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction	K_h	=	17153 kN/m^3
Calculated value	β	=	0.22140 m^{-1}
Penetration length of SSP	D	=	$0.46+\frac{3}{0.221}$ = 14.01 m
Whole length of SSP	L	=	3.47−0.40+14.01 = 17.08 m

Therefore, the total length of the sheet pile is 20.00 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 25 H _ H 1000 -250 -16 -22 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	892400		
Sectional Modulus	Z (cm3)	12240		
Maximum bending moment	Mmax (kN・m・m)		1265.97	2022.79
Stress intensity	σ (N/mm2)		118 (180)	188 (270)
Lateral displacement	δ (mm)		49.12 (50.0)	57.47 (75.0)
Penetration depths	D (m)		16.66	14.01
Whole length of SSP	L (m)	20.00		

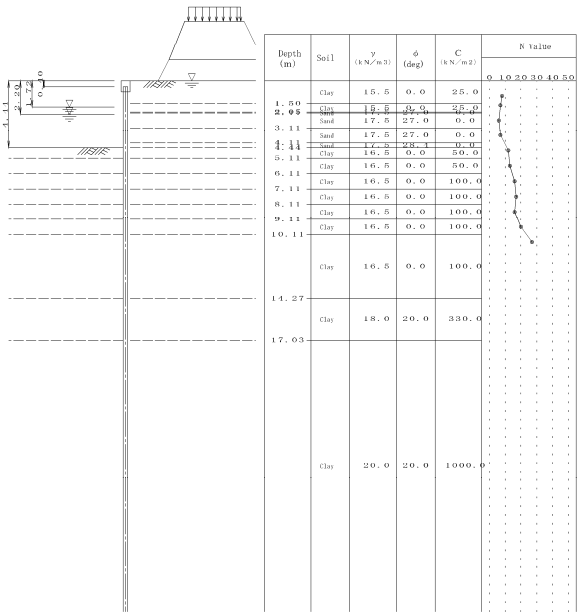
Block No. : R-16
Sta. : 8+940~9+000

Design Cross Section : Sta 8+940
Boring Name : BDM-11

Specification : SSP SP-10H
(Combined) : H 600-200-12-16-13

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	4.44 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_t	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	2.20 m (Normal Condition)
	L_{wp}'	=	1.72 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress　Chang's formula

Penetration depths　$L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water　γ_w = 9.8 kN/m³

Type of water pressure　trapezoidal water pressure

Lateral pressure　calculated in consideration of site conditions

Study case　- Normal Condition
- Seismic Condition

Design earthquake intensity　k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitary load　not considered

Wind load, Impact load　not considered

Minimum angle of rupture　ζ_0 = 10 degrees

Rear side angle of slope　not considered

Angle of rupture (clayey soil)　$\zeta = \tan^{-1}\sqrt{1 - \frac{\Sigma \gamma h + 2Q}{2C}} \cdot \tan\theta$

Equilibrium factor of compression　K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m

E_0 = 2800N

Average N-value　calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value
1	1.00	8
2	1.61	7
3	2.61	6
4	3.61	7
5	4.61	12
6	5.61	13
7	6.61	16
8	7.61	17
9	8.61	16
10	9.61	20

No	Depth m	N Value
11	10.61	27

1.6 Vertical Load

Vertical load on landside　calculated in consideration of embankment shape on landside

Vertical load on riverside　not considered

1.7 Soil Modulus

Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	1.50	1.50
2	2.05	0.55
3	2.11	0.06
4	3.11	1.00
5	4.11	1.00
6	4.44	0.33
7	5.11	0.67
8	6.11	1.00
9	7.11	1.00
10	8.11	1.00
11	9.11	1.00
12	10.11	1.00
13	14.27	4.16
14	17.03	2.76
15	33.50	16.47

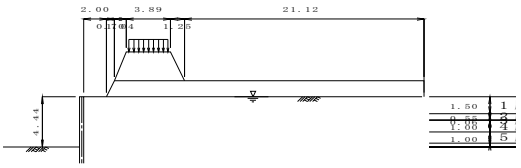
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	1.50	C	7.8	15.50	5.50	0.0	25.0	0.0	0.200	Auto	Auto
2	2.05	C	7.8	15.50	5.50	0.0	25.0	0.0	0.200	Auto	Auto
3	2.11	S	7.0	17.50	7.50	27.0	0.0	0.0	0.200	Auto	Auto
4	3.11	S	6.0	17.50	7.50	27.0	0.0	0.0	0.200	Auto	Auto
5	4.11	S	7.0	17.50	7.50	27.0	0.0	0.0	0.200	Auto	Auto
6	4.44	S	12.0	17.50	7.50	28.4	0.0	0.0	0.200	Auto	Auto
7	5.11	C	12.0	16.50	6.50	0.0	50.0	0.0	0.200	Auto	Auto
8	6.11	C	13.0	16.50	6.50	0.0	50.0	0.0	0.200	Auto	Auto
9	7.11	C	16.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
10	8.11	C	17.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
11	9.11	C	16.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
12	10.11	C	20.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
13	14.27	C	27.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
14	17.03	C	38.2	18.00	8.00	20.0	330.0	0.0	0.200	Auto	Auto
15	33.50	C	44.4	20.00	10.00	20.0	1000.0	0.0	0.200	Auto	Auto

Note)
depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	2.00	2.70	30.00	30.00	1.39	19.0	19.0	30.0	0.0	Auto	Auto
2	Sand	2.70	3.74	7.63	8.88	2.56	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	load area End point m	load strength Normal Condition kN/m2	load strength Seismic Condition kN/m2
1	3.98	7.42	5.0	0.0

Angle of rapture in embankment　calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name　10 H_H 600 -200 - 12-16-13

Young's modulus　E = 200000 N/mm²

Inertia sectional moment　I_0 = 208200 cm⁴

Sectional factor　Z_0 = 4270 cm³

Corrosion margin　t_1 = 1.00 mm (riverside)　t_2 = 1.00 mm (landside)

Corrosion rate (to I_0)　η = 0.83

Corrosion rate (to Z_0)　η = 0.85

Section efficiency (to I_0)　μ = 1.00

Section efficiency (to Z_0)　μ = 1.00

Round unit of SSP length　0.50 m

Allowable stress　σ_a = 180 N/mm (Normal)
σ_a' = 270 N/mm (Seismic)

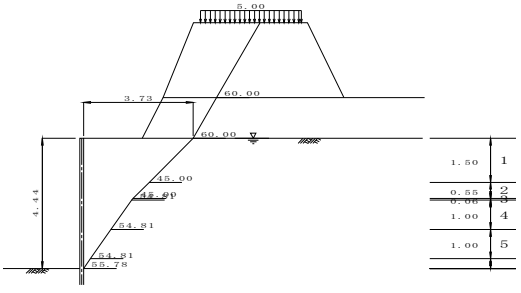
Allowable displacement　δ_a = 50.0 mm (Normal)
δ_a' = 75.0 mm (Seismic)

Bending of cantilever beam　calculated as distributed load of each layer

Reduction of material modulus　Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	4.44 ~ 4.11	Sand	28.4	15.0	0.0	29.20	42.06	43.51	55.78

2	4.11 ~ 3.11	Sand	27.0	15.0	0.0	26.73	42.06	40.28	54.81
3	3.11 ~ 2.11	Sand	27.0	15.0	0.0	19.22	42.06	30.48	54.81
4	2.11 ~ 2.05	Sand	27.0	15.0	0.0	11.72	42.06	20.68	54.81
5	2.05 ~ 1.50	Clay	0.0	15.0	25.0	11.27	42.06	20.09	45.00
6	1.50 ~ 0.00	Clay	0.0	15.0	25.0	8.25	42.06	14.70	45.00
7		embankment	30.0	———	0.0	75.05	5.00	0.00	60.00
8		embankment	30.0	———	0.0	48.64	5.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°

Where,

ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = $\tan^{-1}$k or θ = $\tan^{-1}$k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	55.78	0.33	0.00	0.00	0.22	0.33
2	54.81	1.00	0.22	0.33	0.93	1.33
3	54.81	1.00	0.93	1.33	1.63	2.33
4	54.81	0.06	1.63	2.33	1.68	2.39
5	45.00	0.55	1.68	2.39	2.23	2.94
6	45.00	1.50	2.23	2.94	3.73	4.44
7	60.00	1.39	3.73	4.44	4.53	5.83
8	60.00	2.56	4.53	5.83	6.01	8.39

From the above table, the loading width (L) on the ground surface is 3.73 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	2.47	46.97
2	19.0	5.24	99.65
Σ			146.61

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.1.4 Acting Load by Surcharge Load

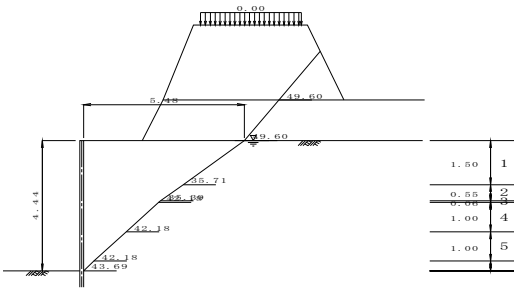
No	Q kN/m2	l m	Qxl kN/m
1	5.0	2.03	10.14
Σ			10.14

Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.1.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times l)+\Sigma P}{L} = \frac{146.61 + 10.14 + 0.00}{3.73} = 42.06\ \mathrm{kN/m^2}$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	4.44 ~ 4.11	Sand	28.4	15.0	0.0	29.20	56.26	43.51	0.200	11.31	43.69
2	4.11 ~ 3.11	Sand	27.0	15.0	0.0	26.73	56.26	40.28	0.200	11.31	42.18
3	3.11 ~ 2.11	Sand	27.0	15.0	0.0	19.22	56.26	30.48	0.200	11.31	42.18
4	2.11 ~ 2.05	Sand	27.0	15.0	0.0	11.72	56.26	20.68	0.200	11.31	42.18
5	2.05 ~ 1.50	Clay	0.0	15.0	25.0	11.27	56.26	20.09	0.200	11.31	35.39
6	1.50 ~ 0.00	Clay	0.0	15.0	25.0	8.25	56.26	14.70	0.200	11.31	35.71
7		embankment	30.0	———	0.0	75.05	0.00	0.00	0.200	11.31	49.60
8		embankment	30.0	———	0.0	48.64	0.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Where,

ζ : angle of active rupture (degree, ζ ≥ 10.00°)
ϕ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = $\tan^{-1}$k or θ = $\tan^{-1}$k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	43.69	0.33	0.00	0.00	0.35	0.33
2	42.18	1.00	0.35	0.33	1.45	1.33
3	42.18	1.00	1.45	1.33	2.55	2.33
4	42.18	0.06	2.55	2.33	2.62	2.39
5	35.39	0.55	2.62	2.39	3.39	2.94
6	35.71	1.50	3.39	2.94	5.48	4.44
7	49.60	1.39	5.48	4.44	6.66	5.83
8	49.60	1.66	6.66	5.83	8.07	7.49

From the above table, the loading width (L) on the ground surface is 5.48 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	5.17	98.27
2	19.0	11.05	210.01
Σ			308.28

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Acting Load by Surcharge Load

No	Q kN/m2	l m	Qxl kN/m
1	0.0	3.44	0.00
Σ			0.00

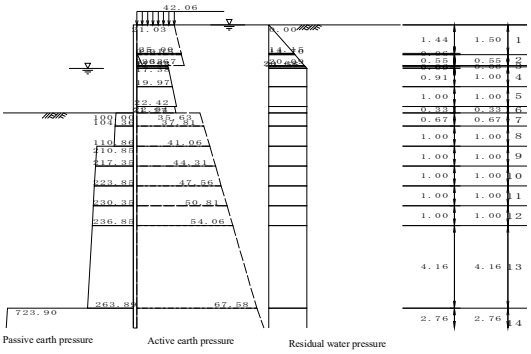
Q: width of surcharge load set by line of active rupture
l: Loading width of uniform load surrounded by main collapse line

2.2.5 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times l)+\Sigma P}{L} = \frac{308.28 + 0.00 + 0.00}{5.48} = 56.26\ \mathrm{kN/m^2}$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 1.44	Clay	5.5	——	25.0 25.0	42.057 50.000	——— ———	——— ———
2	1.44~ 1.50	Clay	5.5	——	25.0 25.0	50.000 50.307	——— ———	——— ———
3	1.50~ 2.05	Clay	5.5	——	25.0 25.0	50.307 53.332	——— ———	——— ———
4	2.05~ 2.11	Sand	7.5	27.0	——— ———	53.332 53.782	0.33738 0.33738	0.32589 0.32589
5	2.11~ 2.20	Sand	7.5	27.0	——— ———	53.782 54.457	0.33738 0.33738	0.32589 0.32589
6	2.20~ 3.11	Sand	7.5	27.0	——— ———	54.457 61.282	0.33738 0.33738	0.32589 0.32589
7	3.11~ 4.11	Sand	7.5	27.0	——— ———	61.282 68.782	0.33738 0.33738	0.32589 0.32589
8	4.11~ 4.44	Sand	7.5	28.4	——— ———	68.782 71.257	0.32022 0.32022	0.30931 0.30931
9	4.44~ 5.11	Clay	6.5	——	50.0 50.0	71.257 75.612	——— ———	——— ———
10	5.11~ 6.11	Clay	6.5	——	50.0 50.0	75.612 82.112	——— ———	——— ———
11	6.11~ 7.11	Clay	6.5	——	100.0 100.0	82.112 88.612	——— ———	——— ———
12	7.11~ 8.11	Clay	6.5	——	100.0 100.0	88.612 95.112	——— ———	——— ———
13	8.11~ 9.11	Clay	6.5	——	100.0 100.0	95.112 101.612	——— ———	——— ———
14	9.11~ 10.11	Clay	6.5	——	100.0 100.0	101.612 108.112	——— ———	——— ———
15	10.11~ 14.27	Clay	6.5	——	100.0 100.0	108.112 135.152	——— ———	——— ———
16	14.27~ 17.03	Clay	8.0	——	330.0 330.0	135.152 157.232	——— ———	——— ———
17	17.03~ 33.50	Clay	10.0	——	1000.0 1000.0	157.232 321.932	——— ———	——— ———

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β＝ 0.00、θ＝ 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cos δ
9	4.44~ 5.11	Clay	6.5	0.0	50.0 50.0	0.000 4.355	——— ———	——— ———
10	5.11~ 6.11	Clay	6.5	0.0	50.0 50.0	4.355 10.855	——— ———	——— ———
11	6.11~ 7.11	Clay	6.5	0.0	100.0 100.0	10.855 17.355	——— ———	——— ———
12	7.11~ 8.11	Clay	6.5	0.0	100.0 100.0	17.355 23.855	——— ———	——— ———
13	8.11~ 9.11	Clay	6.5	0.0	100.0 100.0	23.855 30.355	——— ———	——— ———
14	9.11~ 10.11	Clay	6.5	0.0	100.0 100.0	30.355 36.855	——— ———	——— ———
15	10.11~ 14.27	Clay	6.5	0.0	100.0 100.0	36.855 63.895	——— ———	——— ———
16	14.27~ 17.03	Clay	8.0	20.0	330.0 330.0	63.895 85.975	——— ———	——— ———
17	17.03~ 33.50	Clay	10.0	20.0	1000.0 1000.0	85.975 250.675	——— ———	——— ———

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= -15.00、β＝ 0.00、θ＝ 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\dfrac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 1.44	-7.94 0.00	21.03 25.00	21.03 25.00	0.00 14.15	——— ———
2	1.44~ 1.50	0.00 0.31	25.00 25.15	25.00 25.15	14.15 14.70	——— ———
3	1.50~ 2.05	0.31 3.33	25.15 26.67	25.15 26.67	14.70 20.09	——— ———
4	2.05~ 2.11	17.38 17.53	——— ———	17.38 17.53	20.09 20.68	——— ———
5	2.11~ 2.20	17.53 17.75	——— ———	17.53 17.75	20.68 21.56	——— ———
6	2.20~ 3.11	17.75 19.97	——— ———	17.75 19.97	21.56 21.56	——— ———
7	3.11~ 4.11	19.97 22.42	——— ———	19.97 22.42	21.56 21.56	——— ———
8	4.11~ 4.44	21.27 22.04	——— ———	21.27 22.04	21.56 21.56	——— ———
9	4.44~ 5.11	-28.74 -24.39	35.63 37.81	35.63 37.81	21.56 21.56	100.00 104.36
10	5.11~ 6.11	-24.39 -17.89	37.81 41.06	37.81 41.06	21.56 21.56	104.36 110.86
11	6.11~ 7.11	-117.89 -111.39	41.06 44.31	41.06 44.31	21.56 21.56	210.85 217.35
12	7.11~ 8.11	-111.39 -104.89	44.31 47.56	44.31 47.56	21.56 21.56	217.35 223.85
13	8.11~ 9.11	-104.89 -98.39	47.56 50.81	47.56 50.81	21.56 21.56	223.85 230.35
14	9.11~ 10.11	-98.39 -91.89	50.81 54.06	50.81 54.06	21.56 21.56	230.35 236.85
15	10.11~ 14.27	-91.89 -64.85	54.06 67.58	54.06 67.58	21.56 21.56	236.85 263.89
16	14.27~ 17.03	-524.85 -502.77	67.58 78.62	67.58 78.62	21.56 21.56	723.90 745.97
17	17.03~ 33.50	-1842.77 -1678.07	78.62 160.97	78.62 160.97	21.56 21.56	2085.98 2250.68

- Formula for active earth pressure

Sand $P_{a1}=K_a\cdot\left[\Sigma\gamma h+\dfrac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_{a1}=\Sigma\gamma h+Q-2C$

$P_{a2}=K_a\cdot(\Sigma\gamma h+Q)$

K_a : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1}=\left[K_a(\Sigma\gamma h+Q)-2C\sqrt{K_a}\right]\cdot\cos\delta$

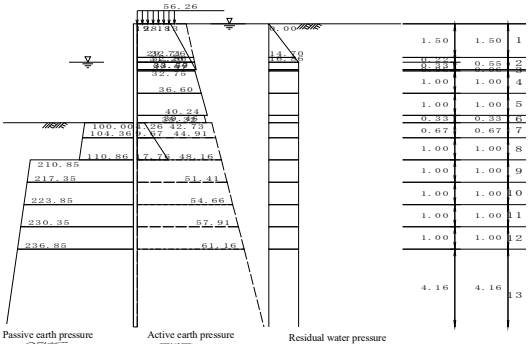
- Formula for passive earth pressure

Sand $P_p=K_p\cdot\left[\Sigma\gamma h+\dfrac{Q}{\cos(-\beta)}\right]\cdot\cos\delta$

Clay $P_p=\Sigma\gamma h+Q+2C$

Mixed soil $P_p=\left[K_p(\Sigma\gamma h+Q)+2C\sqrt{K_p}\right]\cdot\cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γ wlnw kN/m2	k (k')	θ degree	Ka	Ka × cos δ	ζ degree
1	0.00~ 1.50	Clay	5.5	——	25.0 25.0	56.26 64.51	0.00 14.70	0.200 0.200	11.31 11.31	——— ———	——— ———	36.56 35.71
2	1.50~ 1.72	Clay	5.5	——	25.0 25.0	64.51 65.72	14.70 16.86	0.200 0.200	11.31 11.31	——— ———	——— ———	35.71 35.59
3	1.72~ 2.05	Clay	5.5	——	25.0 25.0	65.72 67.54	16.86 20.09	0.200 0.200	11.31 11.31	——— ———	——— ———	35.59 35.39
4	2.05~ 2.11	Sand	7.5	27.0	——— ———	67.54 67.99	20.09 20.68	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
5	2.11~ 3.11	Sand	7.5	27.0	——— ———	67.99 75.49	20.68 30.48	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
6	3.11~ 4.11	Sand	7.5	27.0	——— ———	75.49 82.99	30.48 40.28	0.200 0.200	11.31 11.31	0.50201 0.50201	0.48490 0.48490	——— ———
7	4.11~ 4.44	Sand	7.5	28.4	——— ———	82.99 85.46	40.28 43.51	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	——— ———
8	4.44~ 5.11	Clay	6.5	——	50.0 50.0	85.46 89.82	43.51 50.08	0.200 0.200	11.31 11.31	——— ———	——— ———	40.25 40.08
9	5.11~ 6.11	Clay	6.5	——	50.0 50.0	89.82 96.32	50.08 59.88	0.200 0.200	11.31 11.31	——— ———	——— ———	40.08 39.81

10	6.11~ 7.11	Clay	6.5	——	100.0 100.0	96.32 102.82	59.88 69.68	0.200 0.200	11.31 11.31	——— ———	——— ———	42.63 42.52
11	7.11~ 8.11	Clay	6.5	——	100.0 100.0	102.82 109.32	69.68 79.48	0.200 0.200	11.31 11.31	——— ———	——— ———	42.52 42.41
12	8.11~ 9.11	Clay	6.5	——	100.0 100.0	109.32 115.82	79.48 89.28	0.200 0.200	11.31 11.31	——— ———	——— ———	42.41 42.30
13	9.11~ 10.11	Clay	6.5	——	100.0 100.0	115.82 122.32	89.28 99.08	0.200 0.200	11.31 11.31	——— ———	——— ———	42.30 42.19
14	10.11~ 14.27	Clay	6.5	——	100.0 100.0	122.32 149.36	99.08 139.85	0.200 0.200	11.31 11.31	——— ———	——— ———	42.19 41.71
15	14.27~ 17.03	Clay	8.0	——	330.0 330.0	149.36 171.44	139.85 166.89	0.200 0.200	11.31 11.31	——— ———	——— ———	44.08 43.98
16	17.03~ 33.50	Clay	10.0	——	1000.0 1000.0	171.44 336.14	166.89 328.30	0.200 0.200	11.31 11.31	——— ———	——— ———	44.67 44.43

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cos δ
8	4.44~ 5.11	Clay	6.50	0.0	50.0 50.0	0.000 4.355	0.00 6.57	0.200 0.200	11.31 11.31	——— ———	——— ———
9	5.11~ 6.11	Clay	6.50	0.0	50.0 50.0	4.355 10.855	6.57 16.37	0.200 0.200	11.31 11.31	——— ———	——— ———
10	6.11~ 7.11	Clay	6.50	0.0	100.0 100.0	10.855 17.355	16.37 26.17	0.200 0.200	11.31 11.31	——— ———	——— ———
11	7.11~ 8.11	Clay	6.50	0.0	100.0 100.0	17.355 23.855	26.17 35.97	0.200 0.200	11.31 11.31	——— ———	——— ———
12	8.11~ 9.11	Clay	6.50	0.0	100.0 100.0	23.855 30.355	35.97 45.77	0.200 0.200	11.31 11.31	——— ———	——— ———
13	9.11~ 10.11	Clay	6.50	0.0	100.0 100.0	30.355 36.855	45.77 55.57	0.200 0.200	11.31 11.31	——— ———	——— ———
14	10.11~ 14.27	Clay	6.50	0.0	100.0 100.0	36.855 63.895	55.57 96.33	0.200 0.200	11.31 11.31	——— ———	——— ———
15	14.27~ 17.03	Clay	8.00	20.0	330.0 330.0	63.895 85.975	96.33 123.38	0.200 0.200	11.31 11.31	——— ———	——— ———
16	17.03~ 33.50	Clay	10.00	20.0	1000.0 1000.0	85.975 250.675	123.38 284.79	0.200 0.200	11.31 11.31	——— ———	——— ———

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.
δ = 0.00 degrees, β = 0.00 degrees
Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active Pa1 kN/m2	Active Pa2 kN/m2	Active Pa kN/m2	Residual water pressure Pw kN/m2	Passive Pp kN/m2
1	0.00~ 1.50	19.18 29.71	28.13 32.26	28.13 32.26	0.00 14.70	——— ———
2	1.50~ 1.72	29.71 31.26	32.26 32.86	32.26 32.86	14.70 16.86	——— ———
3	1.72~ 2.05	31.26 33.60	32.86 33.77	32.86 33.77	16.86 16.86	——— ———
4	2.05~ 2.11	32.75 32.97	——— ———	32.75 32.97	16.86 16.86	——— ———
5	2.11~ 3.11	32.97 36.60	——— ———	32.97 36.60	16.86 16.86	——— ———
6	3.11~ 4.11	36.60 40.24	——— ———	36.60 40.24	16.86 16.86	——— ———
7	4.11~ 4.44	38.32 39.46	——— ———	38.32 39.46	16.86 16.86	——— ———
8	4.44~ 5.11	4.26 9.67	42.73 44.91	42.73 44.91	16.86 16.86	100.00 104.36
9	5.11~ 6.11	9.67 17.76	44.91 48.16	44.91 48.16	16.86 16.86	104.36 110.86
10	6.11~ 7.11	-83.44 -75.51	48.16 51.41	48.16 51.41	16.86 16.86	210.85 217.35
11	7.11~ 8.11	-75.51 -67.57	51.41 54.66	51.41 54.66	16.86 16.86	217.35 223.85
12	8.11~ 9.11	-67.57 -59.62	54.66 57.91	54.66 57.91	16.86 16.86	223.85 230.35
13	9.11~ 10.11	-59.62 -51.66	57.91 61.16	57.91 61.16	16.86 16.86	230.35 236.85
14	10.11~ 14.27	-51.66 -18.45	61.16 74.68	61.16 74.68	16.86 16.86	236.85 263.89
15	14.27~ 17.03	-480.14 -453.45	74.68 85.72	74.68 85.72	16.86 16.86	723.90 745.97
16	17.03~ 33.50	-1794.01 -1595.68	85.72 168.07	85.72 168.07	16.86 16.86	2085.98 2250.68

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.72	0.00	0.00
2	2.72	1.00	2.83
3	3.72	2.00	4.00
4	4.44	2.72	4.66

$$p_{dr} = \pm\frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

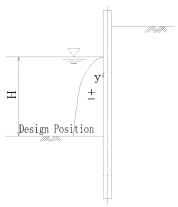
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

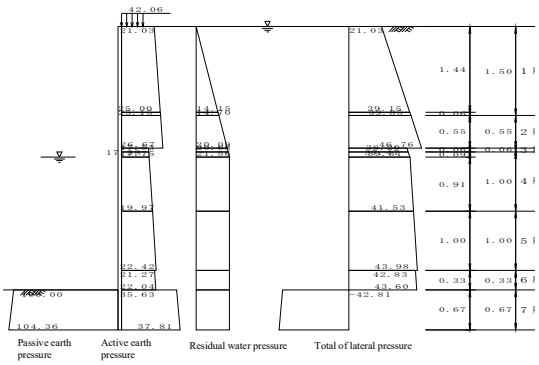
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.44	21.03 25.00	0.00 14.15	——— ———	21.03 39.15
2	1.44~ 1.50	25.00 25.15	14.15 14.70	——— ———	39.15 39.85
3	1.50~ 2.05	25.15 26.67	14.70 20.09	——— ———	39.85 46.76
4	2.05~ 2.11	17.38 17.53	20.09 20.68	——— ———	37.47 38.20
5	2.11~ 2.20	17.53 17.75	20.68 21.56	——— ———	38.20 39.31
6	2.20~ 3.11	17.75 19.97	21.56 21.56	——— ———	39.31 41.53
7	3.11~ 4.11	19.97 22.42	21.56 21.56	——— ———	41.53 43.98
8	4.11~ 4.44	21.27 22.04	21.56 21.56	——— ———	42.83 43.60
9	4.44~ 5.11	35.63 37.81	21.56 21.56	100.00 104.36	-42.81 -44.99

P_a : Active earth pressure

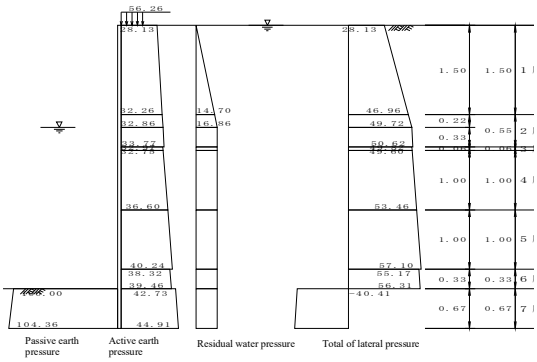
P_w : Residual water pressure

P_p : Passive earth pressure

P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -4.44 m)

4.2 Seismic Condition



No	Depth m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 1.50	28.13 32.26	0.00 14.70	—— ——	28.13 46.96
2	1.50~ 1.72	32.26 32.86	14.70 16.86	—— ——	46.96 49.72
3	1.72~ 2.05	32.86 33.77	16.86 16.86	—— ——	49.72 50.62
4	2.05~ 2.11	32.75 32.97	16.86 16.86	—— ——	49.60 49.82
5	2.11~ 3.11	32.97 36.60	16.86 16.86	—— ——	49.82 53.46
6	3.11~ 4.11	36.60 40.24	16.86 16.86	—— ——	53.46 57.10
7	4.11~ 4.44	38.32 39.46	16.86 16.86	—— ——	55.17 56.31
8	4.44~ 5.11	42.73 44.91	16.86 16.86	100.00 104.36	-40.41 -42.59

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.00 m (GL -4.44 m)

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	4.44	0.17	11.1	12.0	1.97
2	4.61	1.00	12.0	13.0	12.50
3	5.61	1.00	13.0	16.0	14.50
4	6.61	1.00	16.0	17.0	16.50
5	7.61	0.28	17.0	16.7	4.68
		L = Σh = 3.45		ΣA =	50.15

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \dfrac{\Sigma A}{L}$

$= \dfrac{50.15}{3.45}$

$= 14.55$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 14.55 = 40728$ kN/m²

$K_{h0} = \dfrac{1}{0.3} \times \alpha \times 40728 = 135760$ kN/m³ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_{II}/0.3)^{-3/4} = 135760(10.00/0.3)^{-3/4} = 9786$ kN/m³

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 9786 kN/m3.

5.3 Seismic Condition

Assuming Kh = 19008 kN/m3,

$\beta = \sqrt[4]{\dfrac{K_h \cdot B}{4EI}} = 0.342$ m⁻¹

$L = \dfrac{1}{\beta} = 2.92$ m

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -4.44 m) and 2.92 m depth (GL -7.36 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	4.44	0.17	11.1	12.0	1.97
2	4.61	1.00	12.0	13.0	12.50
3	5.61	1.00	13.0	16.0	14.50
4	6.61	0.75	16.0	16.8	12.29
		L = Σh = 2.92		ΣA =	41.25

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \dfrac{\Sigma A}{L}$

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$K_h = K_{h0}\left(\dfrac{B_{II}}{0.3}\right)^{-3/4}$ (B_{II}=10.00m)

$K_{h0} = \dfrac{1}{0.3} \alpha E_0$ (α :Normal Condition =1, Seismi Condition =2)

$E_h = 2800N'$

where:

$\beta = \sqrt[4]{\dfrac{K_h \cdot B}{4EI}}$

Material Name	10 H _ H 600 -200 - 12-16-13		
Unit width	B = 1.0000 m		
Corrosion margin	t_1 = 1.00 mm (active side)	t_2 =	1.00 mm (passive side)
Corrosion rate	η = 0.83		
Section efficiency	μ = 1.00		
Young's modulus	E = 200000 N/mm²		
Inertia sectional moment	I_0 = 208200 cm⁴(original condition)		
	I = 172806 cm⁴(after reduction by corrosion and section)		
Inertia sectional moment	EI = $200000 \times 10^3 \times 172806 \times 10^{-8} = 3.456 \times 10^5$		

No	Depth m	N Value
1	1.00	8
2	1.61	7
3	2.61	6
4	3.61	7
5	4.61	12
6	5.61	13
7	6.61	16
8	7.61	17
9	8.61	16
10	9.61	20

No	Depth m	N Value
11	10.61	27

5.2 Normal Condition

Assuming Kh = 9786 kN/m3,

$\beta = \sqrt[4]{\dfrac{K_h \cdot B}{4EI}} = 0.290$ m⁻¹

$L = \dfrac{1}{\beta} = 3.45$ m

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -4.44 m) to 3.45 m depth (GL -7.89 m).

$= \dfrac{41.25}{2.92}$

$= 14.13$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 14.13 = 39554$ kN/m²

$K_{h0} = \dfrac{1}{0.3} \times \alpha \times 39554 = 263694$ kN/m³ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_{II}/0.3)^{-3/4} = 263694(10.00/0.3)^{-3/4} = 19008$ kN/m³

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 19008 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 1.44	1.44	21.03 39.15	15.18 28.27	3.96 3.48	60.11 98.31
2	1.44~ 1.50	0.06	39.15 39.85	1.09 1.11	2.98 2.96	3.25 3.29
3	1.50~ 2.05	0.55	39.85 46.76	10.96 12.86	2.76 2.57	30.21 33.09
4	2.05~ 2.11	0.06	37.47 38.20	1.12 1.15	2.37 2.35	2.66 2.69
5	2.11~ 2.20	0.09	38.20 39.31	1.72 1.77	2.30 2.27	3.95 4.02
6	2.20~ 3.11	0.91	39.31 41.53	17.88 18.90	1.94 1.63	34.64 30.86
7	3.11~ 4.11	1.00	41.53 43.98	20.77 21.99	1.00 0.66	20.70 14.59
8	4.11~ 4.44	0.33	42.83 43.60	7.07 7.19	0.22 0.11	1.55 0.79
			ΣP = 169.03		ΣM = 344.72	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 0.0 kN/m
depth to acting position H_t = 0.0 m

moment	M_m	=	0.0 kN･m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	4.44 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m$ = 0.00 kN･m

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{344.72}{169.03} = 2.04 \text{ m}$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN ・ m
1	0.00~ 1.50	1.50	28.13 46.96	21.10 35.22	3.94 3.44	83.13 121.15
2	1.50~ 1.72	0.22	46.96 49.72	5.17 5.47	2.87 2.79	14.81 15.28
3	1.72~ 2.05	0.33	49.72 50.62	8.20 8.35	2.61 2.50	21.41 20.88
4	2.05~ 2.11	0.06	49.60 49.82	1.49 1.49	2.37 2.35	3.53 3.51
5	2.11~ 3.11	1.00	49.82 53.46	24.91 26.73	2.00 1.66	49.74 44.46
6	3.11~ 4.11	1.00	53.46 57.10	26.73 28.55	1.00 0.66	26.64 18.94
7	4.11~ 4.44	0.33	55.17 56.31	9.10 9.29	0.22 0.11	2.00 1.02
				ΣP = 211.80	ΣM = 426.49	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	0.00 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	0.0 kN･m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	4.44 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below

$M_t = P_t \cdot (H + L_k - H_t) + M_m$ = 0.00 kN･m

height of acting position of load	h_0	=	2.04 m
moment	M_0	=	344.72 kN･m/m
in consideration of ψ_m = 1.321,			
maximum moment	M_{max}	=	455.34 kN･m/m
depth of generated position of M_{max}	l_m	=	1.481 m
depth of 1st fixed point	l_i	=	4.189 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	19008 kN/m³
calculated value	β	=	0.34243 m⁻¹
resultant earth force (lateral)	P_0	=	219.75 kN/m
height of acting position of load	h_0	=	1.98 m
moment	M_0	=	434.56 kN･m/m
in consideration of ψ_m = 1.264,			
maximum moment	M_{max}	=	549.25 kN･m/m
depth of generated position of M_{max}	l_m	=	1.173 m
depth of 1st fixed point	l_i	=	3.467 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 600 -200 - 12-16-13		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.85
Section efficiency	μ	=	1.00
Module of section	Z_0	=	4270 cm³ (original condition)
	Z	=	3630 cm³ (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{455.34 \times 10^6}{3630 \times 10^3} = 125 \text{ N/mm}^2 \leqq \sigma_a = 180 \text{ N/mm}^2$$

6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{549.25 \times 10^6}{3630 \times 10^3} = 151 \text{ N/mm}^2 \leqq \sigma_a = 270 \text{ N/mm}^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

Modulus of deformation

No	Depth. m	Y m	α	ζ	P kN	Q kN
1	0.00~ 1.44	3.96 3.48	0.892 0.783	0.279 0.227	15.18 28.27	4.242 6.407
2	1.44~ 1.50	2.98 2.96	0.671 0.666	0.175 0.173	1.09 1.11	0.191 0.192

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN ・ m
1	1.72~ 2.72	1.00	0.0 2.8	0.00 1.41	2.39 2.05	0.00 2.90
2	2.72~ 3.72	1.00	2.8 4.0	1.41 2.00	1.39 1.05	1.96 2.11
3	3.72~ 4.44	0.72	4.0 4.7	1.44 1.68	0.48 0.24	0.69 0.40
				ΣPdw = 7.95	Σ Mdw = 8.07	

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{434.56}{219.75} = 1.98 \text{ m}$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name	10 H _ H 600 -200 - 12-16-13		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.83
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm²
Inertia sectional moment	I_0	=	208200 cm⁴ (original condition)
	I	=	172806 cm⁴ (after reduction by corrosion and section)
$EI = 200000 \times 10^3 \times 172806 \times 10^{-8}$		=	3.456×10^5

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	9786 kN/m³
calculated value	β	=	0.29006 m⁻¹
resultant earth force (lateral)	P_0	=	169.03 kN/m

3	1.50~ 2.05	2.76 2.57	0.621 0.580	0.153 0.136	10.96 12.86	1.675 1.742
4	2.05~ 2.11	2.37 2.35	0.534 0.529	0.117 0.115	1.12 1.15	0.132 0.132
5	2.11~ 2.20	2.30 2.27	0.518 0.511	0.111 0.108	1.72 1.77	0.191 0.192
6	2.20~ 3.11	1.94 1.63	0.436 0.368	0.081 0.059	17.88 18.90	1.454 1.122
7	3.11~ 4.11	1.00 0.66	0.224 0.149	0.023 0.011	20.77 21.99	0.484 0.233
8	4.11~ 4.44	0.22 0.11	0.050 0.025	0.001 0.000	7.07 7.19	0.009 0.002
					ΣQ = 18.399	

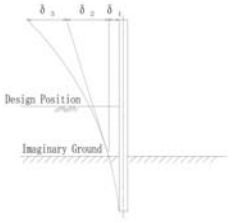
Y : Height from imaginary riverbed to acting position

$$\alpha : \alpha = \frac{Y}{H+L_k}$$

$$\zeta : \zeta = \frac{(3-\alpha)\times\alpha^2}{6}$$

Q : ζ × P
P : Lateral force
H : Depth to design position
L_k : Depth from design position to imaginary ground

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3} = \frac{(1+0.2901\times2.04)\times169.03}{2\times2.00\times10^8\times172806\times10^{-8}\times0.2901^3} = 0.01595 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2} \times (H+L_k) = \frac{(1+2\times0.2901\times2.04)\times169.03}{2\times2.00\times10^8\times172806\times10^{-8}\times0.2901^2} \times (4.44+0.00) = 0.02817 \text{ m}$$

$$\delta_3 = \frac{Q\times(H+L_k)^3}{EI}$$

$$= \frac{18.40\times(4.44+0.00)^3}{2.00\times10^8\times172806\times10^{-8}} = 0.00466 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.01595 + 0.02817 + 0.00466
= 0.04878 m
Size = 48.78 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Modulus of deformation

No	Depth. m	Y m	α	ζ	P kN	Q kN
1	0.00~ 1.50	3.94 3.44	0.887 0.775	0.277 0.223	21.10 35.22	5.850 7.840
2	1.50~ 1.72	2.87 2.79	0.646 0.629	0.164 0.156	5.17 5.47	0.845 0.855
3	1.72~ 2.05	2.61 2.50	0.588 0.563	0.139 0.129	8.20 8.35	1.140 1.076
4	2.05~ 2.11	2.37 2.35	0.534 0.529	0.117 0.115	1.49 1.49	0.174 0.172
5	2.11~ 3.11	2.00 1.66	0.450 0.375	0.086 0.061	24.91 26.73	2.141 1.641
6	3.11~ 4.11	1.00 0.66	0.224 0.149	0.023 0.011	26.73 28.55	0.623 0.303
7	4.11~ 4.44	0.22 0.11	0.050 0.025	0.001 0.000	9.10 9.29	0.011 0.003
					Σ Q =	22.674

Y : Height from imaginary riverbed to acting position
α : $\alpha = \frac{Y}{H+L_k}$
ζ : $\zeta = \frac{(3-\alpha)\times\alpha^2}{6}$
Q : $\zeta \times P$
P : Lateral force
H : Depth to design position
L_k : Depth from design position to imaginary ground

Dynamic water pressure due to earthquake is added to modulus of deformation Q

No	Depth. m	Y m	α	ζ	Pdw kN	Qdw kN
1	1.72~ 2.72	2.39 2.05	0.538 0.462	0.119 0.090	0.00 1.41	0.000 0.128
2	2.72~ 3.72	1.39 1.05	0.312 0.237	0.044 0.026	1.41 2.00	0.062 0.052
3	3.72~ 4.44	0.48 0.24	0.108 0.054	0.006 0.001	1.44 1.68	0.008 0.002

Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	208200 cm^4 (original condition)
	I	=	208200 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 208200 × 10^{-8}		=	4.164 × 10^5

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$
$$L = H - H_{ix} + D$$
$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 9786 kN/m^3
Calculated value β = 0.27686 m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.277} = 10.84$ m
Whole length of SSP $L = 4.44 - 0.40 + 10.84 = 14.88$ m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction K_h = 19008 kN/m^3
Calculated value β = 0.32685 m^{-1}

Penetration length of SSP $D = 0.00 + \frac{3}{0.327} = 9.18$ m
Whole length of SSP $L = 4.44 - 0.40 + 9.18 = 13.22$ m

Therefore, the total length of the sheet pile is 15.00 m from the rounded length value of 0.50 m.

8 Calculation Result

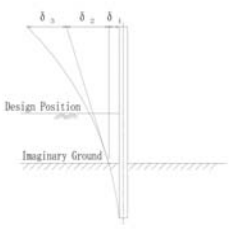
SSP 10 H _ H 600 -200 - 12-16-13

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	208200		
Sectional Modulus	Z (cm3)	4270		
Maximum bending moment	Mmax (kN・m・m)		455.34	549.25
Stress intensity	σ (N/mm2)		125 (180)	151 (270)
Lateral displacement	δ (mm)		48.78 (50.0)	47.43 (75.0)
Penetration depths	D (m)		10.84	9.18
Whole length of SSP	L (m)	15.00		

Σ Qdw =	0.252

Therefore, the deformation coefficient Q is expressed by
Q = 22.674 + 0.252 = 22.926

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$
$$= \frac{(1+0.3424\times1.98)\times219.75}{2\times2.00\times10^8\times172806\times10^{-8}\times0.3424^3} = 0.01328 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$
$$= \frac{(1+2\times0.3424\times1.98)\times219.75}{2\times2.00\times10^8\times172806\times10^{-8}\times0.3424^2}\times(4.44+0.00) = 0.02834 \text{ m}$$

$$\delta_3 = \frac{Q\times(H+L_k)^3}{EI}$$
$$= \frac{22.93\times(4.44+0.00)^3}{2.00\times10^8\times172806\times10^{-8}} = 0.00581 \text{ m}$$

$\delta = \delta 1 + \delta 2 + \delta 3$
= 0.01328 + 0.02834 + 0.00581
= 0.04743 m
Size = 47.43 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

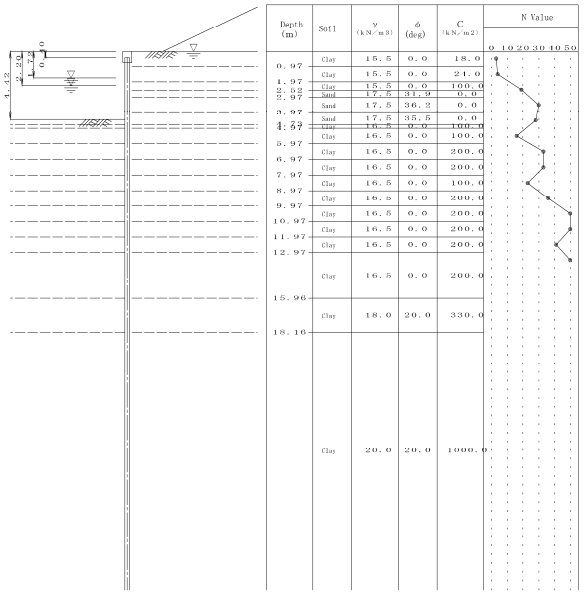
Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name	10 H _ H 600 -200 - 12-16-13		
Unit width	B	=	1.0000 m
Corrosion rate	η	=	1.00

Block No.	: R-17
Sta.	: 9+000~9+200
Design Cross Section	: Sta 9+000
Boring Name	: BMRL-25
Specification	: SSP SP-10H
(Combined)	: H 400-200-9-12-13

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



Depth (m)	Soil	γ (kN/m3)	φ (deg)	C (kN/m2)
0.97	Clay	15.5	0.0	18.0
1.97	Clay	15.5	0.0	24.0
2.52	Clay	15.5	0.0	100.0
2.97	Sand	17.5	31.9	0.0
3.97	Sand	17.5	36.2	0.0
4.73	Sand	17.5	35.5	0.0
5.97	Clay	16.5	0.0	100.0
6.97	Clay	16.5	0.0	200.0
7.97	Clay	16.5	0.0	200.0
8.97	Clay	16.5	0.0	100.0
9.97	Clay	16.5	0.0	200.0
10.97	Clay	16.5	0.0	200.0
11.97	Clay	16.5	0.0	200.0
12.97	Clay	16.5	0.0	200.0
15.96	Clay	18.0	20.0	330.0
18.16	Clay	20.0	20.0	1000.0

1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	4.42 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_h	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	2.20 m (Normal Condition)
	L_{wp}'	=	1.72 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress: Chang's formula

Penetration depths: $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water	γ_w = 9.8 kN/m^3
Type of water pressure	trapezoidal water pressure
Lateral pressure	calculated in consideration of site conditions
Study case	- Normal Condition - Seismic Condition
Design earthquake intensity	k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitary load	not considered
Wind load, Impact load	not considered
Minimum angle of rupture	ζ_0 = 10 degrees
Rear side angle of slope	not considered

Angle of rupture (clayey soil)

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h + Q}$$

Equilibrium factor of compression: K_c = 0.50 (considered in Seismic Condition)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \quad (\alpha: \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_H = 10.00 m

E_0 = 2800N

Average N-value: calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value
1	0.47	3
2	1.47	4
3	2.47	19
4	3.47	30
5	4.47	28
6	5.47	16
7	6.47	33
8	7.47	33
9	8.47	23
10	9.47	36

No	Depth m	N Value
11	10.47	50
12	11.47	50
13	12.47	41
14	13.47	50

1.6 Vertical Load

Vertical load on landside: calculated in consideration of embankment shape on landside

Vertical load on riverside: not considered

1.7 Soil Modulus

Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	0.97	0.97
2	1.97	1.00
3	2.52	0.55
4	2.97	0.45
5	3.97	1.00
6	4.73	0.76
7	4.97	0.24
8	5.97	1.00
9	6.97	1.00
10	7.97	1.00
11	8.97	1.00
12	9.97	1.00
13	10.97	1.00
14	11.97	1.00
15	12.97	1.00
16	15.96	2.99
17	18.16	2.20
18	33.50	15.34

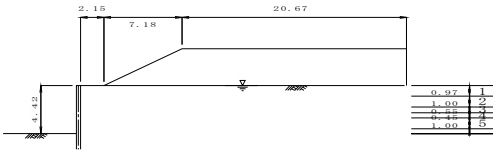
No	Depth m	earth Soil	N Value	γ kN/m3	γ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition
1	0.97	C	3.0	15.50	5.50	0.0	18.0	0.0	0.200	Auto	Auto
2	1.97	C	4.0	15.50	5.50	0.0	24.0	0.0	0.200	Auto	Auto
3	2.52	C	19.0	15.50	5.50	0.0	100.0	0.0	0.200	Auto	Auto
4	2.97	S	19.0	17.50	7.50	31.9	0.0	0.0	0.200	Auto	Auto
5	3.97	S	30.0	17.50	7.50	36.2	0.0	0.0	0.200	Auto	Auto
6	4.73	S	28.0	17.50	7.50	35.5	0.0	0.0	0.200	Auto	Auto
7	4.97	C	28.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
8	5.97	C	16.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
9	6.97	C	33.0	16.50	6.50	0.0	200.0	0.0	0.200	Auto	Auto
10	7.97	C	33.0	16.50	6.50	0.0	200.0	0.0	0.200	Auto	Auto
11	8.97	C	23.0	16.50	6.50	0.0	100.0	0.0	0.200	Auto	Auto
12	9.97	C	36.0	16.50	6.50	0.0	200.0	0.0	0.200	Auto	Auto
13	10.97	C	50.0	16.50	6.50	0.0	200.0	0.0	0.200	Auto	Auto
14	11.97	C	50.0	16.50	6.50	0.0	200.0	0.0	0.200	Auto	Auto
15	12.97	C	41.0	16.50	6.50	0.0	200.0	0.0	0.200	Auto	Auto
16	15.96	C	50.0	16.50	6.50	0.0	200.0	0.0	0.200	Auto	Auto
17	18.16	C	38.2	18.00	8.00	20.0	330.0	0.0	0.200	Auto	Auto
18	33.50	C	44.4	20.00	10.00	20.0	1000.0	0.0	0.200	Auto	Auto

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Aetive	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	Top Left m	Top Right m	Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	Seismic Condition degree
1	Sand	2.15	9.33	30.00	30.00	3.40	19.0	19.0	30.0	0.0	Auto	Auto

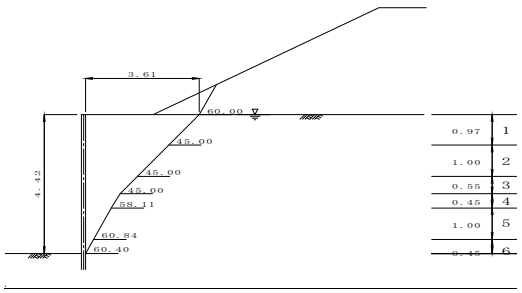
Angle of rapture in embankment: calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name	10 H _ H 400 -200 -9 -12 -13		
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	87800 cm^4
Sectional factor	Z_0	=	2320 m
Corrosion margin	t_1	=	1.00 mm (riverside) t_2 = 1.00 mm (landside)
Corrosion rate (to I_0)	η	=	0.80
Corrosion rate (to Z_0)	η	=	0.81
Section efficiency (to I_0)	μ	=	1.00
Section efficiency (to Z_0)	μ	=	1.00
Round unit of SSP length			0.50 m
Allowable stress	σ_a	=	180 N/mm (Normal)
	σ_a'	=	270 N/mm (Seismic)
Allowable displacement	δ_a	=	50.0 mm (Normal)
	δ_a'	=	75.0 mm (Seismic)
Bending of cantilever beam			calculated as distributed load of each layer
Reduction of material modulus			Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction Not reduced: I_0 applied to calculation of penetration depth Reduced: I_0 applied to calculation of section forces and displacement Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	$\Sigma\gamma h$ kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	4.42 ~ 3.97	Sand	35.5	15.0	0.0	28.11	3.67	43.32	60.40
2	3.97 ~ 2.97	Sand	36.2	15.0	0.0	24.74	3.67	38.91	60.84
3	2.97 ~ 2.52	Sand	31.9	15.0	0.0	17.24	3.67	29.11	58.11
4	2.52 ~ 1.97	Clay	0.0	15.0	100.0	13.86	3.67	24.70	45.00
5	1.97 ~ 0.97	Clay	0.0	15.0	24.0	10.84	3.67	19.31	45.00
6	0.97 ~ 0.00	Clay	0.0	15.0	18.0	5.34	3.67	9.51	45.00
7		embankment	30.0	——	0.0	64.60	0.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since $\theta = 0°$

Where,

- ζ : angle of active rupture (degree, $\zeta \geq 10.00°$)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  $\theta = \tan^{-1}k$ or $\theta = \tan^{-1}k'$
- γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m^2)
- C : cohesive force of soil (kN/m^2)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	60.40	0.45	0.00	0.00	0.26	0.45
2	60.84	1.00	0.26	0.45	0.81	1.45
3	58.11	0.45	0.81	1.45	1.09	1.90
4	45.00	0.55	1.09	1.90	1.64	2.45
5	45.00	1.00	1.64	2.45	2.64	3.45
6	45.00	0.97	2.64	3.45	3.61	4.42
7	60.00	0.95	3.61	4.42	4.16	5.37

From the above table, the loading width (L) on the ground surface is 3.61 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	$\gamma \times A$ kN/m
1	19.0	0.70	13.26
Σ			13.26

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

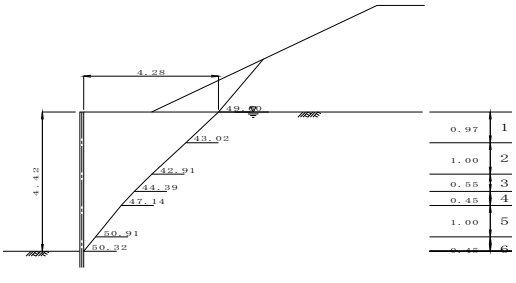
2.1.4 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{13.26 + 0.00 + 0.00}{3.61}$$

$$= 3.67 \text{ kN/m}^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	$\Sigma\gamma h$ kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	4.42 ~ 3.97	Sand	35.5	15.0	0.0	28.11	7.99	43.32	0.200	11.31	50.32
2	3.97 ~ 2.97	Sand	36.2	15.0	0.0	24.74	7.99	38.91	0.200	11.31	50.91
3	2.97 ~ 2.52	Sand	31.9	15.0	0.0	17.24	7.99	29.11	0.200	11.31	47.14
4	2.52 ~ 1.97	Clay	0.0	15.0	100.0	13.86	7.99	24.70	0.200	11.31	44.39
5	1.97 ~ 0.97	Clay	0.0	15.0	24.0	10.84	7.99	19.31	0.200	11.31	42.91
6	0.97 ~ 0.00	Clay	0.0	15.0	18.0	5.34	7.99	9.51	0.200	11.31	43.02
7		embankment	30.0	——	0.0	64.60	0.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\dfrac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h+Q}$$

Where,

- ζ : angle of active rupture (degree, $\zeta \geq 10.00°$)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  $\theta = \tan^{-1}k$ or $\theta = \tan^{-1}k'$
- γ : unit weight of soil (kN/m^3) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m^2)
- C : cohesive force of soil (kN/m^2)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	50.32	0.45	0.00	0.00	0.37	0.45
2	50.91	1.00	0.37	0.45	1.19	1.45
3	47.14	0.45	1.19	1.45	1.60	1.90
4	44.39	0.55	1.60	1.90	2.17	2.45
5	42.91	1.00	2.17	2.45	3.24	3.45
6	43.02	0.97	3.24	3.45	4.28	4.42
7	49.60	1.69	4.28	4.42	5.72	6.11

From the above table, the loading width (L) on the ground surface is 4.28 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	$\gamma \times A$ kN/m
1	19.0	1.80	34.18
Σ			34.18

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Calculated Load

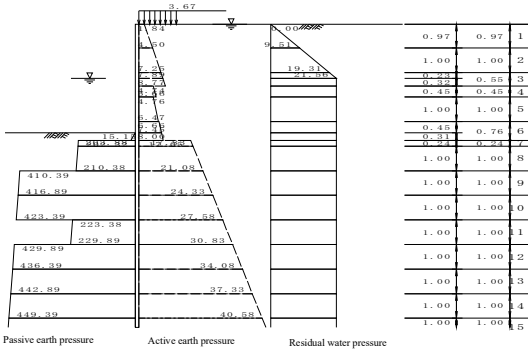
$$Q = \frac{\Sigma(\gamma \times A) + \Sigma(Q \times l) + \Sigma P}{L}$$

$$= \frac{34.18 + 0.00 + 0.00}{4.28}$$

$$= 7.99 \text{ kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cosδ
1	0.00~ 0.97	Clay	5.5	——	18.0 18.0	3.670 9.005	—— ——	—— ——
2	0.97~ 1.97	Clay	5.5	——	24.0 24.0	9.005 14.505	—— ——	—— ——
3	1.97~ 2.20	Clay	5.5	——	100.0 100.0	14.505 15.770	—— ——	—— ——
4	2.20~ 2.52	Clay	5.5	——	100.0 100.0	15.770 17.530	—— ——	—— ——
5	2.52~ 2.97	Sand	7.5	31.9	—— ——	17.530 20.905	0.28015 0.28015	0.27060 0.27060
6	2.97~ 3.97	Sand	7.5	36.2	—— ——	20.905 28.405	0.23596 0.23596	0.22792 0.22792
7	3.97~ 4.42	Sand	7.5	35.5	—— ——	28.405 31.780	0.24280 0.24280	0.23452 0.23452
8	4.42~ 4.73	Sand	7.5	35.5	—— ——	31.780 34.105	0.24280 0.24280	0.23452 0.23452
9	4.73~ 4.97	Clay	6.5	——	100.0 100.0	34.105 35.665	—— ——	—— ——
10	4.97~ 5.97	Clay	6.5	——	100.0 100.0	35.665 42.165	—— ——	—— ——
11	5.97~ 6.97	Clay	6.5	——	200.0 200.0	42.165 48.665	—— ——	—— ——
12	6.97~ 7.97	Clay	6.5	——	200.0 200.0	48.665 55.165	—— ——	—— ——
13	7.97~ 8.97	Clay	6.5	——	100.0 100.0	55.165 61.665	—— ——	—— ——
14	8.97~ 9.97	Clay	6.5	——	200.0 200.0	61.665 68.165	—— ——	—— ——
15	9.97~ 10.97	Clay	6.5	——	200.0 200.0	68.165 74.665	—— ——	—— ——
16	10.97~ 11.97	Clay	6.5	——	200.0 200.0	74.665 81.165	—— ——	—— ——
17	11.97~ 12.97	Clay	6.5	——	200.0 200.0	81.165 87.665	—— ——	—— ——
18	12.97~ 15.96	Clay	6.5	——	200.0 200.0	87.665 107.100	—— ——	—— ——
19	15.96~ 18.16	Clay	8.0	——	330.0 330.0	107.100 124.700	—— ——	—— ——
20	18.16~ 33.50	Clay	10.0	——	1000.0 1000.0	124.700 278.100	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β= 0.00、θ= 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cosδ
8	4.42~ 4.73	Sand	7.5	35.5	—— ——	0.000 2.325	6.74695 6.74695	6.51706 6.51706
9	4.73~ 4.97	Clay	6.5	0.0	100.0 100.0	2.325 3.885	—— ——	—— ——
10	4.97~ 5.97	Clay	6.5	0.0	100.0 100.0	3.885 10.385	—— ——	—— ——
11	5.97~ 6.97	Clay	6.5	0.0	200.0 200.0	10.385 16.885	—— ——	—— ——
12	6.97~ 7.97	Clay	6.5	0.0	200.0 200.0	16.885 23.385	—— ——	—— ——
13	7.97~ 8.97	Clay	6.5	0.0	100.0 100.0	23.385 29.885	—— ——	—— ——
14	8.97~ 9.97	Clay	6.5	0.0	200.0 200.0	29.885 36.385	—— ——	—— ——
15	9.97~ 10.97	Clay	6.5	0.0	200.0 200.0	36.385 42.885	—— ——	—— ——
16	10.97~ 11.97	Clay	6.5	0.0	200.0 200.0	42.885 49.385	—— ——	—— ——
17	11.97~ 12.97	Clay	6.5	0.0	200.0 200.0	49.385 55.885	—— ——	—— ——
18	12.97~ 15.96	Clay	6.5	0.0	200.0 200.0	55.885 75.320	—— ——	—— ——
19	15.96~ 18.16	Clay	8.0	20.0	330.0 330.0	75.320 92.920	—— ——	—— ——
20	18.16~ 33.50	Clay	10.0	20.0	1000.0 1000.0	92.920 246.320	—— ——	—— ——

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= -15.00、β= 0.00、θ= 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.97	-32.33 -26.99	1.84 4.50	1.84 4.50	0.00 9.51	—— ——
2	0.97~ 1.97	-38.99 -33.49	4.50 7.25	4.50 7.25	9.51 19.31	—— ——
3	1.97~ 2.20	-185.49 -184.23	7.25 7.89	7.25 7.89	19.31 21.56	—— ——
4	2.20~ 2.52	-184.23 -182.47	7.89 8.77	7.89 8.77	21.56 21.56	—— ——
5	2.52~ 2.97	4.74 5.66	—— ——	4.74 5.66	21.56 21.56	—— ——
6	2.97~ 3.97	4.76 6.47	—— ——	4.76 6.47	21.56 21.56	—— ——
7	3.97~ 4.42	6.66 7.45	—— ——	6.66 7.45	21.56 21.56	—— ——
8	4.42~ 4.73	7.45 8.00	—— ——	7.45 8.00	21.56 21.56	0.00 15.15
9	4.73~ 4.97	-165.89 -164.33	17.05 17.83	17.05 17.83	21.56 21.56	202.32 203.88
10	4.97~ 5.97	-164.33 -157.83	17.83 21.08	17.83 21.08	21.56 21.56	203.88 210.38
11	5.97~ 6.97	-357.83 -351.33	21.08 24.33	21.08 24.33	21.56 21.56	410.39 416.89
12	6.97~ 7.97	-351.33 -344.83	24.33 27.58	24.33 27.58	21.56 21.56	416.89 423.39
13	7.97~ 8.97	-144.83 -138.33	27.58 30.83	27.58 30.83	21.56 21.56	223.38 229.89
14	8.97~ 9.97	-338.33 -331.83	30.83 34.08	30.83 34.08	21.56 21.56	429.89 436.39
15	9.97~ 10.97	-331.83 -325.33	34.08 37.33	34.08 37.33	21.56 21.56	436.39 442.89
16	10.97~ 11.97	-325.33 -318.83	37.33 40.58	37.33 40.58	21.56 21.56	442.89 449.39
17	11.97~ 12.97	-318.83 -312.33	40.58 43.83	40.58 43.83	21.56 21.56	449.39 455.89
18	12.97~ 15.96	-312.33 -292.90	43.83 53.55	43.83 53.55	21.56 21.56	455.89 475.32
19	15.96~ 18.16	-552.90 -535.30	53.55 62.35	53.55 62.35	21.56 21.56	735.32 752.92
20	18.16~ 33.50	-1875.30 -1721.90	62.35 139.05	62.35 139.05	21.56 21.56	2092.92 2246.32

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

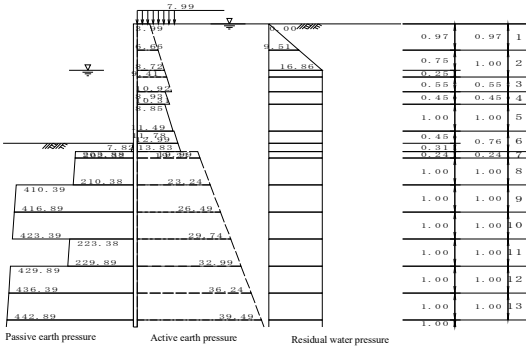
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 0.97	Clay	5.5	——	18.0 18.0	7.99 13.32	0.00 9.51	0.200 0.200	11.31 11.31	—— ——	—— ——	43.78 43.02
2	0.97~ 1.72	Clay	5.5	——	24.0 24.0	13.32 17.45	9.51 16.86	0.200 0.200	11.31 11.31	—— ——	—— ——	43.49 43.06
3	1.72~ 1.97	Clay	5.5	——	24.0 24.0	17.45 18.82	16.86 19.31	0.200 0.200	11.31 11.31	—— ——	—— ——	43.06 42.91
4	1.97~ 2.52	Clay	5.5	——	100.0 100.0	18.82 21.85	19.31 24.70	0.200 0.200	11.31 11.31	—— ——	—— ——	44.47 44.39
5	2.52~ 2.97	Sand	7.5	31.9	—— ——	21.85 25.22	24.70 29.11	0.200 0.200	11.31 11.31	0.42299 0.42299	0.40858 0.40858	—— ——
6	2.97~ 3.97	Sand	7.5	36.2	—— ——	25.22 32.72	29.11 38.91	0.200 0.200	11.31 11.31	0.36344 0.36344	0.35106 0.35106	—— ——
7	3.97~ 4.42	Sand	7.5	35.5	—— ——	32.72 36.10	38.91 43.32	0.200 0.200	11.31 11.31	0.37261 0.37261	0.35992 0.35992	—— ——
8	4.42~ 4.73	Sand	7.5	35.5	—— ——	36.10 38.42	43.32 46.35	0.200 0.200	11.31 11.31	0.37261 0.37261	0.35992 0.35992	—— ——
9	4.73~ 4.97	Clay	6.5	——	100.0 100.0	38.42 39.98	46.35 48.71	0.200 0.200	11.31 11.31	—— ——	—— ——	43.94 43.90
10	4.97~ 5.97	Clay	6.5	——	100.0 100.0	39.98 46.48	48.71 58.51	0.200 0.200	11.31 11.31	—— ——	—— ——	43.90 43.73
11	5.97~ 6.97	Clay	6.5	——	200.0 200.0	46.48 52.98	58.51 68.31	0.200 0.200	11.31 11.31	—— ——	—— ——	44.35 44.26
12	6.97~ 7.97	Clay	6.5	——	200.0 200.0	52.98 59.48	68.31 78.11	0.200 0.200	11.31 11.31	—— ——	—— ——	44.26 44.17
13	7.97~ 8.97	Clay	6.5	——	100.0 100.0	59.48 65.98	78.11 87.91	0.200 0.200	11.31 11.31	—— ——	—— ——	43.39 43.23
14	8.97~ 9.97	Clay	6.5	——	200.0 200.0	65.98 72.48	87.91 97.71	0.200 0.200	11.31 11.31	—— ——	—— ——	44.08 44.00
15	9.97~ 10.97	Clay	6.5	——	200.0 200.0	72.48 78.98	97.71 107.51	0.200 0.200	11.31 11.31	—— ——	—— ——	44.00 43.91
16	10.97~ 11.97	Clay	6.5	——	200.0 200.0	78.98 85.48	107.51 117.31	0.200 0.200	11.31 11.31	—— ——	—— ——	43.91 43.83
17	11.97~ 12.97	Clay	6.5	——	200.0 200.0	85.48 91.98	117.31 127.11	0.200 0.200	11.31 11.31	—— ——	—— ——	43.83 43.74
18	12.97~ 15.96	Clay	6.5	——	200.0 200.0	91.98 111.42	127.11 156.41	0.200 0.200	11.31 11.31	—— ——	—— ——	43.74 43.49
19	15.96~ 18.16	Clay	8.0	——	330.0 330.0	111.42 129.02	156.41 177.97	0.200 0.200	11.31 11.31	—— ——	—— ——	44.06 43.92
20	18.16~ 33.50	Clay	10.0	——	1000.0 1000.0	129.02 282.42	177.97 328.30	0.200 0.200	11.31 11.31	—— ——	—— ——	44.64 44.21

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ = 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta+\theta) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}} \cdot \tan\theta$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	γwhw kN/m2	k (k')	θ degree	Kp	Kp × cosδ
8	4.42~ 4.73	Sand	7.50	35.5	—— ——	0.000 2.325	0.00 3.04	0.200 0.200	11.31 11.31	3.36140 3.36140	3.36140 3.36140
9	4.73~ 4.97	Clay	6.50	0.0	100.0 100.0	2.325 3.885	3.04 5.39	0.200 0.200	11.31 11.31	—— ——	—— ——
10	4.97~ 5.97	Clay	6.50	0.0	100.0 100.0	3.885 10.385	5.39 15.19	0.200 0.200	11.31 11.31	—— ——	—— ——
11	5.97~ 6.97	Clay	6.50	0.0	200.0 200.0	10.385 16.885	15.19 24.99	0.200 0.200	11.31 11.31	—— ——	—— ——
12	6.97~ 7.97	Clay	6.50	0.0	200.0 200.0	16.885 23.385	24.99 34.79	0.200 0.200	11.31 11.31	—— ——	—— ——
13	7.97~ 8.97	Clay	6.50	0.0	100.0 100.0	23.385 29.885	34.79 44.59	0.200 0.200	11.31 11.31	—— ——	—— ——
14	8.97~ 9.97	Clay	6.50	0.0	200.0 200.0	29.885 36.385	44.59 54.39	0.200 0.200	11.31 11.31	—— ——	—— ——
15	9.97~ 10.97	Clay	6.50	0.0	200.0 200.0	36.385 42.885	54.39 64.19	0.200 0.200	11.31 11.31	—— ——	—— ——
16	10.97~ 11.97	Clay	6.50	0.0	200.0 200.0	42.885 49.385	64.19 73.99	0.200 0.200	11.31 11.31	—— ——	—— ——
17	11.97~ 12.97	Clay	6.50	0.0	200.0 200.0	49.385 55.885	73.99 83.79	0.200 0.200	11.31 11.31	—— ——	—— ——
18	12.97~ 15.96	Clay	6.50	0.0	200.0 200.0	55.885 75.320	83.79 113.09	0.200 0.200	11.31 11.31	—— ——	—— ——
19	15.96~ 18.16	Clay	8.00	20.0	330.0 330.0	75.320 92.920	113.09 134.65	0.200 0.200	11.31 11.31	—— ——	—— ——
20	18.16~ 33.50	Clay	10.00	20.0	1000.0 1000.0	92.920 246.320	134.65 284.98	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta \cdot \cos(\delta-\theta) \cdot \left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.97	-26.38 -19.91	3.99 6.66	3.99 6.66	0.00 9.51	—— ——
2	0.97~ 1.72	-31.94 -26.93	6.66 8.72	6.66 8.72	9.51 16.86	—— ——
3	1.72~ 1.97	-26.93 -25.26	8.72 9.41	8.72 9.41	16.86 16.86	—— ——
4	1.97~ 2.52	-177.38 -173.73	9.41 10.92	9.41 10.92	16.86 16.86	—— ——
5	2.52~ 2.97	8.93 10.31	—— ——	8.93 10.31	16.86 16.86	—— ——
6	2.97~ 3.97	8.85 11.49	—— ——	8.85 11.49	16.86 16.86	—— ——
7	3.97~ 4.42	11.78 12.99	—— ——	11.78 12.99	16.86 16.86	—— ——
8	4.42~ 4.73	12.99 13.83	—— ——	12.99 13.83	16.86 16.86	0.00 7.82
9	4.73~ 4.97	-153.74 -151.86	19.21 19.99	19.21 19.99	16.86 16.86	202.32 203.88
10	4.97~ 5.97	-151.86 -144.00	19.99 23.24	19.99 23.24	16.86 16.86	203.88 210.38
11	5.97~ 6.97	-344.11 -336.28	23.24 26.49	23.24 26.49	16.86 16.86	410.39 416.89
12	6.97~ 7.97	-336.28 -328.44	26.49 29.74	26.49 29.74	16.86 16.86	416.89 423.39
13	7.97~ 8.97	-128.25 -120.36	29.74 32.99	29.74 32.99	16.86 16.86	223.38 229.89
14	8.97~ 9.97	-320.60 -312.75	32.99 36.24	32.99 36.24	16.86 16.86	429.89 436.39
15	9.97~ 10.97	-312.75 -304.90	36.24 39.49	36.24 39.49	16.86 16.86	436.39 442.89
16	10.97~ 11.97	-304.90 -297.04	39.49 42.74	39.49 42.74	16.86 16.86	442.89 449.39
17	11.97~ 12.97	-297.04 -289.18	42.74 45.99	42.74 45.99	16.86 16.86	449.39 455.89
18	12.97~ 15.96	-289.18 -265.65	45.99 55.71	45.99 55.71	16.86 16.86	455.89 475.32
19	15.96~ 18.16	-525.91 -504.66	55.71 64.51	55.71 64.51	16.86 16.86	735.32 752.92
20	18.16~ 33.50	-1845.01 -1660.28	64.51 141.21	64.51 141.21	16.86 16.86	2092.92 2246.32

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.72	0.00	0.00
2	2.72	1.00	2.82
3	3.72	2.00	3.99
4	4.42	2.70	4.63

$$p_{dw} = \pm\frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

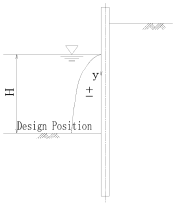
Where,

k_{hs}: design seismic coefficient

γ_w : unit weight of water

H : water depth of riverside

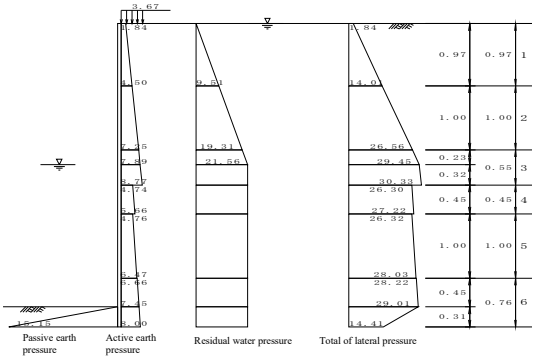
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

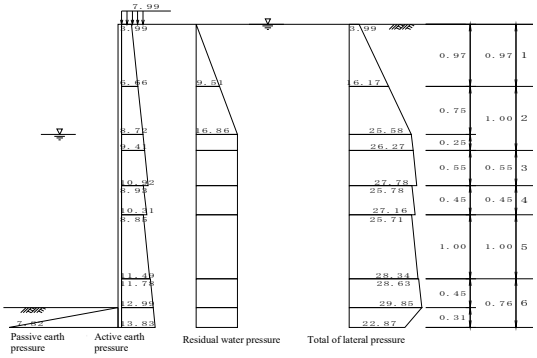
4.1 Normal Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.97	1.84 4.50	0.00 9.51	——— ———	1.84 14.01
2	0.97~ 1.97	4.50 7.25	9.51 19.31	——— ———	14.01 26.56
3	1.97~ 2.20	7.25 7.89	19.31 21.56	——— ———	26.56 29.45
4	2.20~ 2.52	7.89 8.77	21.56 21.56	——— ———	29.45 30.33
5	2.52~ 2.97	4.74 5.66	21.56 21.56	——— ———	26.30 27.22
6	2.97~ 3.97	4.76 6.47	21.56 21.56	——— ———	26.32 28.03
7	3.97~ 4.42	6.66 7.45	21.56 21.56	——— ———	28.22 29.01
8	4.42~ 4.73	7.45 8.00	21.56 21.56	0.00 15.15	29.01 14.41
9	4.73~ 4.97	17.05 17.83	21.56 21.56	202.32 203.88	-163.71 -164.49

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.31 m (GL -4.75 m)
Let the virtual ground surface Lk = 0.31 m (GL -4.73 m).



4.2 Seismic Condition

No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.97	3.99 6.66	0.00 9.51	——— ———	3.99 16.17
2	0.97~ 1.72	6.66 8.72	9.51 16.86	——— ———	16.17 25.58
3	1.72~ 1.97	8.72 9.41	16.86 16.86	——— ———	25.58 26.27
4	1.97~ 2.52	9.41 10.92	16.86 16.86	——— ———	26.27 27.78
5	2.52~ 2.97	8.93 10.31	16.86 16.86	——— ———	25.78 27.16
6	2.97~ 3.97	8.85 11.49	16.86 16.86	——— ———	25.71 28.34
7	3.97~ 4.42	11.78 12.99	16.86 16.86	——— ———	28.63 29.85
8	4.42~ 4.73	12.99 13.83	16.86 16.86	0.00 7.82	29.85 22.87
9	4.73~ 4.97	19.21 19.99	16.86 16.86	202.32 203.88	-166.26 -167.04

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 0.31 m (GL -4.75 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0}\left(\frac{B_{II}}{0.3}\right)^{-3/4} \qquad (B_{II}=10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3}\alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

Material Name	10 H _ H 400 -200 -9 -12 -13				
Unit width	B	=	1.0000 m		
Corrosion margin	t_1	=	1.00 mm (active side)	t_2 =	1.00 mm (passive side)
Corrosion rate	η	=	0.80		
Section efficiency	μ	=	0.80		
Young's modulus	E	=	200000 N/mm^2		
Inertia sectional moment	I_0	=	87800 cm^4(original condition)		
	I	=	56192 cm^4(after reduction by corrosion and section)		
Inertia sectional moment	EI	=	$200000 \times 10^3 \times 56192 \times 10^{-8} = 1.124 \times 10^5$		

No	Depth m	N Value
1	0.47	3
2	1.47	4
3	2.47	19
4	3.47	30
5	4.47	28
6	5.47	16
7	6.47	33
8	7.47	33
9	8.47	23
10	9.47	36

No	Depth m	N Value
11	10.47	50
12	11.47	50
13	12.47	41
14	13.47	50

5.2 Normal Condition

Assuming Kh = 16928 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.441\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 2.27\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -4.73 m) to 2.27 m depth (GL -7.00 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	4.73	0.74	24.9	16.0	15.13
2	5.47	1.00	16.0	33.0	24.50
3	6.47	0.53	33.0	33.0	17.49
		L = Σh = 2.27		Σ A =	57.12

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{57.12}{2.27} = 25.16$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 25.16 = 70452\ \text{kN/m}^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 70452 = 234840\ \text{kN/m}^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_{II}/0.3)^{-3/4} = 234840(10.00/0.3)^{-3/4} = 16928\ \text{kN/m}^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 16928 kN/m3.

5.3 Seismic Condition

Assuming Kh = 32033 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.517\ \text{m}^{-1}$$

$$L = \frac{1}{\beta} = 1.94\ \text{m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -4.73 m) and 1.94 m depth (GL -6.67 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	4.73	0.74	24.9	16.0	15.13
2	5.47	1.00	16.0	33.0	24.50
3	6.47	0.20	33.0	33.0	6.45
		L = Σh = 1.94		Σ A =	46.08

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L}$

$$= \frac{46.08}{1.94}$$

$$= 23.81$$

Kh is recalculated from the calculated average N value.

$$E_0 = 2800N' = 2800 \times 23.81 = 66658 \ kN/m^2$$

$$K_{h0} = \frac{1}{0.3} \times \alpha \times 66658 = 444388 \ kN/m^3 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$K_h = K_{h0}(B_H/0.3)^{-3/4} = 444388(10.00/0.3)^{-3/4} = 32033 \ kN/m^3$$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 32033 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.97	0.97	1.84 14.01	0.89 6.79	4.41 4.08	3.92 27.74
2	0.97~ 1.97	1.00	14.01 26.56	7.00 13.28	3.43 3.09	24.00 41.08
3	1.97~ 2.20	0.23	26.56 29.45	3.05 3.39	2.68 2.61	8.20 8.83
4	2.20~ 2.52	0.32	29.45 30.33	4.71 4.85	2.42 2.32	11.42 11.24
5	2.52~ 2.97	0.45	26.30 27.22	5.92 6.12	2.06 1.91	12.19 11.70
6	2.97~ 3.97	1.00	26.32 28.03	13.16 14.02	1.43 1.09	18.78 15.33
7	3.97~ 4.42	0.45	28.22 29.01	6.35 6.53	0.61 0.46	3.87 3.00
8	4.42~ 4.73	0.31	29.01 14.41	4.50 2.23	0.21 0.10	0.93 0.23
				ΣP= 102.80	ΣM= 202.45	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	0.0 kN/m
depth to acting position	H_t	=	0.0 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	4.42 m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y' m	Moment Mdw kN・m
1	1.72~ 2.72	1.00	0.0 2.8	0.00 1.41	2.68 2.34	0.00 3.30
2	2.72~ 3.72	1.00	2.8 4.0	1.41 1.99	1.68 1.34	2.36 2.68
3	3.72~ 4.42	0.70	4.0 4.6	1.39 1.62	0.78 0.54	1.08 0.88
				ΣPdw= 7.83	Σ Mdw= 10.30	

h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}}$$

$$= \frac{224.80}{114.87} = 1.96 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 114.87}{4.73} = 48.57 \ kN/m$$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name	10 H _ H 400 -200 -9 -12 -13		
Unit width	B	=	1.0000 m
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.80
Section efficiency	μ	=	1.00
Young's modulus	E	=	200000 N/mm^2
Inertia sectional moment	I_0	=	87800 cm^4 (original condition)
	I	=	56192 cm^4 (after reduction by corrosion and section)

$EI = 200000 \times 10^3 \times 56192 \times 10^{-8} = 1.124 \times 10^6$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_m = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp(-\tan^{-1}\frac{1}{1+2\beta h_0})$$

$$M_{max} = M_0 \cdot \phi_m$$

$$l_m = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

Depth of Imaginary riverbed from riverbed L_k = 0.31 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 0.00$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t}$$

$$= \frac{202.45}{102.80} = 1.97 \ m$$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 102.80}{4.73} = 43.47 \ kN/m$$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00~ 0.97	0.97	3.99 16.17	1.94 7.84	4.41 4.08	8.53 32.02
2	0.97~ 1.72	0.75	16.17 25.58	6.06 9.59	3.51 3.26	21.28 31.27
3	1.72~ 1.97	0.25	25.58 26.27	3.20 3.28	2.93 2.84	9.36 9.34
4	1.97~ 2.52	0.55	26.27 27.78	7.22 7.64	2.58 2.39	18.61 18.28
5	2.52~ 2.97	0.45	25.78 27.16	5.80 6.11	2.06 1.91	11.95 11.67
6	2.97~ 3.97	1.00	25.71 28.34	12.86 14.17	1.43 1.09	18.34 15.49
7	3.97~ 4.42	0.45	28.63 29.85	6.44 6.72	0.61 0.46	3.93 3.09
8	4.42~ 4.73	0.31	29.85 22.87	4.63 3.54	0.21 0.10	0.96 0.37
				ΣP= 107.04	ΣM= 214.49	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load	P_t	=	0.00 kN/m
depth to acting position	H_t	=	0.00 m
moment	M_m	=	0.0 kN・m/m
depth to acting position	H_m	=	0.00 m
Height from riverbed to top of coping	H	=	4.42 m
Depth of Imaginary riverbed from riverbed	L_k	=	0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 0.00$ kN・m

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	=	16928 kN/m^3
calculated value	β	=	0.44052 m^{-1}
resultant earth force (lateral)	P_0	=	102.80 kN/m
height of acting position of load	h_0	=	1.97 m
moment	M_0	=	202.45 kN・m/m
in consideration of ψ_m = 1.182, maximum moment	M_{max}	=	239.32 kN・m/m
depth of generated position of M_{max}	l_m	=	0.796 m
depth of 1st fixed point	l_i	=	2.579 m

6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	=	32033 kN/m^3
calculated value	β	=	0.51667 m^{-1}
resultant earth force (lateral)	P_0	=	114.87 kN/m
height of acting position of load	h_0	=	1.96 m
moment	M_0	=	224.80 kN・m/m
in consideration of ψ_m = 1.144, maximum moment	M_{max}	=	257.08 kN・m/m
depth of generated position of M_{max}	l_m	=	0.618 m
depth of 1st fixed point	l_i	=	2.139 m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	10 H _ H 400 -200 -9 -12 -13		
Corrosion margin	t_1	=	1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate	η	=	0.81
Section efficiency	μ	=	1.00
Module of section	Z_0	=	2320 cm^3 (original condition)
	Z	=	1897 cm^3 (after reduction by corrosion and section)

6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{239.32 \times 10^6}{1879 \times 10^3} = 127 \ N/mm^2 \leqq \sigma_a = 180 \ N/mm^2$$

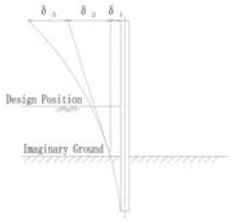
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{257.08 \times 10^6}{1879 \times 10^3} = 137 \ N/mm^2 \leqq \sigma_a = 270 \ N/mm^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation

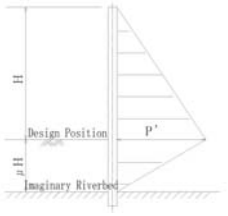


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.4405\times 1.97)\times 102.80}{2\times 2.00\times 10^8\times 56192\times 10^{-8}\times 0.4405^3} = 0.00999 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.4405\times 1.97)\times 102.80}{2\times 2.00\times 10^8\times 56192\times 10^{-8}\times 0.4405^2}\times(4.42+0.31) = 0.03049 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{0.31}{4.42} = 0.070$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{43.47\times 4.42^4}{120\times 2.00\times 10^8\times 56192\times 10^{-8}}(4+20\times 0.070+40\times 0.070^2+35\times 0.070^3+11\times 0.070^4)$$

$$= 0.00690 \text{ m}$$

δ = δ1 + δ2 + δ3
= 0.00999 + 0.03049 + 0.00690
= 0.04739 m
Size = 47.39 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground

$$\mu = \frac{L_k}{H} = \frac{0.31}{4.42} = 0.070$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{48.57\times 4.42^4}{120\times 2.00\times 10^8\times 56192\times 10^{-8}}(4+20\times 0.070+40\times 0.070^2+35\times 0.070^3+11\times 0.070^4)$$

$$= 0.00771 \text{ m}$$

δ = δ1 + δ2 + δ3
= 0.00745 + 0.02737 + 0.00771
= 0.04253 m
Size = 42.53 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name		10 H _ H 400 -200 -9 -12 -13
Unit width	B	= 1.0000 m
Corrosion rate	η	= 1.00
Section efficiency	μ	= 1.00
Young's modulus	E	= 200000 N/mm²
Inertia sectional moment	I_0	= 87800 cm⁴ (original condition)
	I	= 87800 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 87800 × 10⁻⁸		= 1.756 × 10⁵

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1t} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

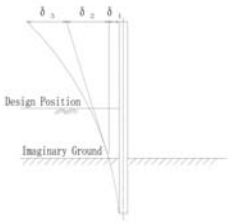
Modules of lateral subgrade reaction $K_h = 16928$ kN/m³
Calculated value $\beta = 0.39401$ m⁻¹

Penetration length of SSP $D = 0.31 + \frac{3}{0.394} = 7.92$ m
Whole length of SSP $L = 4.42 - 0.40 + 7.92 = 11.94$ m

δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation

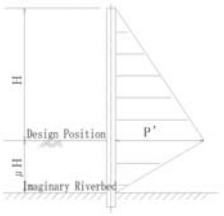


$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.5167\times 1.96)\times 114.87}{2\times 2.00\times 10^8\times 56192\times 10^{-8}\times 0.5167^3} = 0.00745 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times 0.5167\times 1.96)\times 114.87}{2\times 2.00\times 10^8\times 56192\times 10^{-8}\times 0.5167^2}\times(4.42+0.31) = 0.02737 \text{ m}$$



7.1.2 Seismic Condition

Modules of lateral subgrade reaction $K_h = 32033$ kN/m³
Calculated value $\beta = 0.46212$ m⁻¹

Penetration length of SSP $D = 0.31 + \frac{3}{0.462} = 6.80$ m
Whole length of SSP $L = 4.42 - 0.40 + 6.80 = 10.82$ m

Therefore, the total length of the sheet pile is 12.00 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 10 H _ H 400 -200 -9 -12 -13

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	87800		
Sectional Modulus	Z (cm3)	2320		
Maximum bending moment	Mmax (kN・m・m)		239.32	257.08
Stress intensity	σ (N/mm2)		127 (180)	137 (270)
Lateral displacement	δ (mm)		47.39 (50.0)	42.53 (75.0)
Penetration depths	D (m)		7.92	6.80
Whole length of SSP	L (m)	12.00		

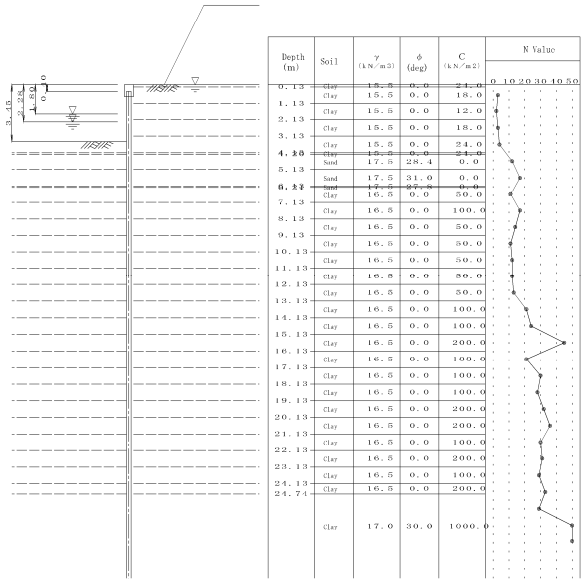
Block No. : R-18
Sta. : 9+200~9+380

Design Cross Section : Sta 9+280
Boring Name : BR13

Specification : SSP SP-25H
（Combined） : H 1000-300-16-32-18

1 Design Condition

1.1 Longitudinal Section of SSP & Considered Geological Survey Log



1.2 Dimensions of Structure

Depth from coping top to riverbed	H	=	3.45 m
Depth from coping top to rear side ground	H_0	=	0.00 m
Depth from coping top to SSP top	H_t	=	0.40 m
Landside WL	L_{wa}	=	0.00 m (Normal Condition)
	L_{wa}'	=	0.00 m (Seismic Condition)
Riverside WL	L_{wp}	=	2.28 m (Normal Condition)
	L_{wp}'	=	1.80 m (Seismic Condition)

1.3 Applied Formula

Formula for generated stress : Chang's formula

Penetration depths : $L = \frac{3}{\beta}$

1.4 Design Constant

Unit weight of water : γ_w = 9.8 kN/m³

Type of water pressure : trapezoidal water pressure

Lateral pressure : calculated in consideration of site conditions

Study case :
- Normal Condition
- Seismic Condition

Design earthquake intensity : k = 0.200

Dynamic water pressure due to earthquake considered as distributed load

Arbitrary load	Horizontal load	P_t	= 44.8 kN/m	(Normal Condition)
		P_t'	= 105.5 kN/m	(Seismic Condition)
	Depth of acting point	H_t	= 0.0 m	(Normal Condition)
		H_t'	= 0.0 m	(Seismic Condition)
	Moment	M_m	= 11.9 kN･m/m	(Normal Condition)
		M_m'	= 122.9 kN･m/m	(Seismic Condition)
	Depth of acting point	H_m'	= 0.00 m	(Seismic Condition)
		H_m	= 0.00 m	(Normal Condition)

('Depth' means distance from top of coping)

1.5 Modulus of Lateral Subgrade Reaction

Applied formula

$$K_h = K_{h0}\left(\frac{B_{il}}{0.3}\right)^{-3/4}$$

$$K_{h0} = \frac{1}{0.3}\ \alpha\ E_0 \quad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

B_{il} = 10.00 m

E_0 = 2800N

Average N-value : calculated from average N-value between imaginary riverbed and depth as 1/β

N-value distribution

No	Depth m	N Value	No	Depth m	N Value	No	Depth m	N Value
1	0.63	3	11	10.63	12	21	20.63	36
2	1.63	2	12	11.63	12	22	21.63	30
3	2.63	3	13	12.63	13	23	22.63	31
4	3.63	4	14	13.63	21	24	23.63	29
5	4.63	12	15	14.63	24	25	24.63	33
6	5.63	17	16	15.63	45	26	25.63	29
7	6.63	11	17	16.63	21	27	26.63	50
8	7.63	17	18	17.63	30	28	27.63	50
9	8.63	14	19	18.63	28	29	28.63	50
10	9.63	11	20	19.63	32			

1.6 Vertical Load

Vertical load on landside : calculated in consideration of embankment shape on landside

Vertical load on riverside : not considered

1.7 Soil Modulus

No	Depth m (Include Projection Length)	Thickness m (excluding projected length)
1	0.13	0.13
2	1.13	1.00
3	2.13	1.00
4	3.13	1.00
5	4.13	1.00
6	4.20	0.07
7	5.13	0.93
8	6.13	1.00
9	6.21	0.08
10	7.13	0.92
11	8.13	1.00
12	9.13	1.00
13	10.13	1.00
14	11.13	1.00
15	12.13	1.00
16	13.13	1.00
17	14.13	1.00
18	15.13	1.00
19	16.13	1.00
20	17.13	1.00
21	18.13	1.00
22	19.13	1.00
23	20.13	1.00
24	21.13	1.00
25	22.13	1.00
26	23.13	1.00
27	24.13	1.00
28	24.74	0.61
29	28.63	3.89

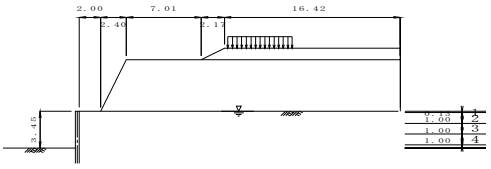
No	Depth m	earth Soil	N Value	γ kN/m3	γ ' kN/m3	φ degree	C kN/m2	a	k'	ζ (degree) Normal Condition	ζ (degree) Seismic Condition	Kh (kN/m3) Normal Condition	Kh (kN/m3) Seismic Condition
1	0.13	C	4.0	15.50	5.70	0.0	24.0	0.0	0.200	Auto	Auto		
2	1.13	C	3.0	15.50	5.70	0.0	18.0	0.0	0.200	Auto	Auto		
3	2.13	C	2.0	15.50	5.70	0.0	12.0	0.0	0.200	Auto	Auto		
4	3.13	C	3.0	15.50	5.70	0.0	18.0	0.0	0.200	Auto	Auto		
5	4.13	C	4.0	15.50	5.70	0.0	24.0	0.0	0.200	Auto	Auto		
6	4.20	C	4.0	15.50	5.70	0.0	24.0	0.0	0.200	Auto	Auto		
7	5.13	S	12.0	17.50	7.70	28.4	0.0	0.0	0.200	Auto	Auto		
8	6.13	S	17.0	17.50	7.70	31.0	0.0	0.0	0.200	Auto	Auto		
9	6.21	S	11.0	17.50	7.70	27.8	0.0	0.0	0.200	Auto	Auto		
10	7.13	C	11.0	16.50	6.70	0.0	50.0	0.0	0.200	Auto	Auto		
11	8.13	C	17.0	16.50	6.70	0.0	100.0	0.0	0.200	Auto	Auto		
12	9.13	C	14.0	16.50	6.70	0.0	50.0	0.0	0.200	Auto	Auto		
13	10.13	C	11.0	16.50	6.70	0.0	50.0	0.0	0.200	Auto	Auto		
14	11.13	C	12.0	16.50	6.70	0.0	50.0	0.0	0.200	Auto	Auto		
15	12.13	C	12.0	16.50	6.70	0.0	50.0	0.0	0.200	Auto	Auto		
16	13.13	C	13.0	16.50	6.70	0.0	50.0	0.0	0.200	Auto	Auto		
17	14.13	C	21.0	16.50	6.70	0.0	100.0	0.0	0.200	Auto	Auto		
18	15.13	C	24.0	16.50	6.70	0.0	100.0	0.0	0.200	Auto	Auto		
19	16.13	C	45.0	16.50	6.70	0.0	200.0	0.0	0.200	Auto	Auto		
20	17.13	C	21.0	16.50	6.70	0.0	100.0	0.0	0.200	Auto	Auto		
21	18.13	C	30.0	16.50	6.70	0.0	100.0	0.0	0.200	Auto	Auto		
22	19.13	C	28.0	16.50	6.70	0.0	100.0	0.0	0.200	Auto	Auto		
23	20.13	C	32.0	16.50	6.70	0.0	200.0	0.0	0.200	Auto	Auto		
24	21.13	C	36.0	16.50	6.70	0.0	200.0	0.0	0.200	Auto	Auto		
25	22.13	C	30.0	16.50	6.70	0.0	100.0	0.0	0.200	Auto	Auto		
26	23.13	C	31.0	16.50	6.70	0.0	200.0	0.0	0.200	Auto	Auto		
27	24.13	C	29.0	16.50	6.70	0.0	100.0	0.0	0.200	Auto	Auto		
28	24.74	C	33.0	16.50	6.70	0.0	200.0	0.0	0.200	Auto	Auto		
29	28.63	C	121.5	17.00	7.20	30.0	1000.0	0.0	0.200	Auto	Auto		

Note) depth : from top of coping to bottom of the layer
soil : sandy(S), clayey(C), mixed (M)
N-value : average N-value in the layer
γ : wet unit weight of soil
γ ' : saturated unit weight of soil
φ : internal friction angle of soil
C_o : soil adhesion
a : slope of soil adhesion
k' : design seismic coefficient (underwater)
ζ : angle of active rupture
kh : modulus of subgrade reaction

Angle of wall friction

Angle of wall friction	Normal Condition	Seismic Condition
Active	15.00 °	15.00 °
Passive	-15.00 °	0.00 °

1.8 Embankment on Landside



Fill shape and soil constants

No	Soil	X Coordinate Bottom Left m	X Coordinate Top Left m	X Coordinate Top Right m	X Coordinate Bottom Right m	Thickness h m	soil single weight γ Normal Condition kN/m3	soil single weight γ Seismic Condition kN/m3	internal friction angle φ degree	stickiness C kN/m2	decay angle ζ Normal Condition degree	decay angle ζ Seismic Condition degree
1	Sand	2.00	4.40	30.00	30.00	4.80	19.0	19.0	30.0	0.0	Auto	Auto
2	Sand	11.41	13.58	30.00	30.00	1.08	19.0	19.0	30.0	0.0	Auto	Auto

Surcharge load acting on embankment

No	load area From m	load area End point m	load strength Normal Condition kN/m2	load strength Seismic Condition kN/m2
1	13.88	19.88	10.0	5.0

Angle of rapture in embankment calculated in consideration of embankment conditions

1.9 Steel Sheet Pile (SSP)

Material name 25 H_H 1000 -300 -16 -32 -18
Young's modulus $E = 200000\ N/mm^2$
Inertia sectional moment $I_0 = 1129800\ cm^4$
Sectional factor $Z_0 = 16330\ cm^3$

Corrosion margin $t_1 = 1.00$ mm (riverside) $t_2 = 1.00$ mm (landside)

Corrosion rate (to I_0) $\eta = 0.89$
Corrosion rate (to Z_0) $\eta = 0.90$
Section efficiency (to I_0) $\mu = 1.00$
Section efficiency (to Z_0) $\mu = 1.00$

Round unit of SSP length 0.50 m

Allowable stress $\sigma_a = 180\ N/mm$ (Normal)
$\sigma_a' = 270\ N/mm$ (Seismic)

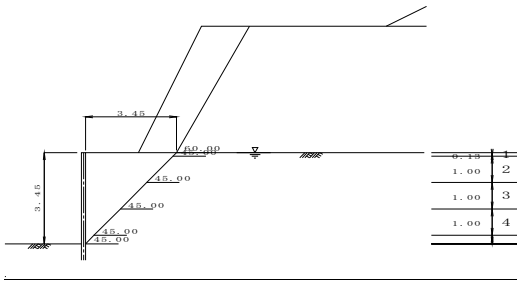
Allowable displacement $\delta_a = 50.0$ mm (Normal)
$\delta_a' = 75.0$ mm (Seismic)

Bending of cantilever beam calculated as distributed load of each layer

Reduction of material modulus
Reduced: I_0 applied to calculation of lateral coefficient of subgrade reaction
Not reduced: I_0 applied to calculation of penetration depth
Reduced: I_0 applied to calculation of section forces and displacement
Reduced: Z_0 applied to calculation of stresses

2 Calculation of Acting Load

2.1 Normal Condition



2.1.1 Angle of Active Rupture

No	Depth. m	Soil	φ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	Angle of Rupture ζ degree
1	3.45～3.13	Clay	0.0	15.0	24.0	19.66	43.24	33.81	45.00
2	3.13～2.13	Clay	0.0	15.0	18.0	17.84	43.24	30.67	45.00
3	2.13～1.13	Clay	0.0	15.0	12.0	12.14	43.24	20.87	45.00
4	1.13～0.13	Clay	0.0	15.0	18.0	6.44	43.24	11.07	45.00
5	0.13～0.00	Clay	0.0	15.0	24.0	0.74	43.24	1.27	45.00
6		embankment	30.0	——	0.0	111.72	10.00	0.00	60.00

・Angle of active rupture of sandy soil

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Angle of active rupture of clayey soil

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

Angle of active rupture of clayey soil ζ is set as 45° since θ = 0°
Where,
ζ : angle of active rupture (degree, ζ ≥ 10.00°)
φ : internal friction angle (degree)
δ : wall friction angle (degree)
θ : earthquake combination angle (degree)
θ = $\tan^{-1}$k or θ = $\tan^{-1}$k'
γ : unit weight of soil (kN/m³) (ascending force considered under WL)
h : thickness of layer (m)
Q : surcharge load (kN/m²)
C cohesive force of soil (kN/m²)

2.1.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate X (m)	bottom coordinate Y (m)	top coordinate X (m)	top coordinate Y (m)
1	45.00	0.32	0.00	0.00	0.32	0.32
2	45.00	1.00	0.32	0.32	1.32	1.32
3	45.00	1.00	1.32	1.32	2.32	2.32
4	45.00	1.00	2.32	2.32	3.32	3.32
5	45.00	0.13	3.32	3.32	3.45	3.45
6	60.00	4.80	3.45	3.45	6.22	8.25

From the above table, the loading width (L) on the ground surface is 3.45 m.

2.1.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	7.85	149.17
Σ			149.17

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

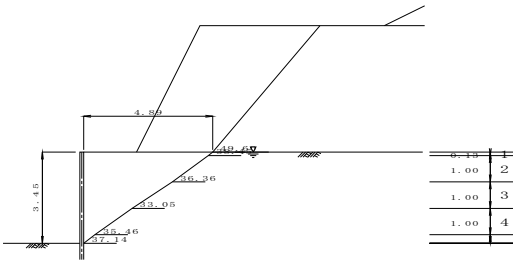
2.1.4 Calculated Load

$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{149.17 + 0.00 + 0.00}{3.45}$$

$$= 43.24\ kN/m^2$$

2.2 Seismic Condition



2.2.1 Angle of Active Rupture

No	Depth. m	Soil	ϕ degree	δ degree	C kN/m2	Σγh kN/m2	Q kN/m2	γwhw kN/m2	k (k')	θ degree	Angle of Rupture ζ degree
1	3.45～3.13	Clay	0.0	15.0	24.0	19.66	69.59	33.81	0.200	11.31	37.14
2	3.13～2.13	Clay	0.0	15.0	18.0	17.84	69.59	30.67	0.200	11.31	35.46
3	2.13～1.13	Clay	0.0	15.0	12.0	12.14	69.59	20.87	0.200	11.31	33.05
4	1.13～0.13	Clay	0.0	15.0	18.0	6.44	69.59	11.07	0.200	11.31	36.36
5	0.13～0.00	Clay	0.0	15.0	24.0	0.74	69.59	1.27	0.200	11.31	38.45
6		embankment	30.0	——	0.0	111.72	5.00	0.00	0.200	11.31	49.60

・Major collapse angle of Sand, intermediate soil, and split rock

$$\zeta = 90 - \tan^{-1}\frac{-\sin(\phi+\delta)+\sqrt{\frac{\cos(\delta+\theta)\cdot\sin(\phi+\delta)}{\sin(\phi-\theta)}}}{\cos(\phi+\delta)}$$

・Major collapse angle of cohesive soil

$$\zeta = 45 - \frac{1}{2}\tan^{-1}\frac{a}{\sqrt{b^2-a^2}}$$

$$a = \sin\theta$$

$$b = \sin\theta + \frac{2C\cos\theta}{\Sigma\gamma h + Q}$$

Where,

- ζ : angle of active rupture (degree, ζ ≥ 10.00°)
- ϕ : internal friction angle (degree)
- δ : wall friction angle (degree)
- θ : earthquake combination angle (degree)
  θ = tan⁻¹k or θ = tan⁻¹k'
- γ : unit weight of soil (kN/m³) (ascending force considered under WL)
- h : thickness of layer (m)
- Q : surcharge load (kN/m²)
- C : cohesive force of soil (kN/m²)

2.2.2 Coordinates of Collapse Line

No	Angle of Rupture ζ degree	Thickness Z m	bottom coordinate		top coordinate	
			X (m)	Y (m)	X (m)	Y (m)
1	37.14	0.32	0.00	0.00	0.42	0.32
2	35.46	1.00	0.42	0.32	1.83	1.32
3	33.05	1.00	1.83	1.32	3.36	2.32
4	36.36	1.00	3.36	2.32	4.72	3.32
5	38.45	0.13	4.72	3.32	4.89	3.45
6	49.60	4.80	4.89	3.45	8.97	8.25

From the above table, the loading width (L) on the ground surface is 4.89 m.

2.2.3 Acting Load by Embankment

No	γ kN/m3	A m2	γ × A kN/m
1	19.0	17.89	339.97
Σ			339.97

γ : unit weight of embankment soil
A: sectional area of embankment enclosed by line of active rupture

2.2.4 Calculated Load

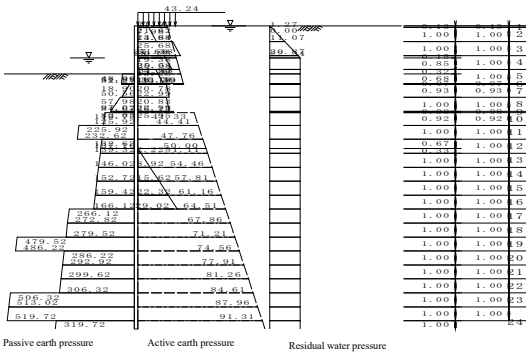
$$Q = \frac{\Sigma(\gamma\times A)+\Sigma(Q\times 1)+\Sigma P}{L}$$

$$= \frac{339.97 + 0.00 + 0.00}{4.89}$$

$$= 69.59\ \text{kN/m}^2$$

3 Lateral Forth

3.1 Normal Condition



3.1.1 Soil Modulus of Active Side

	Depth. m	Soil	γ kN/m3	ϕ degree	C kN/m2	Σγh+Qa kN/m2	Ka	Ka × cos δ
1	0.00~ 0.13	Clay	5.7	——	24.0 24.0	43.238 43.979	—— ——	—— ——
2	0.13~ 1.13	Clay	5.7	——	18.0 18.0	43.979 49.679	—— ——	—— ——
3	1.13~ 2.13	Clay	5.7	——	12.0 12.0	49.679 55.379	—— ——	—— ——
4	2.13~ 2.28	Clay	5.7	——	18.0 18.0	55.379 56.234	—— ——	—— ——
5	2.28~ 3.13	Clay	5.7	——	18.0 18.0	56.234 61.079	—— ——	—— ——
6	3.13~ 3.45	Clay	5.7	——	24.0 24.0	61.079 62.903	—— ——	—— ——
7	3.45~ 4.13	Clay	5.7	——	24.0 24.0	62.903 66.779	—— ——	—— ——
8	4.13~ 4.20	Clay	5.7	——	24.0 24.0	66.779 67.178	—— ——	—— ——
9	4.20~ 5.13	Sand	7.7	28.4	—— ——	67.178 74.339	0.32022 0.32022	0.30931 0.30931
10	5.13~ 6.13	Sand	7.7	31.0	—— ——	74.339 82.039	0.29008 0.29008	0.28020 0.28020
11	6.13~ 6.21	Sand	7.7	27.8	—— ——	82.039 82.655	0.32749 0.32749	0.31633 0.31633
12	6.21~ 7.13	Clay	6.7	——	50.0 50.0	82.655 88.819	—— ——	—— ——
13	7.13~ 8.13	Clay	6.7	——	100.0 100.0	88.819 95.519	—— ——	—— ——
14	8.13~ 8.80	Clay	6.7	——	50.0 50.0	95.519 100.000	—— ——	—— ——
15	8.80~ 9.13	Clay	6.7	——	50.0 50.0	100.000 102.219	—— ——	—— ——
16	9.13~ 10.13	Clay	6.7	——	50.0 50.0	102.219 108.919	—— ——	—— ——
17	10.13~ 11.13	Clay	6.7	——	50.0 50.0	108.919 115.619	—— ——	—— ——
18	11.13~ 12.13	Clay	6.7	——	50.0 50.0	115.619 122.319	—— ——	—— ——
19	12.13~ 13.13	Clay	6.7	——	50.0 50.0	122.319 129.019	—— ——	—— ——
20	13.13~ 14.13	Clay	6.7	——	100.0 100.0	129.019 135.719	—— ——	—— ——
21	14.13~ 15.13	Clay	6.7	——	100.0 100.0	135.719 142.419	—— ——	—— ——
22	15.13~ 16.13	Clay	6.7	——	200.0 200.0	142.419 149.119	—— ——	—— ——
23	16.13~ 17.13	Clay	6.7	——	100.0 100.0	149.119 155.819	—— ——	—— ——
24	17.13~ 18.13	Clay	6.7	——	100.0 100.0	155.819 162.519	—— ——	—— ——
25	18.13~ 19.13	Clay	6.7	——	100.0 100.0	162.519 169.219	—— ——	—— ——
26	19.13~ 20.13	Clay	6.7	——	200.0 200.0	169.219 175.919	—— ——	—— ——
27	20.13~ 21.13	Clay	6.7	——	200.0 200.0	175.919 182.619	—— ——	—— ——
28	21.13~ 22.13	Clay	6.7	——	100.0 100.0	182.619 189.319	—— ——	—— ——
29	22.13~ 23.13	Clay	6.7	——	200.0 200.0	189.319 196.019	—— ——	—— ——
30	23.13~ 23.72	Clay	6.7	——	100.0 100.0	196.019 200.000	—— ——	—— ——
31	23.72~ 24.13	Clay	6.7	——	100.0 100.0	200.000 202.719	—— ——	—— ——
32	24.13~ 24.74	Clay	6.7	——	200.0 200.0	202.719 206.806	—— ——	—— ——
33	24.74~ 28.63	Clay	7.2	——	1000.0 1000.0	206.806 234.814	—— ——	—— ——

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;
δ= 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Qp kN/m2	Kp	Kp × cosδ
7	3.45~ 4.13	Clay	5.7	0.0	24.0 24.0	0.000 3.876	———	———
8	4.13~ 4.20	Clay	5.7	0.0	24.0 24.0	3.876 4.275	———	———
9	4.20~ 5.13	Sand	7.7	28.4	——— ———	4.275 11.436	4.57728 4.57728	4.42131 4.42131
10	5.13~ 6.13	Sand	7.7	31.0	——— ———	11.436 19.136	5.24888 5.24888	5.07003 5.07003
11	6.13~ 6.21	Sand	7.7	27.8	——— ———	19.136 19.752	4.43813 4.43813	4.28690 4.28690
12	6.21~ 7.13	Clay	6.7	0.0	50.0 50.0	19.752 25.916	———	———
13	7.13~ 8.13	Clay	6.7	0.0	100.0 100.0	25.916 32.616	———	———
14	8.13~ 8.80	Clay	6.7	0.0	50.0 50.0	32.616 37.097	———	———
15	8.80~ 9.13	Clay	6.7	0.0	50.0 50.0	37.097 39.316	———	———
16	9.13~ 10.13	Clay	6.7	0.0	50.0 50.0	39.316 46.016	———	———
17	10.13~ 11.13	Clay	6.7	0.0	50.0 50.0	46.016 52.716	———	———
18	11.13~ 12.13	Clay	6.7	0.0	50.0 50.0	52.716 59.416	———	———
19	12.13~ 13.13	Clay	6.7	0.0	50.0 50.0	59.416 66.116	———	———
20	13.13~ 14.13	Clay	6.7	0.0	100.0 100.0	66.116 72.816	———	———
21	14.13~ 15.13	Clay	6.7	0.0	100.0 100.0	72.816 79.516	———	———
22	15.13~ 16.13	Clay	6.7	0.0	200.0 200.0	79.516 86.216	———	———
23	16.13~ 17.13	Clay	6.7	0.0	100.0 100.0	86.216 92.916	———	———
24	17.13~ 18.13	Clay	6.7	0.0	100.0 100.0	92.916 99.616	———	———
25	18.13~ 19.13	Clay	6.7	0.0	100.0 100.0	99.616 106.316	———	———
26	19.13~ 20.13	Clay	6.7	0.0	200.0 200.0	106.316 113.016	———	———
27	20.13~ 21.13	Clay	6.7	0.0	200.0 200.0	113.016 119.716	———	———
28	21.13~ 22.13	Clay	6.7	0.0	100.0 100.0	119.716 126.416	———	———
29	22.13~ 23.13	Clay	6.7	0.0	200.0 200.0	126.416 133.116	———	———
30	23.13~ 23.72	Clay	6.7	0.0	100.0 100.0	133.116 137.097	———	———
31	23.72~ 24.13	Clay	6.7	0.0	100.0 100.0	137.097 139.816	———	———
32	24.13~ 24.74	Clay	6.7	0.0	200.0 200.0	139.816 143.903	———	———
33	24.74~ 28.63	Clay	7.2	30.0	1000.0 1000.0	143.903 171.911	———	———

Coefficient of passive earth pressure of sandy soil Ka is calculated by the formula below;
δ= -15.00、β = 0.00、θ = 0.00

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.1.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00~ 0.13	-4.76 -4.02	21.62 21.99	21.62 21.99	0.00 1.27	———
2	0.13~ 1.13	7.98 13.68	21.99 24.84	21.99 24.84	1.27 11.07	———
3	1.13~ 2.13	25.68 31.38	24.84 27.69	25.68 31.38	11.07 20.87	———
4	2.13~ 2.28	19.38 20.23	27.69 28.12	27.69 28.12	20.87 22.34	———
5	2.28~ 3.13	20.23 25.08	28.12 30.54	28.12 30.54	22.34 22.34	———
6	3.13~ 3.45	13.08 14.90	30.54 31.45	30.54 31.45	22.34 22.34	———
7	3.45~ 4.13	14.90 18.78	31.45 33.39	31.45 33.39	22.34 22.34	48.00 51.88
8	4.13~ 4.20	18.78 19.18	33.39 33.59	33.39 33.59	22.34 22.34	51.88 52.27
9	4.20~ 5.13	20.78 22.99	——— ———	20.78 22.99	22.34 22.34	18.90 50.56
10	5.13~ 6.13	20.83 22.99	——— ———	20.83 22.99	22.34 22.34	57.98 97.02
11	6.13~ 6.21	25.95 26.15	——— ———	25.95 26.15	22.34 22.34	82.03 84.67
12	6.21~ 7.13	-17.35 -11.18	41.33 44.41	41.33 44.41	22.34 22.34	119.75 125.92
13	7.13~ 8.13	-111.18 -104.48	44.41 47.76	44.41 47.76	22.34 22.34	225.92 232.62
14	8.13~ 8.80	-4.48 0.00	47.76 50.00	47.76 50.00	22.34 22.34	132.62 137.10
15	8.80~ 9.13	0.00 2.22	50.00 51.11	50.00 51.11	22.34 22.34	137.10 139.32
16	9.13~ 10.13	2.22 8.92	51.11 54.46	51.11 54.46	22.34 22.34	139.32 146.02
17	10.13~ 11.13	8.92 15.62	54.46 57.81	54.46 57.81	22.34 22.34	146.02 152.72
18	11.13~ 12.13	15.62 22.32	57.81 61.16	57.81 61.16	22.34 22.34	152.72 159.42
19	12.13~ 13.13	22.32 29.02	61.16 64.51	61.16 64.51	22.34 22.34	159.42 166.12
20	13.13~ 14.13	-70.98 -64.28	64.51 67.86	64.51 67.86	22.34 22.34	266.12 272.82
21	14.13~ 15.13	-64.28 -57.58	67.86 71.21	67.86 71.21	22.34 22.34	272.82 279.52
22	15.13~ 16.13	-257.58 -250.88	71.21 74.56	71.21 74.56	22.34 22.34	479.52 486.22
23	16.13~ 17.13	-50.88 -44.18	74.56 77.91	74.56 77.91	22.34 22.34	286.22 292.92
24	17.13~ 18.13	-44.18 -37.48	77.91 81.26	77.91 81.26	22.34 22.34	292.92 299.62
25	18.13~ 19.13	-37.48 -30.78	81.26 84.61	81.26 84.61	22.34 22.34	299.62 306.32
26	19.13~ 20.13	-230.78 -224.08	84.61 87.96	84.61 87.96	22.34 22.34	506.32 513.02
27	20.13~ 21.13	-224.08 -217.38	87.96 91.31	87.96 91.31	22.34 22.34	513.02 519.72
28	21.13~ 22.13	-17.38 -10.68	91.31 94.66	91.31 94.66	22.34 22.34	319.72 326.42
29	22.13~ 23.13	-210.68 -203.98	94.66 98.01	94.66 98.01	22.34 22.34	526.42 533.12
30	23.13~ 23.72	-3.98 0.00	98.01 100.00	98.01 100.00	22.34 22.34	333.12 337.10
31	23.72~ 24.13	0.00 2.72	100.00 101.36	100.00 101.36	22.34 22.34	337.10 339.82
32	24.13~ 24.74	-197.28 -193.19	101.36 103.40	101.36 103.40	22.34 22.34	539.82 543.90
33	24.74~ 28.63	-1793.19 -1765.19	103.40 117.41	103.40 117.41	22.34 22.34	2143.90 2171.91

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$
$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$
K_c : Equilibrium coefficient of compression: 0.5
Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = [K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}] \cdot \cos\delta$

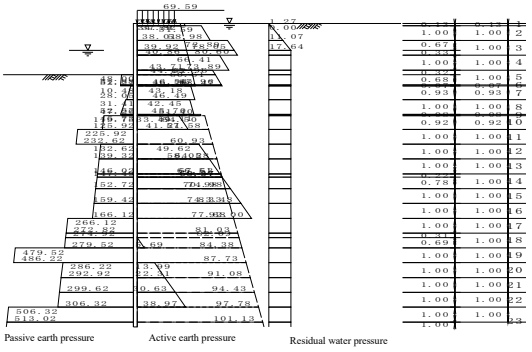
- Formula for passive earth pressure

Sand $P_p = K_p \cdot [\Sigma\gamma h + \frac{Q}{\cos(-\beta)}] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = [K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}] \cdot \cos\delta$

3.2 Seismic Condition



Passive earth pressure　Active earth pressure　Residual water pressure

3.2.1 Soil Modulus of Active Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σγh+Q kN/m2	γwhw kN/m2	k (k')	θ degree	Ka	Ka × cosδ	ζ degree
1	0.00~ 0.13	Clay	5.7	———	24.0 24.0	69.59 70.33	0.00 1.27	0.200 0.200	11.31 11.31	———	———	38.51 38.45
2	0.13~ 1.13	Clay	5.7	———	18.0 18.0	70.33 76.03	1.27 11.07	0.200 0.200	11.31 11.31	———	———	36.84 36.36
3	1.13~ 1.80	Clay	5.7	———	12.0 12.0	76.03 79.85	11.07 17.64	0.200 0.200	11.31 11.31	———	———	33.59 33.23
4	1.80~ 2.13	Clay	5.7	———	12.0 12.0	79.85 81.73	17.64 20.87	0.200 0.200	11.31 11.31	———	———	33.23 33.05
5	2.13~ 3.13	Clay	5.7	———	18.0 18.0	81.73 87.43	20.87 30.67	0.200 0.200	11.31 11.31	———	———	35.90 35.46
6	3.13~ 3.45	Clay	5.7	———	24.0 24.0	87.43 89.25	30.67 33.81	0.200 0.200	11.31 11.31	———	———	37.26 37.14
7	3.45~ 4.13	Clay	5.7	———	24.0 24.0	89.25 93.13	33.81 40.47	0.200 0.200	11.31 11.31	———	———	37.14 36.88
8	4.13~ 4.20	Clay	5.7	———	24.0 24.0	93.13 93.53	40.47 41.16	0.200 0.200	11.31 11.31	———	———	36.88 36.86
9	4.20~ 5.13	Sand	7.7	28.4	——— ———	93.53 100.69	41.16 50.27	0.200 0.200	11.31 11.31	0.47800 0.47800	0.46172 0.46172	———
10	5.13~ 6.13	Sand	7.7	31.0	——— ———	100.69 108.39	50.27 60.07	0.200 0.200	11.31 11.31	0.43652 0.43652	0.42164 0.42164	———
11	6.13~ 6.21	Sand	7.7	27.8	——— ———	108.39 109.01	60.07 60.86	0.200 0.200	11.31 11.31	0.48814 0.48814	0.47151 0.47151	———
12	6.21~ 7.13	Clay	6.7	———	50.0 50.0	109.01 115.17	60.86 69.87	0.200 0.200	11.31 11.31	———	———	39.84 39.60
13	7.13~ 8.13	Clay	6.7	———	100.0 100.0	115.17 121.87	69.87 79.67	0.200 0.200	11.31 11.31	———	———	42.04 41.88

14	8.13– 9.13	Clay	6.7	——	50.0 50.0	121.87 128.57	79.67 89.47	0.200 0.200	11.31 11.31	—— ——	—— ——	39.35 39.10
15	9.13– 10.13	Clay	6.7	——	50.0 50.0	128.57 135.27	89.47 99.27	0.200 0.200	11.31 11.31	—— ——	—— ——	39.10 38.85
16	10.13– 10.35	Clay	6.7	——	50.0 50.0	135.27 136.74	99.27 ——	0.200 ——	11.31 ——	—— ——	—— ——	38.85 ——
17	10.35– 11.13	Clay	6.7	——	50.0 50.0	136.74 141.97	—— 109.07	—— 0.200	—— 11.31	—— ——	—— ——	—— 38.61
18	11.13– 12.13	Clay	6.7	——	50.0 50.0	141.97 148.67	109.07 118.87	0.200 0.200	11.31 11.31	—— ——	—— ——	38.61 38.38
19	12.13– 13.13	Clay	6.7	——	50.0 50.0	148.67 155.37	118.87 128.67	0.200 0.200	11.31 11.31	—— ——	—— ——	38.38 38.14
20	13.13– 14.13	Clay	6.7	——	100.0 100.0	155.37 162.07	128.67 138.47	0.200 0.200	11.31 11.31	—— ——	—— ——	41.14 40.99
21	14.13– 14.44	Clay	6.7	——	100.0 100.0	162.07 164.17	138.47 ——	0.200 ——	11.31 ——	—— ——	—— ——	40.99 ——
22	14.44– 15.13	Clay	6.7	——	100.0 100.0	164.17 168.77	—— 148.27	—— 0.200	—— 11.31	—— ——	—— ——	—— 40.85
23	15.13– 16.13	Clay	6.7	——	200.0 200.0	168.77 175.47	148.27 158.07	0.200 0.200	11.31 11.31	—— ——	—— ——	42.77 42.69
24	16.13– 17.13	Clay	6.7	——	100.0 100.0	175.47 182.17	158.07 167.87	0.200 0.200	11.31 11.31	—— ——	—— ——	40.71 40.57
25	17.13– 18.13	Clay	6.7	——	100.0 100.0	182.17 188.87	167.87 177.67	0.200 0.200	11.31 11.31	—— ——	—— ——	40.57 40.43
26	18.13– 19.13	Clay	6.7	——	100.0 100.0	188.87 195.57	177.67 187.47	0.200 0.200	11.31 11.31	—— ——	—— ——	40.43 40.29
27	19.13– 20.13	Clay	6.7	——	200.0 200.0	195.57 202.27	187.47 197.27	0.200 0.200	11.31 11.31	—— ——	—— ——	42.44 42.37
28	20.13– 21.13	Clay	6.7	——	200.0 200.0	202.27 208.97	197.27 207.07	0.200 0.200	11.31 11.31	—— ——	—— ——	42.37 42.29
29	21.13– 22.13	Clay	6.7	——	100.0 100.0	208.97 215.67	207.07 216.87	0.200 0.200	11.31 11.31	—— ——	—— ——	40.02 39.89
30	22.13– 23.13	Clay	6.7	——	200.0 200.0	215.67 222.37	216.87 226.67	0.200 0.200	11.31 11.31	—— ——	—— ——	42.21 42.13
31	23.13– 24.13	Clay	6.7	——	100.0 100.0	222.37 229.07	226.67 236.47	0.200 0.200	11.31 11.31	—— ——	—— ——	39.76 39.63
32	24.13– 24.74	Clay	6.7	——	200.0 200.0	229.07 233.16	236.47 242.45	0.200 0.200	11.31 11.31	—— ——	—— ——	42.05 42.00
33	24.74– 28.63	Clay	7.2	——	1000.0 1000.0	233.16 261.16	242.45 280.57	0.200 0.200	11.31 11.31	—— ——	—— ——	44.35 44.27

Coefficient of active earth pressure of sandy soil Ka is calculated by the formula below;

δ = 15.00、β = 0.00、θ = 0.00

$$K_a = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta+\theta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\delta+\theta)\cdot\cos(-\beta)}}\right]^2}$$

Angle between surface of collapse and level surface of clayey soil ζ is calculated by the formula below;

$$\zeta = \tan^{-1}\sqrt{1-\frac{\Sigma\gamma h+2Q}{2C}\cdot\tan\theta}$$

3.2.2 Soil Modulus of Passive Side

No	Depth. m	Soil	γ kN/m3	φ degree	C kN/m2	Σ γ h + Qp kN/m2	γ whw kN/m2	k (k')	θ degree	Kp	Kp × cos δ
7	3.45– 4.13	Clay	5.70	0.0	24.0 24.0	0.000 3.876	0.00 6.66	0.200 0.200	11.31 11.31	—— ——	—— ——
8	4.13– 4.20	Clay	5.70	0.0	24.0 24.0	3.876 4.275	6.66 7.35	0.200 0.200	11.31 11.31	—— ——	—— ——
9	4.20– 5.13	Sand	7.70	28.4	—— ——	4.275 11.436	7.35 16.46	0.200 0.200	11.31 11.31	2.45242 2.45242	2.45242 2.45242
10	5.13– 6.13	Sand	7.70	31.0	—— ——	11.436 19.136	16.46 26.26	0.200 0.200	11.31 11.31	2.74701 2.74701	2.74701 2.74701
11	6.13– 6.21	Sand	7.70	27.8	—— ——	19.136 19.752	26.26 27.05	0.200 0.200	11.31 11.31	2.38966 2.38966	2.38966 2.38966
12	6.21– 7.13	Clay	6.70	0.0	50.0 50.0	19.752 25.916	27.05 36.06	0.200 0.200	11.31 11.31	—— ——	—— ——
13	7.13– 8.13	Clay	6.70	0.0	100.0 100.0	25.916 32.616	36.06 45.86	0.200 0.200	11.31 11.31	—— ——	—— ——
14	8.13– 9.13	Clay	6.70	0.0	50.0 50.0	32.616 39.316	45.86 55.66	0.200 0.200	11.31 11.31	—— ——	—— ——
15	9.13– 10.13	Clay	6.70	0.0	50.0 50.0	39.316 46.016	55.66 65.46	0.200 0.200	11.31 11.31	—— ——	—— ——
16	10.13– 10.35	Clay	6.70	0.0	50.0 50.0	46.016 47.490	65.46 ——	0.200 ——	11.31 ——	—— ——	—— ——
17	10.35– 11.13	Clay	6.70	0.0	50.0 50.0	47.490 52.716	—— 75.26	—— 0.200	—— 11.31	—— ——	—— ——
18	11.13– 12.13	Clay	6.70	0.0	50.0 50.0	52.716 59.416	75.26 85.06	0.200 0.200	11.31 11.31	—— ——	—— ——
19	12.13– 13.13	Clay	6.70	0.0	50.0 50.0	59.416 66.116	85.06 94.86	0.200 0.200	11.31 11.31	—— ——	—— ——
20	13.13– 14.13	Clay	6.70	0.0	100.0 100.0	66.116 72.816	94.86 104.66	0.200 0.200	11.31 11.31	—— ——	—— ——
21	14.13– 14.44	Clay	6.70	0.0	100.0 100.0	72.816 74.921	104.66 ——	0.200 ——	11.31 ——	—— ——	—— ——
22	14.44– 15.13	Clay	6.70	0.0	100.0 100.0	74.921 79.516	—— 114.46	—— 0.200	—— 11.31	—— ——	—— ——
23	15.13– 16.13	Clay	6.70	0.0	200.0 200.0	79.516 86.216	114.46 124.26	0.200 0.200	11.31 11.31	—— ——	—— ——
24	16.13– 17.13	Clay	6.70	0.0	100.0 100.0	86.216 92.916	124.26 134.06	0.200 0.200	11.31 11.31	—— ——	—— ——
25	17.13– 18.13	Clay	6.70	0.0	100.0 100.0	92.916 99.616	134.06 143.86	0.200 0.200	11.31 11.31	—— ——	—— ——
26	18.13– 19.13	Clay	6.70	0.0	100.0 100.0	99.616 106.316	143.86 153.66	0.200 0.200	11.31 11.31	—— ——	—— ——
27	19.13– 20.13	Clay	6.70	0.0	200.0 200.0	106.316 113.016	153.66 163.46	0.200 0.200	11.31 11.31	—— ——	—— ——
28	20.13– 21.13	Clay	6.70	0.0	200.0 200.0	113.016 119.716	163.46 173.26	0.200 0.200	11.31 11.31	—— ——	—— ——
29	21.13– 22.13	Clay	6.70	0.0	100.0 100.0	119.716 126.416	173.26 183.06	0.200 0.200	11.31 11.31	—— ——	—— ——
30	22.13– 23.13	Clay	6.70	0.0	200.0 200.0	126.416 133.116	183.06 192.86	0.200 0.200	11.31 11.31	—— ——	—— ——
31	23.13– 24.13	Clay	6.70	0.0	100.0 100.0	133.116 139.816	192.86 202.66	0.200 0.200	11.31 11.31	—— ——	—— ——

32	24.13– 24.74	Clay	6.70	0.0	200.0 200.0	139.816 143.903	202.66 208.64	0.200 0.200	11.31 11.31	—— ——	—— ——
33	24.74– 28.63	Clay	7.20	30.0	1000.0 1000.0	143.903 171.911	208.64 246.76	0.200 0.200	11.31 11.31	—— ——	—— ——

・The coefficient of passive earth pressure (Kp) of Sand is obtained by the following equation.

δ = 0.00 degrees, β = 0.00 degrees

Seismic composite angle θ = tan -1 k

$$K_p = \frac{\cos^2(\phi-\theta)}{\cos\theta\cdot\cos(\delta-\theta)\cdot\left[1-\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\delta-\theta)\cdot\cos(-\beta)}}\right]^2}$$

3.2.3 Lateral Forth

No	Depth. m	Active			Residual water pressure	Passive
		Pa1 kN/m2	Pa2 kN/m2	Pa kN/m2	Pw kN/m2	Pp kN/m2
1	0.00– 0.13	37.82 38.76	34.79 35.16	37.82 38.76	0.00 1.27	—— ——
2	0.13– 1.13	51.59 58.98	35.16 38.01	51.59 58.98	1.27 11.07	——
3	1.13– 1.80	72.89 78.05	38.01 39.92	72.89 78.05	11.07 17.64	—— ——
4	1.80– 2.13	78.05 80.60	39.92 40.86	78.05 80.60	17.64 17.64	—— ——
5	2.13– 3.13	66.41 73.89	40.86 43.71	66.41 73.89	17.64 17.64	——
6	3.13– 3.45	60.61 62.96	43.71 44.63	60.61 62.96	17.64 17.64	—— ——
7	3.45– 4.13	62.96 67.96	44.63 46.56	62.96 67.96	17.64 17.64	48.00 51.88
8	4.13– 4.20	67.96 68.47	46.56 46.76	67.96 68.47	17.64 17.64	51.88 52.27
9	4.20– 5.13	43.18 46.49	—— ——	43.18 46.49	17.64 17.64	10.48 28.05
10	5.13– 6.13	42.45 45.70	—— ——	42.45 45.70	17.64 17.64	31.41 52.57
11	6.13– 6.21	51.11 51.40	—— ——	51.11 51.40	17.64 17.64	45.73 47.20
12	6.21– 7.13	33.49 41.21	54.50 57.58	54.50 57.58	17.64 17.64	119.75 125.92
13	7.13– 8.13	-60.36 -52.14	57.58 60.93	57.58 60.93	17.64 17.64	225.92 232.62
14	8.13– 9.13	49.62 58.05	60.93 64.28	60.93 64.28	17.64 17.64	132.62 139.32
15	9.13– 10.13	58.05 66.51	64.28 67.63	64.28 67.63	17.64 17.64	139.32 146.02
16	10.13– 10.35	66.51 68.37	67.63 68.37	67.63 68.37	17.64 17.64	146.02 147.49
17	10.35– 11.13	68.37 74.98	68.37 70.98	68.37 74.98	17.64 17.64	147.49 152.72
18	11.13– 12.13	74.98 83.48	70.98 74.33	74.98 83.48	17.64 17.64	152.72 159.42
19	12.13– 13.13	83.48 92.00	74.33 77.68	83.48 92.00	17.64 17.64	159.42 166.12
20	13.13– 14.13	-10.89 -2.61	77.68 81.03	77.68 81.03	17.64 17.64	266.12 272.82
21	14.13– 14.44	-2.61 0.00	81.03 82.09	81.03 82.09	17.64 17.64	272.82 274.92
22	14.44– 15.13	0.00 5.69	82.09 84.38	82.09 84.38	17.64 17.64	274.92 279.52
23	15.13– 16.13	-195.96 -187.79	84.38 87.73	84.38 87.73	17.64 17.64	479.52 486.22
24	16.13– 17.13	13.99 22.31	87.73 91.08	87.73 91.08	17.64 17.64	286.22 292.92
25	17.13– 18.13	22.31 30.63	91.08 94.43	91.08 94.43	17.64 17.64	292.92 299.62
26	18.13– 19.13	30.63 38.97	94.43 97.78	94.43 97.78	17.64 17.64	299.62 306.32
27	19.13– 20.13	-163.26 -155.07	97.78 101.13	97.78 101.13	17.64 17.64	506.32 513.02
28	20.13– 21.13	-155.07 -146.88	101.13 104.48	101.13 104.48	17.64 17.64	513.02 519.72
29	21.13– 22.13	55.68 64.05	104.48 107.83	104.48 107.83	17.64 17.64	319.72 326.42
30	22.13– 23.13	-138.68 -130.48	107.83 111.18	107.83 111.18	17.64 17.64	526.42 533.12
31	23.13– 24.13	72.43 80.82	111.18 114.53	111.18 114.53	17.64 17.64	333.12 339.82
32	24.13– 24.74	-122.27 -117.26	114.53 116.58	114.53 116.58	17.64 17.64	539.82 543.90
33	24.74– 28.63	-1719.66 -1685.90	116.58 130.58	116.58 130.58	17.64 17.64	2143.90 2171.91

- Formula for active earth pressure

Sand $P_{a1} = K_a \cdot \left[\Sigma\gamma h + \frac{Q}{\cos(-\beta)}\right] \cdot \cos\delta$

Clay $P_{a1} = \Sigma\gamma h + Q - 2C$

$P_{a2} = K_c \cdot (\Sigma\gamma h + Q)$

K_c : Equilibrium coefficient of compression: 0.5

Larger of Pa1 or Pa2 is applied as active earth pressure (Pa)

Mixed soil $P_{a1} = \left[K_a(\Sigma\gamma h + Q) - 2C\sqrt{K_a}\right] \cdot \cos\delta$

- Formula for passive earth pressure

Sand $P_p = K_p \cdot \left[\Sigma\gamma h + \frac{Q}{\cos(-\beta)}\right] \cdot \cos\delta$

Clay $P_p = \Sigma\gamma h + Q + 2C$

Mixed soil $P_p = \left[K_p(\Sigma\gamma h + Q) + 2C\sqrt{K_p}\right] \cdot \cos\delta$

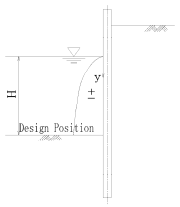
3.2.4 Dynamic Water Pressure due to Earthquake

No	Depth Z m	water level y m	pdw kN/m2
1	1.80	0.00	0.00
2	2.80	1.00	2.20
3	3.45	1.65	2.83

$$p_{dw} = \pm \frac{7}{8} k_{hs} \cdot \gamma_w \cdot \sqrt{H \cdot y}$$

Where,

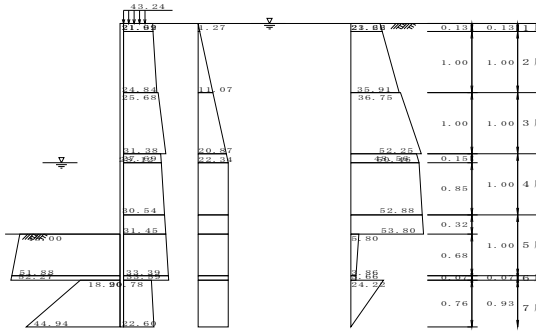
k_{hs}: design seismic coefficient
γ_w : unit weight of water
H : water depth of riverside
y : depth from water surface to the point where active water pressure is calculated



4 Imaginary Riverbed

Imaginary ground level Lk is calculated as the elevation level that the sum of active earth pressure and residual water pressure are balanced with passive earth pressure.

4.1 Normal Condition

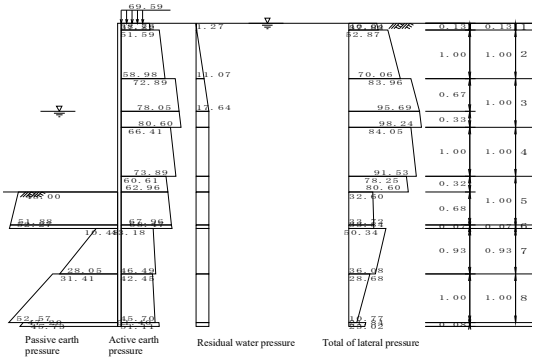


No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.13	21.62 21.99	0.00 1.27	——— ———	21.62 23.26
2	0.13~ 1.13	21.99 24.84	1.27 11.07	——— ———	23.26 35.91
3	1.13~ 2.13	25.68 31.38	11.07 20.87	——— ———	36.75 52.25
4	2.13~ 2.28	27.69 28.12	20.87 22.34	——— ———	48.56 50.46
5	2.28~ 3.13	28.12 30.54	22.34 22.34	——— ———	50.46 52.88
6	3.13~ 3.45	30.54 31.45	22.34 22.34	——— ———	52.88 53.80
7	3.45~ 4.13	31.45 33.39	22.34 22.34	48.00 51.88	5.80 3.86
8	4.13~ 4.20	33.39 33.59	22.34 22.34	51.88 52.27	3.86 3.66
9	4.20~ 4.97	20.78 22.60	22.34 22.34	18.90 44.94	24.22 0.00
10	4.97~ 5.13	22.60 22.99	22.34 22.34	44.94 50.56	0.00 -5.22

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 1.52 m (GL -4.97 m)

4.2 Seismic Condition



No	Depth. m	Pa kN/m2	Pw kN/m2	Pp kN/m2	Ps kN/m2
1	0.00~ 0.13	37.82 38.76	0.00 1.27	——— ———	37.82 40.04
2	0.13~ 1.13	51.59 58.98	1.27 11.07	——— ———	52.87 70.06
3	1.13~ 1.80	72.89 78.05	11.07 17.64	——— ———	83.96 95.69
4	1.80~ 2.13	78.05 80.60	17.64 17.64	——— ———	95.69 98.24
5	2.13~ 3.13	66.41 73.89	17.64 17.64	——— ———	84.05 91.53
6	3.13~ 3.45	60.61 62.96	17.64 17.64	——— ———	78.25 80.60
7	3.45~ 4.13	62.96 67.96	17.64 17.64	48.00 51.88	32.60 33.72
8	4.13~ 4.20	67.96 68.47	17.64 17.64	51.88 52.27	33.72 33.84
9	4.20~ 5.13	43.18 46.49	17.64 17.64	10.48 28.05	50.34 36.08
10	5.13~ 6.13	42.45 45.70	17.64 17.64	31.41 52.57	28.68 10.77
11	6.13~ 6.21	51.11 51.40	17.64 17.64	45.73 47.20	23.02 21.84
12	6.21~ 7.13	54.50 57.58	17.64 17.64	119.75 125.92	-47.61 -50.69

P_a : Active earth pressure
P_w : Residual water pressure
P_p : Passive earth pressure
P_s : Lateral pressure $P_s = P_a + P_w - P_p$

Imaginary riverbed L_k: 2.76 m (GL -6.21 m)

5 Modulus of Lateral Subgrade Reaction

5.1 Modulus of Lateral Subgrade Reaction

The lateral ground reaction coefficient is calculated by averaging a range of $1/\beta$ from the virtual ground surface.
Average N-value is calculated deending on the sectional area.
The lateral subgrade reaction coefficient is calculated by the following equation.

$$K_h = K_{h0} \left(\frac{B_{II}}{0.3} \right)^{-3/4} \qquad (B_{II}=10.00\text{m})$$

$$K_{h0} = \frac{1}{0.3} \alpha E_0 \qquad (\alpha : \text{Normal Condition} = 1, \text{Seismi Condition} = 2)$$

$$E_h = 2800N'$$

where:

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}}$$

Material Name		25 H _ H 1000 -300 -16 -32 -18	
Unit width	B	= 1.0000 m	
Corrosion margin	t_1	= 1.00 mm (active side)	t_2 = 1.00 mm (passive side)
Corrosion rate	η	= 0.89	
Section efficiency	μ	= 1.00	
Young's modulus	E	= 200000 N/mm^2	
Inertia sectional moment	I_0	= 1129800 cm^4(original condition)	
	I	= 1005522 cm^4(after reduction by corrosion and section)	
Inertia sectional moment	EI	= $200000 \times 10^3 \times 1005522 \times 10^{-8} = 2.011 \times 10^6$	

No	Depth m	N Value
1	0.63	3
2	1.63	2
3	2.63	3
4	3.63	4
5	4.63	12
6	5.63	17
7	6.63	11
8	7.63	17
9	8.63	14
10	9.63	11

No	Depth m	N Value
11	10.63	12
12	11.63	12
13	12.63	13
14	13.63	21
15	14.63	24
16	15.63	45
17	16.63	21
18	17.63	30
19	18.63	28
20	19.63	32

No	Depth m	N Value
21	20.63	36
22	21.63	30
23	22.63	31
24	23.63	29
25	24.63	33
26	25.63	29
27	26.63	50
28	27.63	50
29	28.63	50

5.2 Normal Condition

Assuming Kh = 9282 kN/m3,

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4 E I}} = 0.184 \text{ m}^{-1}$$

$$L = \frac{1}{\beta} = 5.43 \text{ m}$$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -4.97 m) to

5.43 m depth (GL -10.39 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	4.96	0.67	13.7	17.0	10.20
2	5.63	1.00	17.0	11.0	14.00
3	6.63	1.00	11.0	17.0	14.00
4	7.63	1.00	17.0	14.0	15.50
5	8.63	1.00	14.0	11.0	12.50
6	9.63	0.76	11.0	11.8	8.66
	L = Σh = 5.43		Σ A =	74.86	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{74.86}{5.43} = 13.80$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 13.80 = 38631\ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 38631 = 128770\ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_h/0.3)^{-3/4} = 128770(10.00/0.3)^{-3/4} = 9282\ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Normal Condition) is 9282 kN/m3.

5.3 Seismic Condition

Assuming Kh = 17784 kN/m3,

$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}} = 0.217\ m^{-1}$

$L = \frac{1}{\beta} = 4.61\ m$

Therefore, average N-value is calculated on the actual N-value from imaginary riverbed (GL -6.21 m) and 4.61 m depth (GL -10.82 m).

No	Depth Z m	Thickness h m	N Value upper	N Value lower	Area A
1	6.21	0.42	13.5	11.0	5.15
2	6.63	1.00	11.0	17.0	14.00
3	7.63	1.00	17.0	14.0	15.50
4	8.63	1.00	14.0	11.0	12.50
5	9.63	1.00	11.0	12.0	11.50
6	10.63	0.19	12.0	12.0	2.30
	L = Σh = 4.61		Σ A =	60.95	

A: (upper N-value + lower N-value) × h/2

Average N-value $N' = \frac{\Sigma A}{L} = \frac{60.95}{4.61} = 13.22$

Kh is recalculated from the calculated average N value.

$E_0 = 2800N' = 2800 \times 13.22 = 37006\ kN/m^2$

$K_{h0} = \frac{1}{0.3} \times \alpha \times 37006 = 246704\ kN/m^3$ (α :Normal Condition =1, Seismi Condition =2)

$K_h = K_{h0}(B_h/0.3)^{-3/4} = 246704(10.00/0.3)^{-3/4} = 17784\ kN/m^3$

Thus, the assumed Kh is equal to the recalculated Kh.
The lateral subgrade reaction coefficient Kh (Seismic Condition) is 17784 kN/m3.

6 Sectional Forces and Displacement

The stress, displacement, and insertion length of the sheet pile are calculated by Chang's equation.

6.1 Calculation of Resultant Lateral Forth P0 and Acting Elevation h0

6.1.1 Normal Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00–0.13	0.13	21.62 23.26	1.41 1.51	4.92 4.88	6.92 7.38
2	0.13–1.13	1.00	23.26 35.91	11.63 17.96	4.50 4.17	52.36 74.85
3	1.13–2.13	1.00	36.75 52.25	18.38 26.13	3.50 3.17	64.35 82.78
4	2.13–2.28	0.15	48.56 50.46	3.64 3.78	2.79 2.74	10.14 10.35
5	2.28–3.13	0.85	50.46 52.88	21.45 22.48	2.40 2.12	51.51 47.61
6	3.13–3.45	0.32	52.88 53.80	8.46 8.61	1.73 1.62	14.62 13.96
7	3.45–4.13	0.68	5.80 3.86	1.97 1.31	1.29 1.06	2.54 1.39
8	4.13–4.20	0.07	3.86 3.66	0.14 0.13	0.81 0.79	0.11 0.10
9	4.20–4.97	0.77	24.22 0.00	9.26 0.00	0.51 0.26	4.73 0.00
				ΣP = 158.24	ΣM = 445.69	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 44.8 kN/m
depth to acting position H_t = 0.0 m
moment M_m = 11.9 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 3.45 m
Depth of Imaginary riverbed from riverbed L_k = 1.52 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 234.33$ kN・m
h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t}{\Sigma P + P_t} = \frac{680.02}{203.04} = 3.35\ m$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 203.04}{4.97} = 81.79\ kN/m$

6.1.2 Seismic Condition

No	Depth. Z m	Thickness h m	Lateral Forth Ps kN/m2	Loads P kN	Arm length Y m	Moment M kN・m
1	0.00–0.13	0.13	37.82 40.04	2.46 2.60	6.17 6.12	15.16 15.93
2	0.13–1.13	1.00	52.87 70.06	26.43 35.03	5.75 5.41	151.90 189.62
3	1.13–1.80	0.67	83.96 95.69	28.13 32.06	4.86 4.63	136.60 148.52
4	1.80–2.13	0.33	95.69 98.24	15.79 16.21	4.30 4.19	67.89 67.92
5	2.13–3.13	1.00	84.05 91.53	42.03 45.76	3.75 3.41	157.46 156.21
6	3.13–3.45	0.32	78.25 80.60	12.52 12.90	2.97 2.87	37.23 36.97
7	3.45–4.13	0.68	32.60 33.72	11.08 11.47	2.53 2.31	28.08 26.45
8	4.13–4.20	0.07	33.72 33.84	1.18 1.18	2.06 2.03	2.43 2.41
9	4.20–5.13	0.93	50.34 36.08	23.41 16.78	1.70 1.39	39.79 23.32
10	5.13–6.13	1.00	28.68 10.77	14.34 5.39	0.75 0.41	10.71 2.23
11	6.13–6.21	0.08	23.02 21.84	0.92 0.87	0.05 0.03	0.05 0.02
				ΣP = 358.53	ΣM = 1316.89	

P_s : active earth pressure + residual water pressure - passive earth pressure
P : load P_s x h/2 x B
B : unit width = 1.000 m
Y : height of acting position from imaginary riverbed
M : moment by load P x Y

Arbitrary load lateral load P_t = 105.5 kN/m
depth to acting position H_t = 0.00 m
moment M_m = 122.9 kN・m/m
depth to acting position H_m = 0.00 m
Height from riverbed to top of coping H = 3.45 m
Depth of Imaginary riverbed from riverbed L_k = 0.00 m

Moment M_t by arbitrary load is as below
$M_t = P_t \cdot (H + L_k - H_t) + M_m = 778.05$ kN・m

Hydrodynamic Pressure

No	Depth. Z m	Thickness h m	Hydrodynamic Pressure pdw kN/m2	Loads Pdw kN	Arm length Y m	Moment Mdw kN・m
1	1.80–2.80	1.00	0.0 2.2	0.00 1.10	4.08 3.74	0.00 4.12
2	2.80–3.45	0.65	2.2 2.8	0.72 0.92	3.19 2.98	2.29 2.74
				ΣPdw = 2.74	Σ Mdw = 9.15	

h_0, Height of acting position of P_0 from imaginary riverbed

$h_0 = \frac{M_0}{P_0} = \frac{\Sigma M + M_t + \Sigma M_{dw}}{\Sigma P + P_t + \Sigma P_{dw}} = \frac{2104.09}{466.77} = 4.51\ m$

When the resultant force of the Lateral Forth is assumed to be a triangular load, the load strength at the design surface position (P') is expressed as follows:

$P' = \frac{2 \times P_0}{(H + L_k)} = \frac{2 \times 466.77}{6.21} = 150.33\ kN/m$

6.2 Sectional Force

Corrosion rate and section efficiency for calculation of sectional forces and displacements are set as followings:

Material name 25 H _ H 1000 -300 -16 -32 -18
Unit width B = 1.0000 m
Corrosion margin t_1 = 1.00 mm (active side) t_2 = 1.00 mm (passive side)
Corrosion rate η = 0.89
Section efficiency μ = 1.00

Young's modulus E = 200000 N/mm²
Inertia sectional moment I_0 = 1129800 cm⁴ (original condition)
I = 1005522 cm⁴ (after reduction by corrosion and section)
EI = 200000 × 10³ × 1005522 × 10⁻⁸ = 2.011 × 10⁶

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

$$\phi_u = \frac{\sqrt{(1+2\beta h_0)^2+1}}{2\beta h_0} \times \exp\left(-\tan^{-1}\frac{1}{1+2\beta h_0}\right)$$

$$M_{max} = M_0 \cdot \phi_u$$

$$l_u = \frac{1}{\beta} \times \tan^{-1}\frac{1}{1+2\beta h_0}$$

$$l_i = \frac{1}{\beta} \times \tan^{-1}\frac{1+\beta h_0}{\beta h_0}$$

$$M_{(x)} = \frac{P_0}{\beta} \times \exp^{-\beta x} (\beta h_0 \cdot \cos\beta x + (1+\beta h_0)\sin\beta x)$$

6.2.1 Normal Condition

modulus of lateral subgrade reaction	K_h	= 9282	kN/m³
calculated value	β	= 0.18431	m⁻¹
resultant earth force (lateral)	P_0	= 203.04	kN/m
height of acting position of load	h_0	= 3.35	m
moment	M_0	= 680.02	kN·m/m
in consideration of ψ_m = 1.302,			
maximum moment	M_{max}	= 885.30	kN·m/m
depth of generated position of M_{max}	l_m	= 2.283	m
depth of 1st fixed point	l_i	= 6.544	m

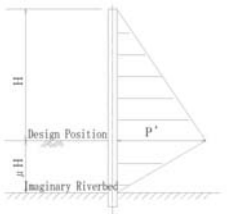
6.2.2 Seismic Condition

modulus of lateral subgrade reaction	K_h	= 17784	kN/m³
calculated value	β	= 0.21684	m⁻¹
resultant earth force (lateral)	P_0	= 466.77	kN/m
height of acting position of load	h_0	= 4.51	m
moment	M_0	= 2104.09	kN·m/m
in consideration of ψ_m = 1.151,			
maximum moment	M_{max}	= 2422.74	kN·m/m
depth of generated position of M_{max}	l_m	= 1.505	m
depth of 1st fixed point	l_i	= 5.127	m

6.3 Stress Intensity

Corrosion rate and section efficiency for check of stresses intensity are set as followings:

Material Name	25 H _ H 1000 -300 -16 -32 -18		
Corrosion margin	t_1 = 1.00 mm (active side)	t_2 = 1.00 mm (passive side)	
Corrosion rate	η = 0.90		
Section efficiency	μ = 1.00		
Module of section	Z_0 = 16330 cm³ (original condition)		
	Z = 16330 cm³ (after reduction by corrosion and section)		



$$\mu = \frac{L_k}{H} = \frac{1.52}{3.45} = 0.439$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{81.79\times3.45^4}{120\times2.00\times10^8\times1005522\times10^{-8}}(4+20\times0.439+40\times0.439^2+35\times0.439^3+11\times0.439^4)$$

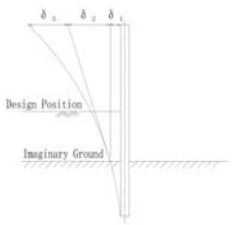
$$= 0.00115 \text{ m}$$

δ = δ1 + δ2 + δ3
= 0.01304 + 0.01649 + 0.00115
= 0.03067 m
Size = 30.67 ≦ δa = 50.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

6.4.2 Seismic Condition

Displacement Calculation



6.3.1 Normal Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{885.30\times10^6}{14697\times10^3} = 60 \text{ N/mm}^2 \leqq \sigma_a = 180 \text{ N/mm}^2$$

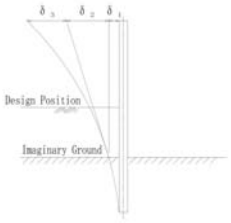
6.3.2 Seismic Condition

$$\sigma = \frac{M_{max}}{Z} = \frac{2422.74\times10^6}{14697\times10^3} = 165 \text{ N/mm}^2 \leqq \sigma_a = 270 \text{ N/mm}^2$$

6.4 Displacement Calculation

6.4.1 Normal Condition

Displacement Calculation



$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.1843\times3.35)\times203.04}{2\times2.00\times10^8\times1005522\times10^{-8}\times0.1843^3} = 0.01304 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

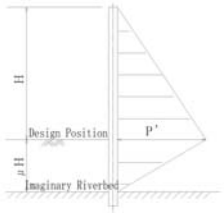
$$= \frac{(1+2\times0.1843\times3.35)\times203.04}{2\times2.00\times10^8\times1005522\times10^{-8}\times0.1843^2}\times(3.45+1.52) = 0.01649 \text{ m}$$

$$\delta_1 = \frac{(1+\beta h_0)\times P_0}{2EI\beta^3}$$

$$= \frac{(1+0.2168\times4.51)\times466.77}{2\times2.00\times10^8\times1005522\times10^{-8}\times0.2168^3} = 0.02251 \text{ m}$$

$$\delta_2 = \frac{(1+2\beta h_0)\times P_0}{2EI\beta^2}\times(H+L_k)$$

$$= \frac{(1+2\times0.2168\times4.51)\times466.77}{2\times2.00\times10^8\times1005522\times10^{-8}\times0.2168^2}\times(3.45+2.76) = 0.04529 \text{ m}$$



$$\mu = \frac{L_k}{H} = \frac{2.76}{3.45} = 0.800$$

$$\delta_3 = \frac{P' H^4}{120EI}(4+20\mu+40\mu^2+35\mu^3+11\mu^4)$$

$$= \frac{150.33\times3.45^4}{120\times2.00\times10^8\times1005522\times10^{-8}}(4+20\times0.800+40\times0.800^2+35\times0.800^3+11\times0.800^4)$$

$$= 0.00600 \text{ m}$$

δ = δ1 + δ2 + δ3
= 0.02251 + 0.04529 + 0.00600
= 0.07380 m
Size = 73.80 ≦ δa = 75.00 mm

Where,
δ_1 : Displacement at imaginary ground
δ_2 : Displacement by angle of inclination slope at imaginary ground
δ_3 : Displacement at higher part of imaginary ground as cantilever
δ : Displacement at top of SSP
δ_a : Allowable displacement

7 Penetration Depth

Corrosion rate and section efficiency for calculation of penetration depth of SSP are as below:

Material Name	25 H _ H 1000 -300 -16 -32 -18		
Unit width	B = 1.0000 m		
Corrosion rate	η = 1.00		
Section efficiency	μ = 1.00		
Young's modulus	E = 200000 N/mm²		

Inertia sectional moment I_0 = 1129800 cm^4 (original condition)
I = 1129800 cm^4 (after reduction by corrosion and section)
EI = 200000 × 10^3 × 1129800 × 10^{-8} = 2.260 × 10^6

7.1 Penetration Depth and Whole Length of SSP (Chang)

Based on the depth of imaginary riverbed as L_k, penetration depth of SSP (D) and whole length of SSP (L) a re calculated as followings:

$$D = L_k + \frac{3}{\beta}$$

$$L = H - H_{1s} + D$$

$$\beta = \sqrt[4]{\frac{K_h \cdot B}{4EI}}$$

7.1.1 Normal Condition

Modules of lateral subgrade reaction K_h = 9282 kN/m^3
Calculated value β = 0.17902 m^{-1}

Penetration length of SSP $D = 1.52 + \frac{3}{0.179} = 18.27$ m
Whole length of SSP $L = 3.45 - 0.40 + 18.27 = 21.32$ m

7.1.2 Seismic Condition

Modules of lateral subgrade reaction K_h = 17784 kN/m^3
Calculated value β = 0.21061 m^{-1}

Penetration length of SSP $D = 2.76 + \frac{3}{0.211} = 17.00$ m
Whole length of SSP $L = 3.45 - 0.40 + 17.00 = 20.05$ m

Therefore, the total length of the sheet pile is 21.50 m from the rounded length value of 0.50 m.

8 Calculation Result

SSP 25 H _ H 1000 -300 -16 -32 -18

			Normal Condition	Seismic Condition
Inertia sectional moment	I (cm4)	1129800		
Sectional Modulus	Z (cm3)	16330		
Maximum bending moment	Mmax (kN・m・m)		885.30	2422.74
Stress intensity	σ (N/mm2)		60 (180)	165 (270)
Lateral displacement	δ (mm)		30.67 (50.0)	73.80 (75.0)
Penetration depths	D (m)		18.27	17.00
Whole length of SSP	L (m)	21.50		

1.2 Dike and Revetment

1.2.1 Slope Stability Analysis

The calculation sheets are shown in the following pages.

1.2.1 SLOPE STABILITY　ANALYSIS

1.2.1.1　Normal and Seismic Conditions

(1)　L5+400

Circular Slip Surface

L+5400

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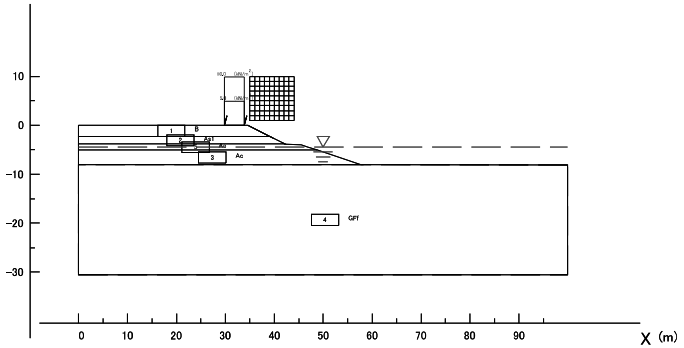
1. Input data list

// Design section //



// Design level of reliability design method //

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

// Combination of action //

// Setting of action //

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

// Partial coefficient concerning analytical technique γ_α //

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

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

No.	Action 1			Action 2											
	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$
1	1.00	1.00	1.00	1.00	1.00	1.00						
2	1.00	1.00	1.00	1.00	1.00	1.00						
3	1.00	1.00	1.00	1.00	1.00	1.00						
4	1.00	1.00	1.00	1.00	1.00	1.00						
5	1.00	1.00	1.00	1.00	1.00	1.00						

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

$$W_d' = \gamma_w W_k'$$

$$C_d = \gamma_c C_k$$

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

- M : Resistance moment
- γ_w : Partial coefficient concerning weight
- W_d' : Effective weight of slice of amount for each unit length splinter (value for design) (kN/m)
- W_k' : Effective weight of slice of amount for each unit length splinter (characteristic value)(kN/m)
- q_d : Perpendicular action because of the upper part of amount of slice (kN/m)
- γ_c : Partial coefficient concerning Cohesion
- C_d : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (value for design) (kN/m²)
- C_k : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (characteristic value) (kN/m²)
- l : Length in base of amount of Slice (m)
- $\gamma_{\tan\phi}$: Partial coefficient concerning shearing resistance angle
- ϕ_d : 0 in case of viscous land board. Shearing resistance angle in drain condition in case of the sandy soil ground etc.(value for design)(°)
- ϕ_k : 0 in case of viscous land board. Shearing resistance angle in drain condition in case of the sandy soil ground etc.(characteristic value)(°)

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

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

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

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

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

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

- $M_{r,vl}$: Resistance moment of distribution load (Think as well as the ground)
- $M_{d,vl}$: Sliding moment of distribution load (Think as well as the ground)
- K : Resistance power coefficient
- r : Radius of slipping circular arc
- F : Distribution load i
- FR : Slipping line orthogonalization direction load value of load i
- FO : Slipping line direction load value of load i
- θ : Angle that slice bottom (slide surface) does to the horizontal
- $\gamma_{vl,i}$: Partial coefficient of distribution load i (Think as well as the ground).
- K_{hp} : The horizontal seismic intensity
- $\gamma_{vlEQ,i}$: Partial coefficient of inertia force of distribution load i (Think as well as the ground).
- ϕ : Internal friction angle of soil

// Partial coefficient to residual water level //

Action number	rRWL
1	1.00
2	1.00

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

- γ_{RWL} : Partial coefficient concerning residual water level
- RWL_d : Difference between residual water level and water level line (value for design) (m)
- RWL_k : Difference between residual water level and water level line (input value) (m)

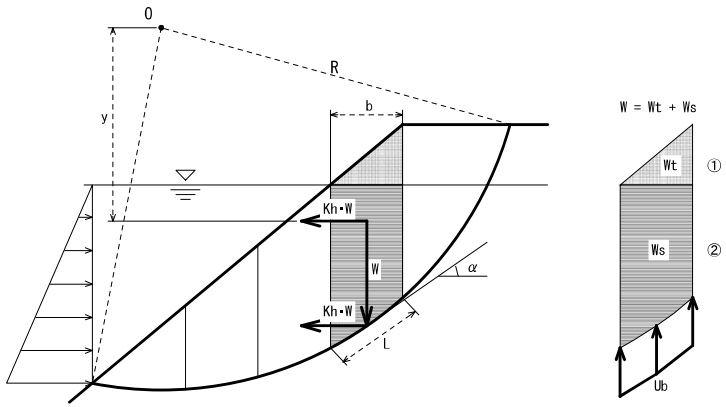
(DATA 01.)　// ANALYSIS //

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

Expression

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

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



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

(DATA 02.)　// CONTROL //

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

(DATA 04.) // SEISMIC LOAD //

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


(DATA 06.) // NODAL POINT //

No.	Coordinate		Y-coordinate
	x (m)	y (m)	before settlement (m)
1	0.00	0.00	0.00
2	29.83	0.00	0.00
3	33.83	0.00	0.00
4	34.53	0.00	0.00
5	39.10	-2.28	0.00
6	0.00	-2.28	0.00
7	0.00	-5.07	0.00
8	48.74	-5.07	0.00
9	42.20	-3.83	0.00
10	45.53	-4.00	0.00
11	46.80	-4.42	0.00
12	0.00	-4.42	0.00
13	0.00	-8.06	0.00
14	57.72	-8.06	0.00
15	100.00	-8.07	0.00
16	100.00	-30.59	0.00
17	0.00	-30.59	0.00
18	0.00	-3.81	0.00
19	42.15	-3.81	0.00

(DATA 07.) // WATER LEVEL //

Unit weight of water (kN/m³) = 10.00

Action No.	Water level line number
1	1
2	1

Water level line number: 1

No.	Coordinate	
	X (m)	Y (m)
1	0.00	-4.42
2	100.00	-4.42

Water level line number: 2

No.	Coordinate	
	X (m)	Y (m)
1	0.00	-2.44
2	39.00	-2.44
3	44.00	-4.42
4	100.00	-4.42

(DATA 08.) // LAYER //

No.	material property No.	The name of the strata
1	5	B
2	6	As1
3	9	Ac
4	8	GFf
5	9	Ac

No.	Num of Node	Node numbers composing a layer	Slip existence
1	6	1 6 5 4 3 2	Slip
2	4	6 18 19 5	Slip
3	4	7 13 14 8	Slip
4	5	13 17 16 15 14	Not Slip
5	8	9 19 18 12 7 8 11 10	Slip

(DATA 09.1) // MATERIAL PROPERTIES //

No.	Nature of soil division	Saturated weight (kN/m³)	Wet weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
5	B	19.00	18.00	1.00	0.00	30.00	0.00	0.000	0.0
6	As1	18.50	17.50	0.00	0.00	27.80	0.00	0.000	0.0
8	GFf	18.00	17.00	******	0.00	30.00	0.00	0.000	0.0
9	Ac	16.50	15.50	50.00	0.00	0.00	0.00	0.000	0.0

(DATA 09.2) // Characteristic of soil //

No.	Action Number									
	Act 1	Act 2								
1	5	5								
2	6	6								
3	9	9								
4	8	8								
5	9	9								

(DATA 11.) // GRID POINT //

No.	Slip direction	Double cutting	GX (m)	GY (m)	X-point	Y-point	X-pitch (m)	Y-pitch (m)	Dx/Dy	NEXCO Radius
1	Downstream	Rigt lump	35.00	10.00	10	10	1.00	1.00	0.000	0.000

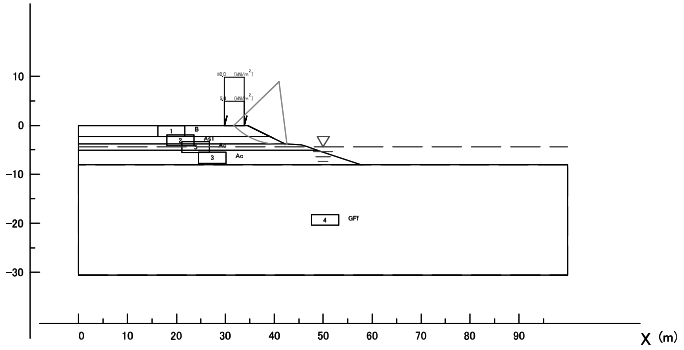
2. Check list

// Check of circular arc //

Action No.	Action name	Bearing force Action ratio	Judgment
1	normal	2.665	OK
2	seismic	1.832	OK

Action No.	Bearing force Action ratio	Partial coefficient r_a	Center of slipping circular arc X (m)	Center of slipping circular arc Y (m)	Radius of circular arc(m)	Resistance Moment (kNm)	Sliding Moment (kNm)
1	2.665	1.00	41.00	9.00	12.942	3685.0	1382.9
2	1.832	1.00	41.00	9.00	12.942	3556.3	1941.4

// Check Result chart //



3. Action01 (normal)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle ϕ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	5	19.00	18.00	9.00	1.00	0.00	30.00	0.00	0.00	0.0
2	6	18.50	17.50	8.50	0.00	0.00	27.80	0.00	0.00	0.0
3	9	16.50	15.50	6.50	50.00	0.00	0.00	0.00	0.00	0.0
4	8	18.00	17.00	8.00	1000.0	0 0.0	030.0	0 0.0	0 0.0	0 0.
0	5	9 16.5	0 15.5	0 6.5	0 50.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.
0										

// Distribution load that considers partial coefficient //

load No.	Left X (m)	Left Y (m)	Left Load Value(kN)	Right X (m)	Right Y (m)	Right Load Value(kN)	Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
1	29.83	0.00	10.0	33.83	0.00	10.0	0.000	0.000	0.000

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

No.	Coordinate X (m)	Coordinate Y (m)	Residual water level
1	0.00	-4.42	
2	100.00	-4.42	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	10.00	0.00	0.001	0.0	0.0	***5
35.00	9.00	0.00	0.001	0.0	0.0	***5
35.00	8.00	0.00	0.001	0.0	0.0	***5
35.00	7.00	0.00	0.001	0.0	0.0	***5
35.00	6.00	0.00	0.001	0.0	0.0	***5
35.00	5.00	0.00	0.001	0.0	0.0	***5
35.00	4.00	0.00	0.001	0.0	0.0	***5
35.00	3.00	0.00	0.001	0.0	0.0	***5
35.00	2.00	0.00	0.001	0.0	0.0	***5
35.00	1.00	0.00	0.001	0.0	0.0	***5
36.00	10.00	0.00	0.001	0.0	0.0	***5
36.00	9.00	0.00	0.001	0.0	0.0	***5
36.00	8.00	0.00	0.001	0.0	0.0	***5
36.00	7.00	0.00	0.001	0.0	0.0	***5
36.00	6.00	0.00	0.001	0.0	0.0	***5
36.00	5.00	0.00	0.001	0.0	0.0	***5
36.00	4.00	0.00	0.001	0.0	0.0	***5
36.00	3.00	0.00	0.001	0.0	0.0	***5
36.00	2.00	0.00	0.001	0.0	0.0	***5
36.00	1.00	0.00	0.001	0.0	0.0	***5
37.00	10.00	0.00	0.001	0.0	0.0	***5
37.00	9.00	0.00	0.001	0.0	0.0	***5
37.00	8.00	0.00	0.001	0.0	0.0	***5
37.00	7.00	0.00	0.001	0.0	0.0	***5
37.00	6.00	0.00	0.001	0.0	0.0	***5
37.00	5.00	0.00	0.001	0.0	0.0	***5
37.00	4.00	0.00	0.001	0.0	0.0	***5
37.00	3.00	0.00	0.001	0.0	0.0	***5
37.00	2.00	0.00	0.001	0.0	0.0	***5
37.00	1.00	0.00	0.001	0.0	0.0	***5
38.00	10.00	0.00	0.001	0.0	0.0	***5
38.00	9.00	0.00	0.001	0.0	0.0	***5
38.00	8.00	0.00	0.001	0.0	0.0	***5
38.00	7.00	0.00	0.001	0.0	0.0	***5
38.00	6.00	0.00	0.001	0.0	0.0	***5
38.00	5.00	0.00	0.001	0.0	0.0	***5
38.00	4.00	9.00	2.966	4742.7	1599.1	
38.00	3.00	0.00	0.001	0.0	0.0	***5
38.00	2.00	-7.66	999.000	0.0	0.0	
38.00	1.00	-7.56	999.000	0.0	0.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	1.00	-6.56	999.000	0.0	0.0	
39.00	10.00	0.00	0.001	0.0	0.0	***5
39.00	9.00	0.00	0.001	0.0	0.0	***5
39.00	8.00	0.00	0.001	0.0	0.0	***5
39.00	7.00	0.00	0.001	0.0	0.0	***5
39.00	6.00	-10.64	999.000	0.0	0.0	
		10.36	2.935	4499.2	1532.9	
39.00	5.00	-9.53	999.000	0.0	0.0	
		9.47	2.953	4131.4	1399.0	
		10.00	3.059	5523.5	1805.6	
39.00	4.00	-9.43	999.000	0.0	0.0	
		8.57	2.976	3718.3	1249.4	
		9.00	3.045	4699.3	1543.4	
39.00	3.00	-9.32	999.000	0.0	0.0	
		-8.32	999.000	0.0	0.0	
		7.68	3.020	3274.2	1084.3	
		8.00	3.059	3919.3	1281.4	
39.00	2.00	-9.21	999.000	0.0	0.0	
		-8.21	999.000	0.0	0.0	
		-7.21	999.000	0.0	0.0	
		6.79	3.111	2811.2	903.5	
		7.00	3.124	3186.0	1019.7	
39.00	1.00	-8.11	999.000	0.0	0.0	
		-7.11	999.000	0.0	0.0	
		-6.11	999.000	0.0	0.0	
		5.89	3.311	2341.1	707.2	
		6.00	3.303	2504.5	758.2	
40.00	10.00	0.00	0.001	0.0	0.0	***5
40.00	9.00	13.50	3.261	7085.5	2173.1	
40.00	8.00	12.60	3.259	6699.7	2055.6	
40.00	7.00	-11.29	999.000	0.0	0.0	
		11.71	3.254	6254.8	1922.2	
		12.00	3.284	7228.2	2201.2	
40.00	6.00	-11.19	999.000	0.0	0.0	
		-10.19	999.000	0.0	0.0	
		10.81	3.251	5763.9	1773.1	
		11.00	3.264	6325.5	1937.9	
40.00	5.00	-11.08	999.000	0.0	0.0	
		-10.08	999.000	0.0	0.0	
		9.92	3.258	5238.2	1608.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
40.00	5.00	10.00	3.261	5460.9	1674.8
40.00	4.00	-9.98	999.000	0.0	0.0
		-8.98	999.000	0.0	0.0
		9.00	3.285	4637.4	1411.8
40.00	3.00	-9.87	999.000	0.0	0.0
		-8.87	999.000	0.0	0.0
		-7.87	999.000	0.0	0.0
		8.00	3.358	3858.4	1149.1
40.00	2.00	-9.77	999.000	0.0	0.0
		-8.77	999.000	0.0	0.0
		-7.77	999.000	0.0	0.0
		-6.77	999.000	0.0	0.0
		7.00	3.529	3128.3	886.5
40.00	1.00	-8.66	999.000	0.0	0.0
		-7.66	999.000	0.0	0.0
		-6.66	999.000	0.0	0.0
41.00	10.00	14.84	3.555	9209.8	2590.7
41.00	9.00	12.94	2.665	3685.0	1382.9
		13.94	3.525	8666.9	2458.8
		14.00	3.508	8860.5	2525.8
41.00	8.00	12.05	3.003	3914.4	1303.6
		13.00	3.517	7948.9	2260.4
41.00	7.00	11.15	3.236	3912.3	1209.0
		12.00	3.540	7065.0	1995.5
41.00	6.00	-11.74	999.000	0.0	0.0
		-10.74	999.000	0.0	0.0
		10.26	3.427	3766.4	1098.9
		11.00	3.588	6210.8	1731.1
41.00	5.00	-11.64	999.000	0.0	0.0
		-10.64	999.000	0.0	0.0
		-9.64	999.000	0.0	0.0
		9.36	3.620	3522.2	973.1
		10.00	3.653	5359.2	1467.2
41.00	4.00	-11.53	999.000	0.0	0.0
		-10.53	999.000	0.0	0.0
		-9.53	999.000	0.0	0.0
		-8.53	999.000	0.0	0.0
		8.47	3.859	3208.9	831.5
		9.00	3.773	4540.8	1203.6
41.00	3.00	-10.43	999.000	0.0	0.0

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
41.00	3.00	-9.43	999.000	0.0	0.0
		-8.43	999.000	0.0	0.0
		8.00	4.009	3769.0	940.0
41.00	2.00	-9.32	999.000	0.0	0.0
		-8.32	999.000	0.0	0.0
41.00	1.00	-8.22	999.000	0.0	0.0
42.00	10.00	14.28	3.757	6212.3	1653.5
		15.00	3.701	9332.1	2521.3
42.00	9.00	13.39	3.896	6079.0	1560.4
		14.00	3.738	8422.8	2253.4
42.00	8.00	12.49	4.020	5835.5	1451.5
		13.00	3.797	7540.2	1985.8
42.00	7.00	11.60	4.127	5475.3	1326.6
		12.00	3.891	6686.4	1718.6
42.00	6.00	-11.30	999.000	0.0	0.0
		-10.30	999.000	0.0	0.0
		10.70	4.265	5058.2	1185.9
		11.00	4.039	5863.5	1451.7
42.00	5.00	-12.19	999.000	0.0	0.0
		-11.19	999.000	0.0	0.0
		-10.19	999.000	0.0	0.0
		9.81	4.478	4608.3	1029.1
		10.00	4.281	5073.8	1185.3
42.00	4.00	-11.09	999.000	0.0	0.0
		-10.09	999.000	0.0	0.0
42.00	3.00	-10.98	999.000	0.0	0.0
		-9.98	999.000	0.0	0.0
		-8.98	999.000	0.0	0.0
42.00	2.00	-9.87	999.000	0.0	0.0
		-8.87	999.000	0.0	0.0
42.00	1.00	-8.77	999.000	0.0	0.0
43.00	10.00	14.73	4.212	7695.6	1827.3
		15.00	4.036	8783.7	2176.2
43.00	9.00	13.83	4.277	7300.6	1706.9
		14.00	4.148	7909.8	1907.0
43.00	8.00	12.94	4.370	6860.8	1569.9
		13.00	4.313	7063.4	1637.9
43.00	7.00	12.00	4.563	6246.4	1368.9
43.00	6.00	11.00	4.964	5461.6	1100.2
43.00	5.00	-11.74	999.000	0.0	0.0

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
43.00	5.00	-10.74	999.000	0.0	0.0	
43.00	4.00	-11.64	999.000	0.0	0.0	
		-10.64	999.000	0.0	0.0	
43.00	3.00	-10.53	999.000	0.0	0.0	
43.00	2.00	-9.43	999.000	0.0	0.0	
43.00	1.00	0.00	0.001	0.0	0.0	***5
44.00	10.00	15.00	4.660	8148.5	1748.8	
44.00	9.00	14.00	4.946	7316.2	1479.1	
44.00	8.00	13.00	5.385	6513.1	1209.6	
44.00	7.00	0.00	0.001	0.0	0.0	***5
44.00	6.00	0.00	0.001	0.0	0.0	***5
44.00	5.00	0.00	0.001	0.0	0.0	***5
44.00	4.00	-11.19	999.000	0.0	0.0	
44.00	3.00	0.00	0.001	0.0	0.0	***5
44.00	2.00	0.00	0.001	0.0	0.0	***5
44.00	1.00	0.00	0.001	0.0	0.0	***5

Table of B.A

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

Center X(m),Y(m)

Y(m)	X(m)	35.00	36.00	37.00	38.00	39.00	40.00
10.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
9.00	Fs	999.000	999.000	999.000	999.000	999.000	3.261
	R(m)	0.00	0.00	0.00	0.00	0.00	13.50
8.00	Fs	999.000	999.000	999.000	999.000	999.000	3.259
	R(m)	0.00	0.00	0.00	0.00	0.00	12.60
7.00	Fs	999.000	999.000	999.000	999.000	999.000	3.254
	R(m)	0.00	0.00	0.00	0.00	0.00	11.71
6.00	Fs	999.000	999.000	999.000	999.000	2.935	3.251
	R(m)	0.00	0.00	0.00	0.00	10.36	10.81
5.00	Fs	999.000	999.000	999.000	999.000	2.953	3.258
	R(m)	0.00	0.00	0.00	0.00	9.47	9.92
4.00	Fs	999.000	999.000	999.000	2.966	2.976	3.285
	R(m)	0.00	0.00	0.00	9.00	8.57	9.00
3.00	Fs	999.000	999.000	999.000	999.000	3.020	3.358
	R(m)	0.00	0.00	0.00	0.00	7.68	8.00
2.00	Fs	999.000	999.000	999.000	999.000	3.111	3.529
	R(m)	0.00	0.00	0.00	0.00	6.79	7.00
1.00	Fs	999.000	999.000	999.000	999.000	3.303	999.000
	R(m)	0.00	0.00	0.00	0.00	6.00	0.00

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

Center X(m),Y(m)

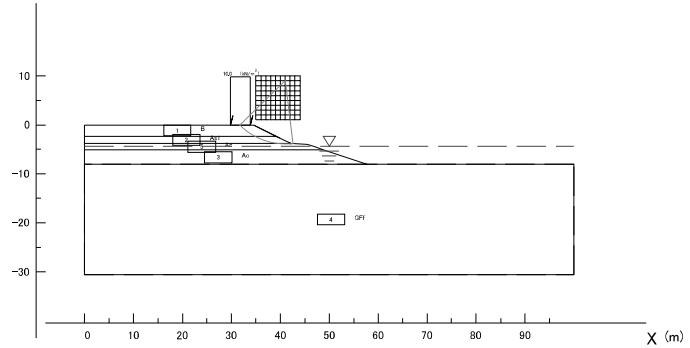
Y(m)	X(m)	41.00	42.00	43.00	44.00
10.00	Fs	3.555	3.701	4.036	4.660
	R(m)	14.84	15.00	15.00	15.00
9.00	Fs	2.665	3.738	4.148	4.946
	R(m)	12.94	14.00	14.00	14.00
8.00	Fs	3.003	3.797	4.313	5.385
	R(m)	12.05	13.00	13.00	13.00
7.00	Fs	3.236	3.891	4.563	999.000
	R(m)	11.15	12.00	12.00	0.00
6.00	Fs	3.427	4.039	4.964	999.000
	R(m)	10.26	11.00	11.00	0.00
5.00	Fs	3.620	4.281	999.000	999.000
	R(m)	9.36	10.00	0.00	0.00
4.00	Fs	3.773	999.000	999.000	999.000
	R(m)	9.00	0.00	0.00	0.00
3.00	Fs	4.009	999.000	999.000	999.000
	R(m)	8.00	0.00	0.00	0.00
2.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00
1.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	2.665
Failure circle X(m)	=	41.00
Y(m)	=	9.00
R(m)	=	12.942
Resisting moment(kNm)	=	3685.0
Sliding moment(kNm)	=	1382.9
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



WARNING ***5 There are no arc contacting with base line.

count = 49

4. Action02 (seismic)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	5	19.00	18.00	9.00	1.00	0.00	30.00	0.00	0.00	0.0
2	6	18.50	17.50	8.50	0.00	0.00	27.80	0.00	0.00	0.0
3	9	16.50	15.50	6.50	50.00	0.00	0.00	0.00	0.00	0.0
4	8	18.00	17.00	8.00	1000.0	0 0.0	030.0	0 0.0	0 0.0	0 0.
0	5	9 16.5	0 15.5	0 6.5	0 50.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.
0										

// Distribution load that considers partial coefficient //

load No.	Left			Right			Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)			
2	29.83	0.00	5.0	33.83	0.00	5.0	0.000	0.200	0.000

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

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	-4.42	
2	100.00	-4.42	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	10.00	0.00	0.001	0.0	0.0	***5
35.00	9.00	0.00	0.001	0.0	0.0	***5
35.00	8.00	0.00	0.001	0.0	0.0	***5
35.00	7.00	0.00	0.001	0.0	0.0	***5
35.00	6.00	0.00	0.001	0.0	0.0	***5
35.00	5.00	0.00	0.001	0.0	0.0	***5
35.00	4.00	0.00	0.001	0.0	0.0	***5
35.00	3.00	0.00	0.001	0.0	0.0	***5
35.00	2.00	0.00	0.001	0.0	0.0	***5
35.00	1.00	0.00	0.001	0.0	0.0	***5
36.00	10.00	0.00	0.001	0.0	0.0	***5
36.00	9.00	0.00	0.001	0.0	0.0	***5
36.00	8.00	0.00	0.001	0.0	0.0	***5
36.00	7.00	0.00	0.001	0.0	0.0	***5
36.00	6.00	0.00	0.001	0.0	0.0	***5
36.00	5.00	0.00	0.001	0.0	0.0	***5
36.00	4.00	0.00	0.001	0.0	0.0	***5
36.00	3.00	0.00	0.001	0.0	0.0	***5
36.00	2.00	0.00	0.001	0.0	0.0	***5
36.00	1.00	0.00	0.001	0.0	0.0	***5
37.00	10.00	0.00	0.001	0.0	0.0	***5
37.00	9.00	0.00	0.001	0.0	0.0	***5
37.00	8.00	0.00	0.001	0.0	0.0	***5
37.00	7.00	0.00	0.001	0.0	0.0	***5
37.00	6.00	0.00	0.001	0.0	0.0	***5
37.00	5.00	0.00	0.001	0.0	0.0	***5
37.00	4.00	0.00	0.001	0.0	0.0	***5
37.00	3.00	0.00	0.001	0.0	0.0	***5
37.00	2.00	0.00	0.001	0.0	0.0	***5
37.00	1.00	0.00	0.001	0.0	0.0	***5
38.00	10.00	0.00	0.001	0.0	0.0	***5
38.00	9.00	0.00	0.001	0.0	0.0	***5
38.00	8.00	0.00	0.001	0.0	0.0	***5
38.00	7.00	0.00	0.001	0.0	0.0	***5
38.00	6.00	0.00	0.001	0.0	0.0	***5
38.00	5.00	0.00	0.001	0.0	0.0	***5
38.00	4.00	9.00	1.907	4650.5	2438.9	
38.00	3.00	0.00	0.001	0.0	0.0	***5
38.00	2.00	-7.66	999.000	0.0	0.0	
38.00	1.00	-7.56	999.000	0.0	0.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	1.00	-6.56	999.000	0.0	0.0	
39.00	10.00	0.00	0.001	0.0	0.0	***5
39.00	9.00	0.00	0.001	0.0	0.0	***5
39.00	8.00	0.00	0.001	0.0	0.0	***5
39.00	7.00	0.00	0.001	0.0	0.0	***5
39.00	6.00	-10.64	999.000	0.0	0.0	
		10.36	1.953	4380.8	2243.0	
39.00	5.00	-9.53	999.000	0.0	0.0	
		9.47	1.973	4026.8	2040.6	
		10.00	2.013	5417.1	2691.3	
39.00	4.00	-9.43	999.000	0.0	0.0	
		8.57	1.992	3627.7	1820.9	
		9.00	2.014	4607.0	2286.9	
39.00	3.00	-9.32	999.000	0.0	0.0	
		-8.32	999.000	0.0	0.0	
		7.68	2.018	3197.7	1584.5	
		8.00	2.028	3841.4	1893.8	
39.00	2.00	-9.21	999.000	0.0	0.0	
		-8.21	999.000	0.0	0.0	
		-7.21	999.000	0.0	0.0	
		6.79	2.063	2749.0	1332.6	
		7.00	2.064	3122.7	1512.6	
39.00	1.00	-8.11	999.000	0.0	0.0	
		-7.11	999.000	0.0	0.0	
		-6.11	999.000	0.0	0.0	
		5.89	2.150	2293.5	1066.8	
		6.00	2.146	2456.2	1144.8	
40.00	10.00	0.00	0.001	0.0	0.0	***5
40.00	9.00	13.50	2.172	6925.7	3189.3	
40.00	8.00	12.60	2.178	6553.4	3008.5	
40.00	7.00	-11.29	999.000	0.0	0.0	
		11.71	2.181	6122.2	2807.5	
		12.00	2.172	7093.6	3266.2	
40.00	6.00	-11.19	999.000	0.0	0.0	
		-10.19	999.000	0.0	0.0	
		10.81	2.182	5645.3	2586.7	
		11.00	2.173	6205.5	2855.4	
40.00	5.00	-11.08	999.000	0.0	0.0	
		-10.08	999.000	0.0	0.0	
		9.92	2.188	5133.7	2346.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
40.00	5.00	10.00	2.182	5355.8	2454.4
40.00	4.00	-9.98	999.000	0.0	0.0
		-8.98	999.000	0.0	0.0
		9.00	2.203	4547.4	2064.0
40.00	3.00	-9.87	999.000	0.0	0.0
		-8.87	999.000	0.0	0.0
		-7.87	999.000	0.0	0.0
		8.00	2.246	3783.9	1684.9
40.00	2.00	-9.77	999.000	0.0	0.0
		-8.77	999.000	0.0	0.0
		-7.77	999.000	0.0	0.0
		-6.77	999.000	0.0	0.0
		7.00	2.329	3069.6	1318.1
40.00	1.00	-8.66	999.000	0.0	0.0
		-7.66	999.000	0.0	0.0
		-6.66	999.000	0.0	0.0
41.00	10.00	14.84	2.354	9035.4	3838.2
41.00	9.00	12.94	1.832	3556.3	1941.4
		13.94	2.337	8506.4	3640.0
		14.00	2.319	8699.3	3752.0
41.00	8.00	12.05	2.074	3795.2	1830.2
		13.00	2.339	7802.9	3336.5
41.00	7.00	11.15	2.236	3803.8	1701.1
		12.00	2.367	6934.4	2930.2
41.00	6.00	-11.74	999.000	0.0	0.0
		-10.74	999.000	0.0	0.0
		10.26	2.361	3669.7	1554.0
		11.00	2.406	6096.0	2533.5
41.00	5.00	-11.64	999.000	0.0	0.0
		-10.64	999.000	0.0	0.0
		-9.64	999.000	0.0	0.0
		9.36	2.475	3438.0	1389.2
		10.00	2.450	5260.4	2146.9
41.00	4.00	-11.53	999.000	0.0	0.0
		-10.53	999.000	0.0	0.0
		-9.53	999.000	0.0	0.0
		-8.53	999.000	0.0	0.0
		8.47	2.599	3137.8	1207.3
		9.00	2.517	4458.3	1771.0
41.00	3.00	-10.43	999.000	0.0	0.0

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
41.00	3.00	-9.43	999.000	0.0	0.0
		-8.43	999.000	0.0	0.0
		8.00	2.633	3703.1	1406.7
41.00	2.00	-9.32	999.000	0.0	0.0
		-8.32	999.000	0.0	0.0
41.00	1.00	-8.22	999.000	0.0	0.0
42.00	10.00	14.28	2.592	6069.1	2341.7
		15.00	2.457	9162.7	3728.5
42.00	9.00	13.39	2.681	5946.7	2218.5
		14.00	2.491	8269.5	3319.1
42.00	8.00	12.49	2.753	5715.1	2075.6
		13.00	2.537	7403.3	2918.1
42.00	7.00	11.60	2.805	5367.3	1913.4
		12.00	2.599	6566.1	2526.1
42.00	6.00	-11.30	999.000	0.0	0.0
		-10.30	999.000	0.0	0.0
		10.70	2.866	4963.5	1732.1
		11.00	2.687	5760.0	2143.6
42.00	5.00	-12.19	999.000	0.0	0.0
		-11.19	999.000	0.0	0.0
		-10.19	999.000	0.0	0.0
		9.81	2.955	4527.5	1532.1
		10.00	2.816	4987.6	1771.3
42.00	4.00	-11.09	999.000	0.0	0.0
		-10.09	999.000	0.0	0.0
42.00	3.00	-10.98	999.000	0.0	0.0
		-9.98	999.000	0.0	0.0
		-8.98	999.000	0.0	0.0
42.00	2.00	-9.87	999.000	0.0	0.0
		-8.87	999.000	0.0	0.0
42.00	1.00	-8.77	999.000	0.0	0.0
43.00	10.00	14.73	2.842	7551.5	2657.2
		15.00	2.690	8628.2	3207.4
43.00	9.00	13.83	2.867	7169.0	2500.8
		14.00	2.762	7771.5	2813.9
43.00	8.00	12.94	2.902	6742.5	2323.3
		13.00	2.859	6942.7	2428.7
43.00	7.00	12.00	2.993	6143.6	2052.5
43.00	6.00	11.00	3.190	5377.1	1685.8
43.00	5.00	-11.74	999.000	0.0	0.0

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
43.00	5.00	-10.74	999.000	0.0	0.0	
43.00	4.00	-11.64	999.000	0.0	0.0	
		-10.64	999.000	0.0	0.0	
43.00	3.00	-10.53	999.000	0.0	0.0	
43.00	2.00	-9.43	999.000	0.0	0.0	
43.00	1.00	0.00	0.001	0.0	0.0	***5
44.00	10.00	15.00	3.075	8015.2	2606.3	
44.00	9.00	14.00	3.229	7201.5	2230.3	
44.00	8.00	13.00	3.445	6417.4	1862.8	
44.00	7.00	0.00	0.001	0.0	0.0	***5
44.00	6.00	0.00	0.001	0.0	0.0	***5
44.00	5.00	0.00	0.001	0.0	0.0	***5
44.00	4.00	-11.19	999.000	0.0	0.0	
44.00	3.00	0.00	0.001	0.0	0.0	***5
44.00	2.00	0.00	0.001	0.0	0.0	***5
44.00	1.00	0.00	0.001	0.0	0.0	***5

Table of B.A

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

Center X(m),Y(m)

Y(m)	X(m)	35.00	36.00	37.00	38.00	39.00	40.00
10.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
9.00	Fs	999.000	999.000	999.000	999.000	999.000	2.172
	R(m)	0.00	0.00	0.00	0.00	0.00	13.50
8.00	Fs	999.000	999.000	999.000	999.000	999.000	2.178
	R(m)	0.00	0.00	0.00	0.00	0.00	12.60
7.00	Fs	999.000	999.000	999.000	999.000	999.000	2.172
	R(m)	0.00	0.00	0.00	0.00	0.00	12.00
6.00	Fs	999.000	999.000	999.000	999.000	1.953	2.173
	R(m)	0.00	0.00	0.00	0.00	10.36	11.00
5.00	Fs	999.000	999.000	999.000	999.000	1.973	2.182
	R(m)	0.00	0.00	0.00	0.00	9.47	10.00
4.00	Fs	999.000	999.000	999.000	1.907	1.992	2.203
	R(m)	0.00	0.00	0.00	9.00	8.57	9.00
3.00	Fs	999.000	999.000	999.000	999.000	2.018	2.246
	R(m)	0.00	0.00	0.00	0.00	7.68	8.00
2.00	Fs	999.000	999.000	999.000	999.000	2.063	2.329
	R(m)	0.00	0.00	0.00	0.00	6.79	7.00
1.00	Fs	999.000	999.000	999.000	999.000	2.146	999.000
	R(m)	0.00	0.00	0.00	0.00	6.00	0.00

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

Center X(m),Y(m)

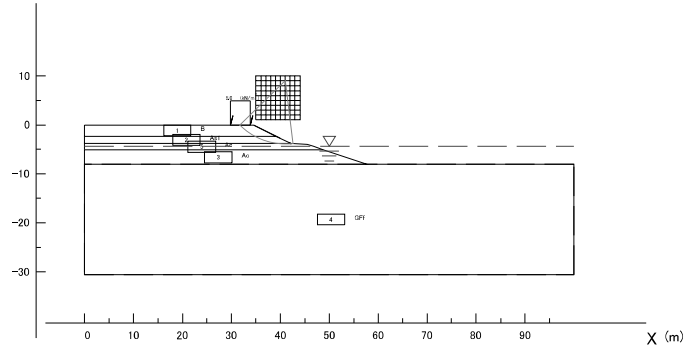
Y(m)	X(m)	41.00	42.00	43.00	44.00
10.00	Fs	2.354	2.457	2.690	3.075
	R(m)	14.84	15.00	15.00	15.00
9.00	Fs	1.832	2.491	2.762	3.229
	R(m)	12.94	14.00	14.00	14.00
8.00	Fs	2.074	2.537	2.859	3.445
	R(m)	12.05	13.00	13.00	13.00
7.00	Fs	2.236	2.599	2.993	999.000
	R(m)	11.15	12.00	12.00	0.00
6.00	Fs	2.361	2.687	3.190	999.000
	R(m)	10.26	11.00	11.00	0.00
5.00	Fs	2.450	2.816	999.000	999.000
	R(m)	10.00	10.00	0.00	0.00
4.00	Fs	2.517	999.000	999.000	999.000
	R(m)	9.00	0.00	0.00	0.00
3.00	Fs	2.633	999.000	999.000	999.000
	R(m)	8.00	0.00	0.00	0.00
2.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00
1.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	1.832
Failure circle X(m)	=	41.00
Y(m)	=	9.00
R(m)	=	12.942
Resisting moment(kNm)	=	3556.3
Sliding moment(kNm)	=	1941.4
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



WARNING ***5 There are no arc contacting with base line.
count = 49

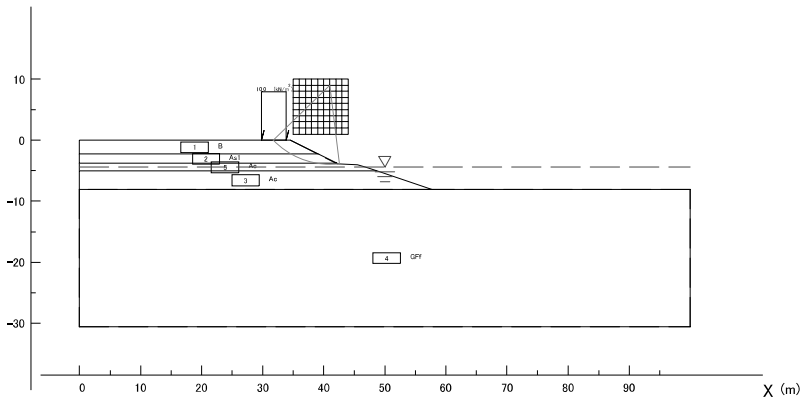
33

Test of Embankment Stability

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

Scale : 1/ 792

Required Bearing force Action ratio	F S	=	1.000	
Bearing force Action ratio		=	2.665	≧ 1.0 (OK)
Center of arc	X	=	41.00	(m)
	Y	=	9.00	(m)
Radius	R	=	12.942	(m)
Resisting moment	M R	=	3685.0	(kNm)
Sliding moment	M D	=	1382.9	(kNm)
Partial coefficient concerning	γ α	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	19.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.50	17.50	27.80	0.00	0.00	0.000	0.000
3	16.50	15.50	0.00	50.00	0.00	0.000	0.000
4	18.00	17.00	30.00	1000.00	0.00	0.000	0.000
5	16.50	15.50	0.00	50.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)

Safety Factor (Ordinary Condition)

Test of Embankment Stability

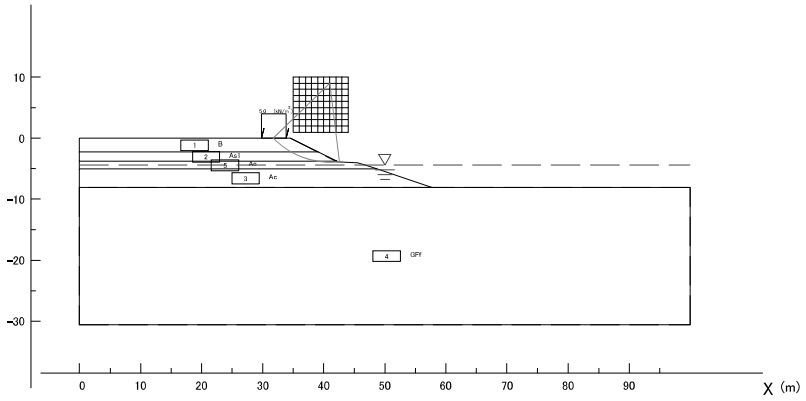
Action number = 2

Action name : seismic

Examination at earthquake : It does.

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	1.832	≧ 1.0 (OK)
Center of arc	X	=	41.00	(m)
	Y	=	9.00	(m)
Radius	R	=	12.942	(m)
Resisting moment	M_R	=	3556.3	(kNm)
Sliding moment	M_D	=	1941.4	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.200	0.000
2	18.50	17.50	27.00	0.00	0.00	0.200	0.000
3	16.50	15.50	0.00	50.00	0.00	0.200	0.000
4	18.00	17.00	30.00	1000.00	0.00	0.200	0.000
5	16.50	15.50	0.00	50.00	0.00	0.200	0.000

Water unit weight = 10.00 (kN/m³)

Safety Factor (Seismic Condition)

1.2.1 SLOPE STABILITY　ANALYSIS

1.2.1.1　Normal and Seismic Conditions

(2)　L5+780

Circular Slip Surface

L+5780

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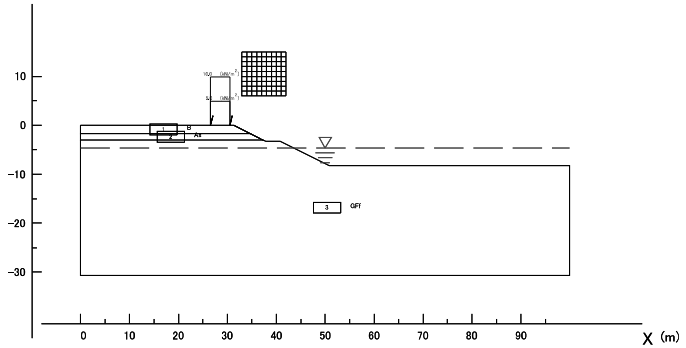
1. Input data list

// Design section //



// Design level of reliability design method //

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

// Combination of action //

// Setting of action //

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

// Partial coefficient concerning analytical technique γ_α //

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

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

No.	Action 1			Action 2											
	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$
1	1.00	1.00	1.00	1.00	1.00	1.00						
2	1.00	1.00	1.00	1.00	1.00	1.00						
3	1.00	1.00	1.00	1.00	1.00	1.00						

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

$$W_d' = \gamma_w W_k'$$

$$C_d = \gamma_c C_k$$

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

M : Resistance moment

γ_w : Partial coefficient concerning weight

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

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

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

γ_c : Partial coefficient concerning Cohesion

C_d : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (value for design) (kN/m²)

C_k : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (characteristic value) (kN/m²)

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

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

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

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

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

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

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

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

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

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

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

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

K : Resistance power coefficient

r : Radius of slipping circular arc

F : Distribution load i

FR : Slipping line orthogonalization direction load value of load i

FO : Slipping line direction load value of load i

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

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

K_{hp} : The horizontal seismic intensity

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

ϕ : Internal friction angle of soil

// Partial coefficient to residual water level //

Action number	rRWL
1	1.00
2	1.00

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

γ_{RWL} : Partial coefficient concerning residual water level

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

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

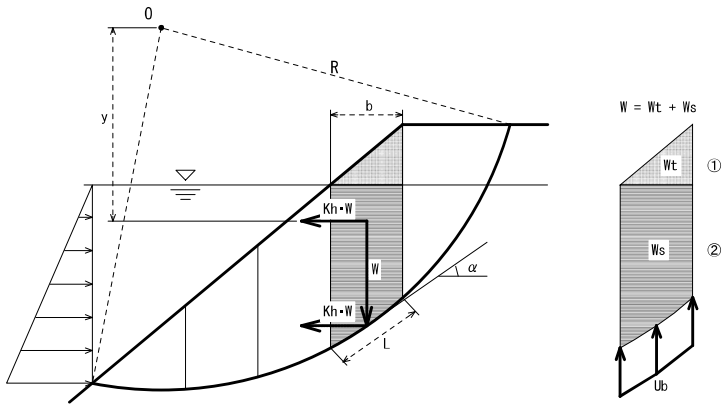
(DATA 01.)　// ANALYSIS //

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

Expression

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

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



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

(DATA 02.)　// CONTROL //

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

(DATA 04.) // SEISMIC LOAD //

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


(DATA 06.) // NODAL POINT //

No.	Coordinate		Y-coordinate
	x (m)	y (m)	before settlement (m)
1	0.00	0.00	0.00
2	26.55	0.00	0.00
3	30.55	0.00	0.00
4	31.25	0.00	0.00
5	34.68	-1.71	0.00
6	0.00	-1.71	0.00
7	0.00	-2.97	0.00
8	37.19	-2.97	0.00
9	37.81	-3.28	0.00
10	40.81	-3.28	0.00
11	50.72	-8.23	0.00
12	100.00	-8.23	0.00
13	100.00	-30.61	0.00
14	0.00	-30.61	0.00
15	0.00	-4.63	0.00

(DATA 07.) // WATER LEVEL //

Unit weight of water (kN/m^3) = 10.00

Action No.	Water level line number
1	1
2	1

Water level line number: 1

No.	Coordinate	
	X (m)	Y (m)
1	0.00	-4.63
2	100.00	-4.63

Water level line number: 2

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

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

(DATA 08.) // LAYER //

No.	material property No.	The name of the strata
1	5	B
2	6	As
3	8	GFf

No.	Num of Node	Node numbers composing a layer	Slip existence
1	6	1 6 5 4 3 2	Slip
2	4	6 7 8 5	Slip
3	9	7 15 14 13 12 11 10 9 8	Slip

(DATA 09.1) // MATERIAL PROPERTIES //

No.	Nature of soil division	Saturated weight (kN/m³)	Wet weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
5	B	19.00	18.00	1.00	0.00	30.00	0.00	0.000	0.0
6	As	18.50	17.50	0.00	0.00	27.00	0.00	0.000	0.0
8	GFf	18.00	17.00	******	0.00	30.00	0.00	0.000	0.0

(DATA 09.2) // Characteristic of soil //

No.	Action Number									
	Act 1	Act 2								
1	5	5								
2	6	6								
3	8	8								

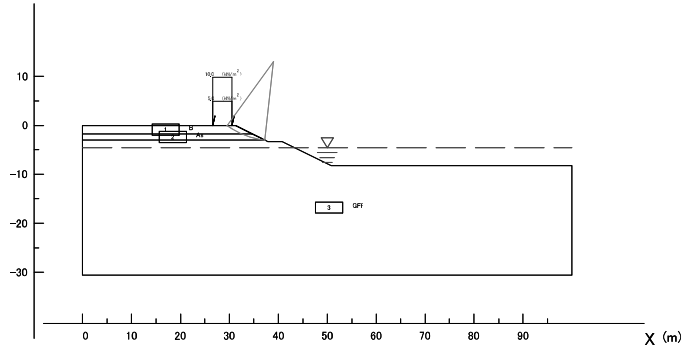
2. Check list

// Check of circular arc //

Action No.	Action name	Bearing force Action ratio	Judgment
1	normal	6.128	OK
2	seismic	4.435	OK

Action No.	Bearing force Action ratio	Partial coefficient r_a	Center of slipping circular arc X (m)	Center of slipping circular arc Y (m)	Radius of circular arc(m)	Resistance Moment (kNm)	Sliding Moment (kNm)
1	6.128	1.00	39.00	13.00	16.092	4249.2	693.4
2	4.435	1.00	39.00	13.00	16.092	4183.6	943.3

// Check Result chart //



3. Action01 (normal)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	5	19.00	18.00	9.00	1.00	0.00	30.00	0.00	0.00	0.0
2	6	18.50	17.50	8.50	0.00	0.00	27.00	0.00	0.00	0.0
3	8	18.00	17.00	8.00	1000.0	0 0.0	030.0	0 0.0	0 0.0	0 0.
0										

// Distribution load that considers partial coefficient //

load No.	Left			Right			Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)			
1	26.55	0.00	10.0	30.55	0.00	10.0	0.000	0.000	0.000

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

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	-4.63	
2	100.00	-4.63	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	15.00	5.10	999.000	0.0	0.0	***6
		6.10	999.000	0.0	0.0	***6
		7.10	999.000	0.0	0.0	***6
		8.10	999.000	0.0	0.0	***6
		9.10	999.000	0.0	0.0	***6
		10.10	999.000	0.0	0.0	***6
		11.10	999.000	0.0	0.0	***6
		12.10	999.000	0.0	0.0	***6
		13.10	999.000	0.0	0.0	***6
		14.10	999.000	0.0	0.0	***6
		15.10	999.000	0.0	0.0	***6
		19.10	94.465	241137.6	2552.7	
		20.10	99.116	366372.2	3696.4	
		21.10	91.797	462682.5	5040.3	
		22.00	85.040	550986.7	6479.2	
33.00	14.00	4.11	999.000	0.0	0.0	***6
		5.11	999.000	0.0	0.0	***6
		6.11	999.000	0.0	0.0	***6
		7.11	999.000	0.0	0.0	***6
		8.11	999.000	0.0	0.0	***6
		9.11	999.000	0.0	0.0	***6
		10.11	999.000	0.0	0.0	***6
		11.11	999.000	0.0	0.0	***6
		12.11	999.000	0.0	0.0	***6
		13.11	999.000	0.0	0.0	***6
		14.11	999.000	0.0	0.0	***6
		18.11	92.481	223470.0	2416.4	
		19.11	97.869	342489.8	3499.5	
		20.11	91.074	433674.2	4761.8	
		21.00	84.692	517007.6	6104.6	
33.00	13.00	3.12	999.000	0.0	0.0	***6
		4.12	999.000	0.0	0.0	***6
		5.12	999.000	0.0	0.0	***6
		6.12	999.000	0.0	0.0	***6
		7.12	999.000	0.0	0.0	***6
		8.12	999.000	0.0	0.0	***6
		9.12	999.000	0.0	0.0	***6
		10.12	999.000	0.0	0.0	***6
		11.12	999.000	0.0	0.0	***6
		12.12	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	13.00	13.12	999.000	0.0	0.0	***6
		17.12	90.468	206299.3	2280.4	
		18.12	96.568	319076.2	3304.2	
		19.12	90.337	405225.0	4485.7	
		20.00	84.359	483621.7	5732.9	
33.00	12.00	2.13	999.000	0.0	0.0	***6
		3.13	999.000	0.0	0.0	***6
		4.13	999.000	0.0	0.0	***6
		5.13	999.000	0.0	0.0	***6
		6.13	999.000	0.0	0.0	***6
		7.13	999.000	0.0	0.0	***6
		8.13	999.000	0.0	0.0	***6
		9.13	999.000	0.0	0.0	***6
		10.13	999.000	0.0	0.0	***6
		11.13	999.000	0.0	0.0	***6
		12.13	999.000	0.0	0.0	***6
		16.13	88.427	189644.8	2144.6	
		17.13	94.976	295434.1	3110.6	
		18.13	89.587	377362.0	4212.3	
		19.00	84.044	450849.0	5364.4	
33.00	11.00	1.14	999.000	0.0	0.0	***6
		2.14	999.000	0.0	0.0	***6
		3.14	999.000	0.0	0.0	***6
		4.14	999.000	0.0	0.0	***6
		5.14	999.000	0.0	0.0	***6
		6.14	999.000	0.0	0.0	***6
		7.14	999.000	0.0	0.0	***6
		8.14	999.000	0.0	0.0	***6
		9.14	999.000	0.0	0.0	***6
		10.14	999.000	0.0	0.0	***6
		11.14	999.000	0.0	0.0	***6
		15.14	86.361	173528.1	2009.3	
		16.14	92.930	271157.7	2917.9	
		17.14	88.821	350116.7	3941.8	
		18.00	83.751	418711.4	4999.5	
33.00	10.00	0.15	999.000	0.0	0.0	***6
		1.15	999.000	0.0	0.0	***6
		2.15	999.000	0.0	0.0	***6
		3.15	999.000	0.0	0.0	***6
		4.15	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	10.00	5.15	999.000	0.0	0.0	***6
		6.15	999.000	0.0	0.0	***6
		7.15	999.000	0.0	0.0	***6
		8.15	999.000	0.0	0.0	***6
		9.15	999.000	0.0	0.0	***6
		10.15	999.000	0.0	0.0	***6
		14.15	84.275	157976.3	1874.5	
		15.15	90.868	247685.7	2725.8	
		16.15	88.041	323528.2	3674.8	
		17.00	83.484	387232.5	4638.4	
33.00	9.00	-0.83	999.000	0.0	0.0	***6
		0.17	999.000	0.0	0.0	***6
		1.17	999.000	0.0	0.0	***6
		2.17	999.000	0.0	0.0	***6
		3.17	999.000	0.0	0.0	***6
		4.17	999.000	0.0	0.0	***6
		5.17	999.000	0.0	0.0	***6
		6.17	999.000	0.0	0.0	***6
		7.17	999.000	0.0	0.0	***6
		8.17	999.000	0.0	0.0	***6
		9.17	999.000	0.0	0.0	***6
		13.17	82.437	143478.8	1740.5	
		14.17	88.799	225061.9	2534.5	
		15.17	87.244	297643.7	3411.6	
		16.00	83.248	356438.6	4281.7	
33.00	8.00	-1.81	999.000	0.0	0.0	***6
		-0.81	999.000	0.0	0.0	***6
		0.19	999.000	0.0	0.0	***6
		1.19	999.000	0.0	0.0	***6
		2.19	999.000	0.0	0.0	***6
		3.19	999.000	0.0	0.0	***6
		4.19	999.000	0.0	0.0	***6
		5.19	999.000	0.0	0.0	***6
		6.19	999.000	0.0	0.0	***6
		7.19	999.000	0.0	0.0	***6
		8.19	999.000	0.0	0.0	***6
		12.19	80.928	130100.3	1607.6	
		13.19	86.733	203341.6	2344.4	
		14.19	86.433	272525.1	3153.0	
		15.00	83.051	326359.3	3929.6	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	7.00	-2.78	999.000	0.0	0.0	***6
		-1.78	999.000	0.0	0.0	***6
		-0.78	999.000	0.0	0.0	***6
		0.22	999.000	0.0	0.0	***6
		1.22	999.000	0.0	0.0	***6
		2.22	999.000	0.0	0.0	***6
		3.22	999.000	0.0	0.0	***6
		4.22	999.000	0.0	0.0	***6
		5.22	999.000	0.0	0.0	***6
		6.22	999.000	0.0	0.0	***6
		7.22	999.000	0.0	0.0	***6
		11.22	79.392	117214.5	1476.4	
		12.22	84.692	182598.5	2156.0	
		13.22	85.610	248255.6	2899.9	
		14.00	82.900	297027.4	3583.0	
33.00	6.00	-3.75	999.000	0.0	0.0	***6
		-2.75	999.000	0.0	0.0	***6
		-1.75	999.000	0.0	0.0	***6
		-0.75	999.000	0.0	0.0	***6
		0.25	999.000	0.0	0.0	***6
		1.25	999.000	0.0	0.0	***6
		2.25	999.000	0.0	0.0	***6
		3.25	999.000	0.0	0.0	***6
		4.25	999.000	0.0	0.0	***6
		5.25	999.000	0.0	0.0	***6
		6.25	999.000	0.0	0.0	***6
		10.25	77.845	104895.3	1347.5	
		11.25	82.709	162937.4	1970.0	
		12.25	84.782	224954.9	2653.3	
		13.00	82.805	268480.0	3242.3	
34.00	15.00	5.25	999.000	0.0	0.0	***6
		6.25	999.000	0.0	0.0	***6
		7.25	999.000	0.0	0.0	***6
		8.25	999.000	0.0	0.0	***6
		9.25	999.000	0.0	0.0	***6
		10.25	999.000	0.0	0.0	***6
		11.25	999.000	0.0	0.0	***6
		12.25	999.000	0.0	0.0	***6
		13.25	999.000	0.0	0.0	***6
		14.25	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	15.00	15.25	999.000	0.0	0.0	***6
		19.25	92.844	261462.7	2816.1	
		20.25	91.545	368023.3	4020.1	
		21.25	84.588	464158.6	5487.3	
		22.00	79.427	537760.2	6770.5	
34.00	14.00	4.27	999.000	0.0	0.0	***6
		5.27	999.000	0.0	0.0	***6
		6.27	999.000	0.0	0.0	***6
		7.27	999.000	0.0	0.0	***6
		8.27	999.000	0.0	0.0	***6
		9.27	999.000	0.0	0.0	***6
		10.27	999.000	0.0	0.0	***6
		11.27	999.000	0.0	0.0	***6
		12.27	999.000	0.0	0.0	***6
		13.27	999.000	0.0	0.0	***6
		14.27	999.000	0.0	0.0	***6
		18.27	90.842	243663.2	2682.3	
		19.27	90.359	345065.8	3818.8	
		20.27	83.825	436147.8	5203.1	
		21.00	78.995	504543.2	6387.0	
34.00	13.00	3.29	999.000	0.0	0.0	***6
		4.29	999.000	0.0	0.0	***6
		5.29	999.000	0.0	0.0	***6
		6.29	999.000	0.0	0.0	***6
		7.29	999.000	0.0	0.0	***6
		8.29	999.000	0.0	0.0	***6
		9.29	999.000	0.0	0.0	***6
		10.29	999.000	0.0	0.0	***6
		11.29	999.000	0.0	0.0	***6
		12.29	999.000	0.0	0.0	***6
		13.29	999.000	0.0	0.0	***6
		16.29	68.044	108342.5	1592.3	
		17.29	88.813	226382.0	2549.0	
		18.29	89.137	322602.4	3619.2	
		19.29	83.053	408731.3	4921.3	
		20.00	78.590	471910.6	6004.7	
34.00	12.00	2.31	999.000	0.0	0.0	***6
		3.31	999.000	0.0	0.0	***6
		4.31	999.000	0.0	0.0	***6
		5.31	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	12.00	6.31	999.000	0.0	0.0	***6
		7.31	999.000	0.0	0.0	***6
		8.31	999.000	0.0	0.0	***6
		9.31	999.000	0.0	0.0	***6
		10.31	999.000	0.0	0.0	***6
		11.31	999.000	0.0	0.0	***6
		12.31	999.000	0.0	0.0	***6
		15.31	67.390	102125.4	1515.4	
		16.31	86.757	209644.8	2416.5	
		17.31	87.879	300665.5	3421.3	
		18.31	82.274	381946.7	4642.3	
		19.00	78.206	439880.6	5624.7	
34.00	11.00	1.34	999.000	0.0	0.0	***6
		2.34	999.000	0.0	0.0	***6
		3.34	999.000	0.0	0.0	***6
		4.34	999.000	0.0	0.0	***6
		5.34	999.000	0.0	0.0	***6
		6.34	999.000	0.0	0.0	***6
		7.34	999.000	0.0	0.0	***6
		8.34	999.000	0.0	0.0	***6
		9.34	999.000	0.0	0.0	***6
		10.34	999.000	0.0	0.0	***6
		11.34	999.000	0.0	0.0	***6
		14.34	66.699	95997.8	1439.3	
		15.34	84.679	193481.8	2284.9	
		16.34	86.584	279293.4	3225.7	
		17.34	81.491	355839.5	4366.6	
		18.00	77.841	408473.8	5247.6	
34.00	10.00	0.37	999.000	0.0	0.0	***6
		1.37	999.000	0.0	0.0	***6
		2.37	999.000	0.0	0.0	***6
		3.37	999.000	0.0	0.0	***6
		4.37	999.000	0.0	0.0	***6
		5.37	999.000	0.0	0.0	***6
		6.37	999.000	0.0	0.0	***6
		7.37	999.000	0.0	0.0	***6
		8.37	999.000	0.0	0.0	***6
		9.37	999.000	0.0	0.0	***6
		10.37	999.000	0.0	0.0	***6
		13.37	65.968	89976.7	1363.9	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	10.00	14.37	82.586	177932.6	2154.5	
		15.37	85.250	258535.9	3032.7	
		16.37	80.708	330468.0	4094.6	
		17.00	77.501	377713.2	4873.7	
34.00	9.00	-0.59	999.000	0.0	0.0	***6
		0.41	999.000	0.0	0.0	***6
		1.41	999.000	0.0	0.0	***6
		2.41	999.000	0.0	0.0	***6
		3.41	999.000	0.0	0.0	***6
		4.41	999.000	0.0	0.0	***6
		5.41	999.000	0.0	0.0	***6
		6.41	999.000	0.0	0.0	***6
		7.41	999.000	0.0	0.0	***6
		8.41	999.000	0.0	0.0	***6
		9.41	999.000	0.0	0.0	***6
		12.41	65.198	84085.9	1289.7	
		13.41	80.487	163046.7	2025.7	
		14.41	83.882	238456.6	2842.8	
		15.41	79.929	305906.9	3827.2	
		16.00	77.193	347624.5	4503.3	
34.00	8.00	-1.54	999.000	0.0	0.0	***6
		-0.54	999.000	0.0	0.0	***6
		0.46	999.000	0.0	0.0	***6
		1.46	999.000	0.0	0.0	***6
		2.46	999.000	0.0	0.0	***6
		3.46	999.000	0.0	0.0	***6
		4.46	999.000	0.0	0.0	***6
		5.46	999.000	0.0	0.0	***6
		6.46	999.000	0.0	0.0	***6
		7.46	999.000	0.0	0.0	***6
		8.46	999.000	0.0	0.0	***6
		11.46	64.392	78359.7	1216.9	
		12.46	78.401	148891.2	1899.1	
		13.46	82.484	219140.8	2656.8	
		14.46	79.165	282257.8	3565.4	
		15.00	76.925	318235.9	4137.0	
34.00	7.00	-2.48	999.000	0.0	0.0	***6
		-1.48	999.000	0.0	0.0	***6
		-0.48	999.000	0.0	0.0	***6
		0.52	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	7.00	1.52	999.000	0.0	0.0	***6
		2.52	999.000	0.0	0.0	***6
		3.52	999.000	0.0	0.0	***6
		4.52	999.000	0.0	0.0	***6
		5.52	999.000	0.0	0.0	***6
		6.52	999.000	0.0	0.0	***6
		7.52	999.000	0.0	0.0	***6
		10.52	63.557	72849.5	1146.2	
		11.52	76.355	135559.3	1775.4	
		12.52	81.072	200708.3	2475.7	
		13.52	78.432	259662.0	3310.7	
		14.00	76.710	289579.2	3775.0	
34.00	6.00	-3.40	999.000	0.0	0.0	***6
		-2.40	999.000	0.0	0.0	***6
		-1.40	999.000	0.0	0.0	***6
		-0.40	999.000	0.0	0.0	***6
		0.60	999.000	0.0	0.0	***6
		1.60	999.000	0.0	0.0	***6
		2.60	999.000	0.0	0.0	***6
		3.60	999.000	0.0	0.0	***6
		4.60	999.000	0.0	0.0	***6
		5.60	999.000	0.0	0.0	***6
		6.60	999.000	0.0	0.0	***6
		9.60	62.717	67635.3	1078.4	
		10.60	74.395	123188.8	1655.9	
		11.60	79.672	183334.6	2301.1	
		12.60	77.754	238328.1	3065.1	
		13.00	76.561	261690.1	3418.1	
35.00	15.00	5.46	999.000	0.0	0.0	***6
		6.46	999.000	0.0	0.0	***6
		7.46	999.000	0.0	0.0	***6
		8.46	999.000	0.0	0.0	***6
		9.46	999.000	0.0	0.0	***6
		10.46	999.000	0.0	0.0	***6
		11.46	999.000	0.0	0.0	***6
		12.46	999.000	0.0	0.0	***6
		13.46	999.000	0.0	0.0	***6
		14.46	999.000	0.0	0.0	***6
		15.46	999.000	0.0	0.0	***6
		18.46	67.287	134094.0	1992.9	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	15.00	19.46	89.944	279057.0	3102.6	
		20.46	84.732	375277.1	4429.0	
		21.46	78.091	471429.7	6036.9	
		22.00	74.860	524261.1	7003.2	
35.00	14.00	4.49	999.000	0.0	0.0	***6
		5.49	999.000	0.0	0.0	***6
		6.49	999.000	0.0	0.0	***6
		7.49	999.000	0.0	0.0	***6
		8.49	999.000	0.0	0.0	***6
		9.49	999.000	0.0	0.0	***6
		10.49	999.000	0.0	0.0	***6
		11.49	999.000	0.0	0.0	***6
		12.49	999.000	0.0	0.0	***6
		13.49	999.000	0.0	0.0	***6
		14.49	999.000	0.0	0.0	***6
		17.49	66.684	127931.4	1918.5	
		18.49	88.438	262708.0	2970.5	
		19.49	83.589	353301.2	4226.7	
		20.49	77.291	444510.1	5751.1	
		21.00	74.344	491816.9	6615.4	
35.00	13.00	3.53	999.000	0.0	0.0	***6
		4.53	999.000	0.0	0.0	***6
		5.53	999.000	0.0	0.0	***6
		6.53	999.000	0.0	0.0	***6
		7.53	999.000	0.0	0.0	***6
		8.53	999.000	0.0	0.0	***6
		9.53	999.000	0.0	0.0	***6
		10.53	999.000	0.0	0.0	***6
		11.53	999.000	0.0	0.0	***6
		12.53	999.000	0.0	0.0	***6
		13.53	999.000	0.0	0.0	***6
		16.53	66.374	122455.5	1844.9	
		17.53	86.890	246744.8	2839.7	
		18.53	82.423	331857.1	4026.3	
		19.53	76.487	418235.4	5468.0	
		20.00	73.845	459947.4	6228.5	
35.00	12.00	2.57	999.000	0.0	0.0	***6
		3.57	999.000	0.0	0.0	***6
		4.57	999.000	0.0	0.0	***6
		5.57	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	12.00	6.57	999.000	0.0	0.0	***6
		7.57	999.000	0.0	0.0	***6
		8.57	999.000	0.0	0.0	***6
		9.57	999.000	0.0	0.0	***6
		10.57	999.000	0.0	0.0	***6
		11.57	999.000	0.0	0.0	***6
		12.57	999.000	0.0	0.0	***6
		15.57	66.587	118021.9	1772.4	
		16.57	85.300	231200.5	2710.4	
		17.57	81.235	310987.5	3828.2	
		18.57	75.680	392656.9	5188.4	
		19.00	73.369	428671.1	5842.7	
35.00	11.00	1.62	999.000	0.0	0.0	***6
		2.62	999.000	0.0	0.0	***6
		3.62	999.000	0.0	0.0	***6
		4.62	999.000	0.0	0.0	***6
		5.62	999.000	0.0	0.0	***6
		6.62	999.000	0.0	0.0	***6
		7.62	999.000	0.0	0.0	***6
		8.62	999.000	0.0	0.0	***6
		9.62	999.000	0.0	0.0	***6
		10.62	999.000	0.0	0.0	***6
		11.62	999.000	0.0	0.0	***6
		14.62	66.688	113447.4	1701.2	
		15.62	83.671	216116.6	2582.9	
		16.62	80.029	290745.4	3633.0	
		17.62	74.874	367837.8	4912.8	
		18.00	72.923	398008.4	5457.9	
35.00	10.00	0.68	999.000	0.0	0.0	***6
		1.68	999.000	0.0	0.0	***6
		2.68	999.000	0.0	0.0	***6
		3.68	999.000	0.0	0.0	***6
		4.68	999.000	0.0	0.0	***6
		5.68	999.000	0.0	0.0	***6
		6.68	999.000	0.0	0.0	***6
		7.68	999.000	0.0	0.0	***6
		8.68	999.000	0.0	0.0	***6
		9.68	999.000	0.0	0.0	***6
		10.68	999.000	0.0	0.0	***6
		13.68	66.677	108782.5	1631.5	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	10.00	14.68	82.003	201541.2	2457.7	
		15.68	78.808	271200.1	3441.3	
		16.68	74.073	343860.5	4642.2	
		17.00	72.517	367981.5	5074.4	
35.00	9.00	-0.25	999.000	0.0	0.0	***6
		0.75	999.000	0.0	0.0	***6
		1.75	999.000	0.0	0.0	***6
		2.75	999.000	0.0	0.0	***6
		3.75	999.000	0.0	0.0	***6
		4.75	999.000	0.0	0.0	***6
		5.75	999.000	0.0	0.0	***6
		6.75	999.000	0.0	0.0	***6
		7.75	999.000	0.0	0.0	***6
		8.75	999.000	0.0	0.0	***6
		9.75	999.000	0.0	0.0	***6
		12.75	66.560	104087.5	1563.8	
		13.75	80.306	187542.9	2335.4	
		14.75	77.581	252441.4	3253.9	
		15.75	73.287	320832.4	4377.8	
		16.00	72.161	338614.7	4692.5	
35.00	8.00	-1.16	999.000	0.0	0.0	***6
		-0.16	999.000	0.0	0.0	***6
		0.84	999.000	0.0	0.0	***6
		1.84	999.000	0.0	0.0	***6
		2.84	999.000	0.0	0.0	***6
		3.84	999.000	0.0	0.0	***6
		4.84	999.000	0.0	0.0	***6
		5.84	999.000	0.0	0.0	***6
		6.84	999.000	0.0	0.0	***6
		7.84	999.000	0.0	0.0	***6
		8.84	999.000	0.0	0.0	***6
		11.84	66.345	99440.1	1498.8	
		12.84	78.594	174221.2	2216.7	
		13.84	76.362	234591.8	3072.1	
		14.84	72.527	298899.3	4121.2	
		15.00	71.851	309934.1	4313.6	
35.00	7.00	-2.06	999.000	0.0	0.0	***6
		-1.06	999.000	0.0	0.0	***6
		-0.06	999.000	0.0	0.0	***6
		0.94	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	7.00	1.94	999.000	0.0	0.0	***6
		2.94	999.000	0.0	0.0	***6
		3.94	999.000	0.0	0.0	***6
		4.94	999.000	0.0	0.0	***6
		5.94	999.000	0.0	0.0	***6
		6.94	999.000	0.0	0.0	***6
		7.94	999.000	0.0	0.0	***6
		10.94	66.162	94697.8	1431.3	
		11.94	76.895	161527.1	2100.6	
		12.94	75.183	217624.0	2894.6	
		13.94	71.827	278050.2	3871.1	
		14.00	71.598	281970.2	3938.2	
35.00	6.00	-2.96	999.000	0.0	0.0	***6
		-1.96	999.000	0.0	0.0	***6
		-0.96	999.000	0.0	0.0	***6
		0.04	999.000	0.0	0.0	***6
		1.04	999.000	0.0	0.0	***6
		2.04	999.000	0.0	0.0	***6
		3.04	999.000	0.0	0.0	***6
		4.04	999.000	0.0	0.0	***6
		5.04	999.000	0.0	0.0	***6
		6.04	999.000	0.0	0.0	***6
		7.04	999.000	0.0	0.0	***6
		10.04	66.747	88710.7	1329.1	
		11.04	75.240	148581.4	1974.8	
		12.04	74.125	200607.3	2706.3	
		13.00	71.420	254757.4	3567.0	
36.00	15.00	5.73	999.000	0.0	0.0	***6
		6.73	999.000	0.0	0.0	***6
		7.73	999.000	0.0	0.0	***6
		8.73	999.000	0.0	0.0	***6
		9.73	999.000	0.0	0.0	***6
		10.73	999.000	0.0	0.0	***6
		11.73	999.000	0.0	0.0	***6
		12.73	999.000	0.0	0.0	***6
		13.73	999.000	0.0	0.0	***6
		14.73	999.000	0.0	0.0	***6
		15.73	999.000	0.0	0.0	***6
		18.73	80.340	182311.6	2269.2	
		19.73	84.437	292375.2	3462.6	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
36.00	15.00	20.73	78.572	387865.6	4936.5	
		21.73	72.559	484333.5	6675.0	
		22.00	71.198	510472.2	7169.7	
36.00	14.00	4.78	999.000	0.0	0.0	***6
		5.78	999.000	0.0	0.0	***6
		6.78	999.000	0.0	0.0	***6
		7.78	999.000	0.0	0.0	***6
		8.78	999.000	0.0	0.0	***6
		9.78	999.000	0.0	0.0	***6
		10.78	999.000	0.0	0.0	***6
		11.78	999.000	0.0	0.0	***6
		12.78	999.000	0.0	0.0	***6
		13.78	999.000	0.0	0.0	***6
		14.78	999.000	0.0	0.0	***6
		17.78	79.879	175578.6	2198.0	
		18.78	83.036	276837.2	3333.9	
		19.78	77.454	366918.3	4737.2	
		20.78	71.706	458579.4	6395.2	
		21.00	70.640	478816.7	6778.3	
36.00	13.00	3.84	999.000	0.0	0.0	***6
		4.84	999.000	0.0	0.0	***6
		5.84	999.000	0.0	0.0	***6
		6.84	999.000	0.0	0.0	***6
		7.84	999.000	0.0	0.0	***6
		8.84	999.000	0.0	0.0	***6
		9.84	999.000	0.0	0.0	***6
		10.84	999.000	0.0	0.0	***6
		11.84	999.000	0.0	0.0	***6
		12.84	999.000	0.0	0.0	***6
		13.84	999.000	0.0	0.0	***6
		16.84	79.330	168819.8	2128.1	
		17.84	81.603	261712.9	3207.1	
		18.84	76.320	346550.3	4540.8	
		19.84	70.849	433533.9	6119.1	
		20.00	70.094	447726.0	6387.5	
36.00	12.00	2.91	999.000	0.0	0.0	***6
		3.91	999.000	0.0	0.0	***6
		4.91	999.000	0.0	0.0	***6
		5.91	999.000	0.0	0.0	***6
		6.91	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
36.00	12.00	7.91	999.000	0.0	0.0	***6
		8.91	999.000	0.0	0.0	***6
		9.91	999.000	0.0	0.0	***6
		10.91	999.000	0.0	0.0	***6
		11.91	999.000	0.0	0.0	***6
		12.91	999.000	0.0	0.0	***6
		15.91	78.691	162070.7	2059.6	
		16.91	80.141	247045.2	3082.6	
		17.91	75.171	326816.8	4347.7	
		18.91	69.991	409263.4	5847.4	
		19.00	69.564	417218.5	5997.6	
36.00	11.00	1.98	999.000	0.0	0.0	***6
		2.98	999.000	0.0	0.0	***6
		3.98	999.000	0.0	0.0	***6
		4.98	999.000	0.0	0.0	***6
		5.98	999.000	0.0	0.0	***6
		6.98	999.000	0.0	0.0	***6
		7.98	999.000	0.0	0.0	***6
		8.98	999.000	0.0	0.0	***6
		9.98	999.000	0.0	0.0	***6
		10.98	999.000	0.0	0.0	***6
		11.98	999.000	0.0	0.0	***6
		14.98	77.963	155376.2	1993.0	
		15.98	78.652	232888.1	2961.0	
		16.98	74.011	307787.3	4158.7	
		17.98	69.136	385851.4	5581.0	
		18.00	69.057	387313.7	5608.6	
36.00	10.00	1.07	999.000	0.0	0.0	***6
		2.07	999.000	0.0	0.0	***6
		3.07	999.000	0.0	0.0	***6
		4.07	999.000	0.0	0.0	***6
		5.07	999.000	0.0	0.0	***6
		6.07	999.000	0.0	0.0	***6
		7.07	999.000	0.0	0.0	***6
		8.07	999.000	0.0	0.0	***6
		9.07	999.000	0.0	0.0	***6
		10.07	999.000	0.0	0.0	***6
		11.07	999.000	0.0	0.0	***6
		13.07	37.060	39202.5	1057.8	
		14.07	77.151	148794.0	1928.6	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
36.00	10.00	15.07	77.142	219312.7	2843.0	
		16.07	72.846	289551.8	3974.8	
		17.00	68.581	358032.9	5220.6	
36.00	9.00	0.17	999.000	0.0	0.0	***6
		1.17	999.000	0.0	0.0	***6
		2.17	999.000	0.0	0.0	***6
		3.17	999.000	0.0	0.0	***6
		4.17	999.000	0.0	0.0	***6
		5.17	999.000	0.0	0.0	***6
		6.17	999.000	0.0	0.0	***6
		7.17	999.000	0.0	0.0	***6
		8.17	999.000	0.0	0.0	***6
		9.17	999.000	0.0	0.0	***6
		10.17	999.000	0.0	0.0	***6
		12.17	44.911	45940.4	1022.9	
		13.17	76.225	142167.2	1865.1	
		14.17	75.632	206237.6	2726.9	
		15.17	71.698	272044.1	3794.3	
		16.00	68.148	329400.0	4833.6	
36.00	8.00	-0.72	999.000	0.0	0.0	***6
		0.28	999.000	0.0	0.0	***6
		1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		11.28	50.132	49048.7	978.4	
		12.28	75.395	134118.7	1778.9	
		13.28	74.181	192820.8	2599.3	
		14.28	70.646	254384.5	3600.8	
		15.00	67.772	301441.4	4447.9	
36.00	7.00	-1.62	999.000	0.0	0.0	***6
		-0.62	999.000	0.0	0.0	***6
		0.38	999.000	0.0	0.0	***6
		1.38	999.000	0.0	0.0	***6
		2.38	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
36.00	7.00	3.38	999.000	0.0	0.0	***6
		4.38	999.000	0.0	0.0	***6
		5.38	999.000	0.0	0.0	***6
		6.38	999.000	0.0	0.0	***6
		7.38	999.000	0.0	0.0	***6
		8.38	999.000	0.0	0.0	***6
		10.38	53.984	49776.1	922.1	
		11.38	75.176	125020.7	1663.0	
		12.38	72.816	179000.8	2458.2	
		13.38	69.718	236491.7	3392.1	
		14.00	67.475	274186.3	4063.6	
36.00	6.00	-2.51	999.000	0.0	0.0	***6
		-1.51	999.000	0.0	0.0	***6
		-0.51	999.000	0.0	0.0	***6
		0.49	999.000	0.0	0.0	***6
		1.49	999.000	0.0	0.0	***6
		2.49	999.000	0.0	0.0	***6
		3.49	999.000	0.0	0.0	***6
		4.49	999.000	0.0	0.0	***6
		5.49	999.000	0.0	0.0	***6
		6.49	999.000	0.0	0.0	***6
		7.49	999.000	0.0	0.0	***6
		9.49	58.495	49917.7	853.4	
		10.49	75.198	115324.8	1533.6	
		11.49	71.561	164855.5	2303.7	
		12.49	68.943	218430.9	3168.3	
		13.00	67.287	247668.0	3680.8	
37.00	15.00	6.06	999.000	0.0	0.0	***6
		7.06	999.000	0.0	0.0	***6
		8.06	999.000	0.0	0.0	***6
		9.06	999.000	0.0	0.0	***6
		10.06	999.000	0.0	0.0	***6
		11.06	999.000	0.0	0.0	***6
		12.06	999.000	0.0	0.0	***6
		13.06	999.000	0.0	0.0	***6
		14.06	999.000	0.0	0.0	***6
		15.06	999.000	0.0	0.0	***6
		16.06	999.000	0.0	0.0	***6
		18.06	29.039	41979.1	1445.6	
		19.06	82.592	212534.8	2573.3	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	15.00	20.06	79.232	310308.2	3916.5	
		21.06	73.092	405557.2	5548.6	
		22.00	68.309	496369.2	7266.6	
37.00	14.00	5.13	999.000	0.0	0.0	***6
		6.13	999.000	0.0	0.0	***6
		7.13	999.000	0.0	0.0	***6
		8.13	999.000	0.0	0.0	***6
		9.13	999.000	0.0	0.0	***6
		10.13	999.000	0.0	0.0	***6
		11.13	999.000	0.0	0.0	***6
		12.13	999.000	0.0	0.0	***6
		13.13	999.000	0.0	0.0	***6
		14.13	999.000	0.0	0.0	***6
		15.13	999.000	0.0	0.0	***6
		17.13	36.395	51287.9	1409.2	
		18.13	81.380	204172.3	2508.9	
		19.13	77.878	295592.8	3795.6	
		20.13	71.991	385680.2	5357.3	
		21.00	67.741	465518.9	6872.0	
37.00	13.00	4.21	999.000	0.0	0.0	***6
		5.21	999.000	0.0	0.0	***6
		6.21	999.000	0.0	0.0	***6
		7.21	999.000	0.0	0.0	***6
		8.21	999.000	0.0	0.0	***6
		9.21	999.000	0.0	0.0	***6
		10.21	999.000	0.0	0.0	***6
		11.21	999.000	0.0	0.0	***6
		12.21	999.000	0.0	0.0	***6
		13.21	999.000	0.0	0.0	***6
		14.21	999.000	0.0	0.0	***6
		16.21	42.297	58184.5	1375.6	
		17.21	80.104	195991.5	2446.7	
		18.21	76.496	281331.6	3677.7	
		19.21	70.877	366438.2	5170.0	
		20.00	67.185	435224.2	6478.0	
37.00	12.00	3.31	999.000	0.0	0.0	***6
		4.31	999.000	0.0	0.0	***6
		5.31	999.000	0.0	0.0	***6
		6.31	999.000	0.0	0.0	***6
		7.31	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	12.00	8.31	999.000	0.0	0.0	***6
		9.31	999.000	0.0	0.0	***6
		10.31	999.000	0.0	0.0	***6
		11.31	999.000	0.0	0.0	***6
		12.31	999.000	0.0	0.0	***6
		13.31	999.000	0.0	0.0	***6
		15.31	47.980	64551.6	1345.4	
		16.31	78.764	188031.4	2387.3	
		17.31	75.087	267578.6	3563.6	
		18.31	69.753	347900.5	4987.6	
		19.00	66.644	405502.6	6084.7	
37.00	11.00	2.41	999.000	0.0	0.0	***6
		3.41	999.000	0.0	0.0	***6
		4.41	999.000	0.0	0.0	***6
		5.41	999.000	0.0	0.0	***6
		6.41	999.000	0.0	0.0	***6
		7.41	999.000	0.0	0.0	***6
		8.41	999.000	0.0	0.0	***6
		9.41	999.000	0.0	0.0	***6
		10.41	999.000	0.0	0.0	***6
		11.41	999.000	0.0	0.0	***6
		12.41	999.000	0.0	0.0	***6
		14.41	61.563	81005.0	1315.8	
		15.41	77.364	180172.1	2328.9	
		16.41	73.667	254232.4	3451.1	
		17.41	68.634	329976.7	4807.7	
		18.00	66.123	376372.9	5692.0	
37.00	10.00	1.51	999.000	0.0	0.0	***6
		2.51	999.000	0.0	0.0	***6
		3.51	999.000	0.0	0.0	***6
		4.51	999.000	0.0	0.0	***6
		5.51	999.000	0.0	0.0	***6
		6.51	999.000	0.0	0.0	***6
		7.51	999.000	0.0	0.0	***6
		8.51	999.000	0.0	0.0	***6
		9.51	999.000	0.0	0.0	***6
		10.51	999.000	0.0	0.0	***6
		11.51	999.000	0.0	0.0	***6
		13.51	68.897	87798.2	1274.3	
		14.51	75.933	171595.0	2259.8	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	10.00	15.51	72.303	240475.4	3325.9	
		16.51	67.584	311820.3	4613.8	
		17.00	65.632	347855.9	5300.1	
37.00	9.00	0.62	999.000	0.0	0.0	***6
		1.62	999.000	0.0	0.0	***6
		2.62	999.000	0.0	0.0	***6
		3.62	999.000	0.0	0.0	***6
		4.62	999.000	0.0	0.0	***6
		5.62	999.000	0.0	0.0	***6
		6.62	999.000	0.0	0.0	***6
		7.62	999.000	0.0	0.0	***6
		8.62	999.000	0.0	0.0	***6
		9.62	999.000	0.0	0.0	***6
		10.62	999.000	0.0	0.0	***6
		12.62	73.798	89984.1	1219.3	
		13.62	75.317	162265.9	2154.4	
		14.62	71.018	226245.4	3185.8	
		15.62	66.621	293352.9	4403.3	
		16.00	65.180	319974.5	4909.1	
37.00	8.00	-0.27	999.000	0.0	0.0	***6
		0.73	999.000	0.0	0.0	***6
		1.73	999.000	0.0	0.0	***6
		2.73	999.000	0.0	0.0	***6
		3.73	999.000	0.0	0.0	***6
		4.73	999.000	0.0	0.0	***6
		5.73	999.000	0.0	0.0	***6
		6.73	999.000	0.0	0.0	***6
		7.73	999.000	0.0	0.0	***6
		8.73	999.000	0.0	0.0	***6
		9.73	999.000	0.0	0.0	***6
		11.73	77.448	89122.6	1150.7	
		12.73	75.123	152264.4	2026.9	
		13.73	69.828	211609.2	3030.4	
		14.73	65.761	274630.8	4176.2	
		15.00	64.783	292754.3	4519.0	
37.00	7.00	-1.17	999.000	0.0	0.0	***6
		-0.17	999.000	0.0	0.0	***6
		0.83	999.000	0.0	0.0	***6
		1.83	999.000	0.0	0.0	***6
		2.83	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	7.00	3.83	999.000	0.0	0.0	***6
		4.83	999.000	0.0	0.0	***6
		5.83	999.000	0.0	0.0	***6
		6.83	999.000	0.0	0.0	***6
		7.83	999.000	0.0	0.0	***6
		8.83	999.000	0.0	0.0	***6
		10.83	80.503	86026.6	1068.6	
		11.83	75.196	141683.8	1884.2	
		12.83	68.755	196634.9	2859.9	
		13.83	65.025	255712.7	3932.6	
		14.00	64.460	266223.6	4130.1	
37.00	6.00	-2.06	999.000	0.0	0.0	***6
		-1.06	999.000	0.0	0.0	***6
		-0.06	999.000	0.0	0.0	***6
		0.94	999.000	0.0	0.0	***6
		1.94	999.000	0.0	0.0	***6
		2.94	999.000	0.0	0.0	***6
		3.94	999.000	0.0	0.0	***6
		4.94	999.000	0.0	0.0	***6
		5.94	999.000	0.0	0.0	***6
		6.94	999.000	0.0	0.0	***6
		7.94	999.000	0.0	0.0	***6
		9.94	83.484	81224.3	972.9	
		10.94	75.667	130621.3	1726.3	
		11.94	68.184	181392.5	2660.3	
		12.94	64.443	236659.5	3672.4	
		13.00	64.242	240414.3	3742.3	
38.00	15.00	6.45	999.000	0.0	0.0	***6
		7.45	999.000	0.0	0.0	***6
		8.45	999.000	0.0	0.0	***6
		9.45	999.000	0.0	0.0	***6
		10.45	999.000	0.0	0.0	***6
		11.45	999.000	0.0	0.0	***6
		12.45	999.000	0.0	0.0	***6
		13.45	999.000	0.0	0.0	***6
		14.45	999.000	0.0	0.0	***6
		15.45	999.000	0.0	0.0	***6
		16.45	999.000	0.0	0.0	***6
		18.45	75.345	125979.9	1672.0	
		19.45	79.880	236648.3	2962.6	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	15.00	20.45	74.275	332638.2	4478.5	
		21.45	68.650	428219.2	6237.8	
		22.00	66.105	481923.9	7290.3	
38.00	14.00	5.54	999.000	0.0	0.0	***6
		6.54	999.000	0.0	0.0	***6
		7.54	999.000	0.0	0.0	***6
		8.54	999.000	0.0	0.0	***6
		9.54	999.000	0.0	0.0	***6
		10.54	999.000	0.0	0.0	***6
		11.54	999.000	0.0	0.0	***6
		12.54	999.000	0.0	0.0	***6
		13.54	999.000	0.0	0.0	***6
		14.54	999.000	0.0	0.0	***6
		15.54	999.000	0.0	0.0	***6
		17.54	80.073	131572.9	1643.2	
		18.54	78.563	228654.2	2910.4	
		19.54	72.941	318773.9	4370.3	
		20.54	67.588	409451.7	6058.1	
		21.00	65.557	451896.7	6893.2	
38.00	13.00	4.65	999.000	0.0	0.0	***6
		5.65	999.000	0.0	0.0	***6
		6.65	999.000	0.0	0.0	***6
		7.65	999.000	0.0	0.0	***6
		8.65	999.000	0.0	0.0	***6
		9.65	999.000	0.0	0.0	***6
		10.65	999.000	0.0	0.0	***6
		11.65	999.000	0.0	0.0	***6
		12.65	999.000	0.0	0.0	***6
		13.65	999.000	0.0	0.0	***6
		14.65	999.000	0.0	0.0	***6
		16.65	81.537	131687.0	1615.1	
		17.65	77.188	220721.6	2859.5	
		18.65	71.597	305245.2	4263.4	
		19.65	66.527	391209.8	5880.5	
		20.00	65.022	422416.0	6496.5	
38.00	12.00	3.75	999.000	0.0	0.0	***6
		4.75	999.000	0.0	0.0	***6
		5.75	999.000	0.0	0.0	***6
		6.75	999.000	0.0	0.0	***6
		7.75	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	12.00	8.75	999.000	0.0	0.0	***6
		9.75	999.000	0.0	0.0	***6
		10.75	999.000	0.0	0.0	***6
		11.75	999.000	0.0	0.0	***6
		12.75	999.000	0.0	0.0	***6
		13.75	999.000	0.0	0.0	***6
		15.75	82.634	130262.2	1576.4	
		16.75	75.796	212019.3	2797.2	
		17.75	70.306	291251.2	4142.6	
		18.75	65.516	372669.5	5688.2	
		19.00	64.506	393498.3	6100.2	
38.00	11.00	2.86	999.000	0.0	0.0	***6
		3.86	999.000	0.0	0.0	***6
		4.86	999.000	0.0	0.0	***6
		5.86	999.000	0.0	0.0	***6
		6.86	999.000	0.0	0.0	***6
		7.86	999.000	0.0	0.0	***6
		8.86	999.000	0.0	0.0	***6
		9.86	999.000	0.0	0.0	***6
		10.86	999.000	0.0	0.0	***6
		11.86	999.000	0.0	0.0	***6
		12.86	999.000	0.0	0.0	***6
		14.86	83.540	127399.8	1525.0	
		15.86	74.516	202519.4	2717.8	
		16.86	69.084	276728.2	4005.7	
		17.86	64.570	353754.3	5478.6	
		18.00	64.013	365162.3	5704.5	
38.00	10.00	1.96	999.000	0.0	0.0	***6
		2.96	999.000	0.0	0.0	***6
		3.96	999.000	0.0	0.0	***6
		4.96	999.000	0.0	0.0	***6
		5.96	999.000	0.0	0.0	***6
		6.96	999.000	0.0	0.0	***6
		7.96	999.000	0.0	0.0	***6
		8.96	999.000	0.0	0.0	***6
		9.96	999.000	0.0	0.0	***6
		10.96	999.000	0.0	0.0	***6
		11.96	999.000	0.0	0.0	***6
		13.96	84.418	123296.0	1460.5	
		14.96	74.105	192309.8	2595.1	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	10.00	15.96	67.938	261734.8	3852.5	
		16.96	63.696	334513.9	5251.8	
		17.00	63.552	337428.0	5309.4	
38.00	9.00	1.07	999.000	0.0	0.0	***6
		2.07	999.000	0.0	0.0	***6
		3.07	999.000	0.0	0.0	***6
		4.07	999.000	0.0	0.0	***6
		5.07	999.000	0.0	0.0	***6
		6.07	999.000	0.0	0.0	***6
		7.07	999.000	0.0	0.0	***6
		8.07	999.000	0.0	0.0	***6
		9.07	999.000	0.0	0.0	***6
		10.07	999.000	0.0	0.0	***6
		11.07	999.000	0.0	0.0	***6
		12.07	21.359	11007.1	515.3	
		13.07	85.433	118113.0	1382.5	
		14.07	73.882	181471.6	2456.2	
		15.07	66.883	246330.7	3683.0	
		16.00	63.137	310317.2	4915.0	
38.00	8.00	0.17	999.000	0.0	0.0	***6
		1.17	999.000	0.0	0.0	***6
		2.17	999.000	0.0	0.0	***6
		3.17	999.000	0.0	0.0	***6
		4.17	999.000	0.0	0.0	***6
		5.17	999.000	0.0	0.0	***6
		6.17	999.000	0.0	0.0	***6
		7.17	999.000	0.0	0.0	***6
		8.17	999.000	0.0	0.0	***6
		9.17	999.000	0.0	0.0	***6
		10.17	999.000	0.0	0.0	***6
		11.17	40.866	19479.2	476.7	
		12.17	86.775	111991.4	1290.6	
		13.17	73.922	170083.3	2300.9	
		14.17	65.934	230576.0	3497.1	
		15.00	62.781	283854.8	4521.3	
38.00	7.00	-0.72	999.000	0.0	0.0	***6
		0.28	999.000	0.0	0.0	***6
		1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	7.00	4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	56.752	24235.3	427.0	
		11.28	88.701	105057.0	1184.4	
		12.28	74.326	158222.8	2128.8	
		13.28	65.500	214533.0	3275.3	
		14.00	62.510	258068.1	4128.5	
38.00	6.00	-1.62	999.000	0.0	0.0	***6
		-0.62	999.000	0.0	0.0	***6
		0.38	999.000	0.0	0.0	***6
		1.38	999.000	0.0	0.0	***6
		2.38	999.000	0.0	0.0	***6
		3.38	999.000	0.0	0.0	***6
		4.38	999.000	0.0	0.0	***6
		5.38	999.000	0.0	0.0	***6
		6.38	999.000	0.0	0.0	***6
		7.38	999.000	0.0	0.0	***6
		8.38	999.000	0.0	0.0	***6
		9.38	103.173	39480.7	382.7	
		10.38	91.600	97426.1	1063.6	
		11.38	75.249	145968.1	1939.8	
		12.38	65.945	198266.2	3006.6	
		13.00	62.354	232987.8	3736.5	
39.00	15.00	6.88	999.000	0.0	0.0	***6
		7.88	999.000	0.0	0.0	***6
		8.88	999.000	0.0	0.0	***6
		9.88	999.000	0.0	0.0	***6
		10.88	999.000	0.0	0.0	***6
		11.88	999.000	0.0	0.0	***6
		12.88	999.000	0.0	0.0	***6
		13.88	999.000	0.0	0.0	***6
		14.88	999.000	0.0	0.0	***6
		15.88	999.000	0.0	0.0	***6
		16.88	999.000	0.0	0.0	***6
		18.88	84.423	164218.4	1945.2	
		19.88	76.435	263860.8	3452.1	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
39.00	15.00	20.88	70.046	359118.5	5126.9	
		21.88	65.049	455545.9	7003.1	
		22.00	64.538	467103.2	7237.6	
39.00	14.00	5.99	999.000	0.0	0.0	***6
		6.99	999.000	0.0	0.0	***6
		7.99	999.000	0.0	0.0	***6
		8.99	999.000	0.0	0.0	***6
		9.99	999.000	0.0	0.0	***6
		10.99	999.000	0.0	0.0	***6
		11.99	999.000	0.0	0.0	***6
		12.99	999.000	0.0	0.0	***6
		13.99	999.000	0.0	0.0	***6
		14.99	999.000	0.0	0.0	***6
		15.99	999.000	0.0	0.0	***6
		17.99	84.882	162562.5	1915.2	
		18.99	75.063	255095.7	3398.4	
		19.99	68.859	344971.4	5009.8	
		20.99	64.093	436713.0	6813.8	
		21.00	64.039	437918.0	6838.4	
39.00	13.00	5.09	999.000	0.0	0.0	***6
		6.09	999.000	0.0	0.0	***6
		7.09	999.000	0.0	0.0	***6
		8.09	999.000	0.0	0.0	***6
		9.09	999.000	0.0	0.0	***6
		10.09	999.000	0.0	0.0	***6
		11.09	999.000	0.0	0.0	***6
		12.09	999.000	0.0	0.0	***6
		13.09	999.000	0.0	0.0	***6
		14.09	999.000	0.0	0.0	***6
		15.09	999.000	0.0	0.0	***6
		16.09	6.128	4249.2	693.4	
		17.09	85.247	159578.7	1872.0	
		18.09	73.718	245516.3	3330.5	
		19.09	67.727	330248.6	4876.1	
		20.00	63.557	409270.3	6439.4	
39.00	12.00	4.20	999.000	0.0	0.0	***6
		5.20	999.000	0.0	0.0	***6
		6.20	999.000	0.0	0.0	***6
		7.20	999.000	0.0	0.0	***6
		8.20	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
39.00	12.00	9.20	999.000	0.0	0.0	***6
		10.20	999.000	0.0	0.0	***6
		11.20	999.000	0.0	0.0	***6
		12.20	999.000	0.0	0.0	***6
		13.20	999.000	0.0	0.0	***6
		14.20	999.000	0.0	0.0	***6
		15.20	26.160	17769.2	679.3	
		16.20	85.622	155410.5	1815.1	
		17.20	72.784	235195.1	3231.4	
		18.20	66.657	315002.2	4725.7	
		19.00	63.100	381176.4	6040.9	
39.00	11.00	3.30	999.000	0.0	0.0	***6
		4.30	999.000	0.0	0.0	***6
		5.30	999.000	0.0	0.0	***6
		6.30	999.000	0.0	0.0	***6
		7.30	999.000	0.0	0.0	***6
		8.30	999.000	0.0	0.0	***6
		9.30	999.000	0.0	0.0	***6
		10.30	999.000	0.0	0.0	***6
		11.30	999.000	0.0	0.0	***6
		12.30	999.000	0.0	0.0	***6
		13.30	999.000	0.0	0.0	***6
		14.30	999.000	22303.1	0.0	***1
		15.30	86.111	150183.9	1744.1	
		16.30	72.352	224202.0	3098.8	
		17.30	65.655	299285.4	4558.5	
		18.00	62.675	353654.0	5642.7	
39.00	10.00	2.41	999.000	0.0	0.0	***6
		3.41	999.000	0.0	0.0	***6
		4.41	999.000	0.0	0.0	***6
		5.41	999.000	0.0	0.0	***6
		6.41	999.000	0.0	0.0	***6
		7.41	999.000	0.0	0.0	***6
		8.41	999.000	0.0	0.0	***6
		9.41	999.000	0.0	0.0	***6
		10.41	999.000	0.0	0.0	***6
		11.41	999.000	0.0	0.0	***6
		12.41	999.000	0.0	0.0	***6
		13.41	114.734	71176.9	620.4	
		14.41	86.833	144011.4	1658.5	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
39.00	10.00	15.41	72.108	212606.0	2948.4	
		16.41	64.732	283151.6	4374.2	
		17.00	62.292	326722.4	5245.0	
39.00	9.00	1.51	999.000	0.0	0.0	***6
		2.51	999.000	0.0	0.0	***6
		3.51	999.000	0.0	0.0	***6
		4.51	999.000	0.0	0.0	***6
		5.51	999.000	0.0	0.0	***6
		6.51	999.000	0.0	0.0	***6
		7.51	999.000	0.0	0.0	***6
		8.51	999.000	0.0	0.0	***6
		9.51	999.000	0.0	0.0	***6
		10.51	999.000	0.0	0.0	***6
		11.51	999.000	0.0	0.0	***6
		12.51	125.095	71643.1	572.7	
		13.51	87.937	136995.5	1557.9	
		14.51	72.110	200473.7	2780.1	
		15.51	63.903	266655.0	4172.8	
		16.00	61.968	300402.9	4847.7	
39.00	8.00	0.62	999.000	0.0	0.0	***6
		1.62	999.000	0.0	0.0	***6
		2.62	999.000	0.0	0.0	***6
		3.62	999.000	0.0	0.0	***6
		4.62	999.000	0.0	0.0	***6
		5.62	999.000	0.0	0.0	***6
		6.62	999.000	0.0	0.0	***6
		7.62	999.000	0.0	0.0	***6
		8.62	999.000	0.0	0.0	***6
		9.62	999.000	0.0	0.0	***6
		10.62	999.000	0.0	0.0	***6
		11.62	136.898	70495.9	515.0	
		12.62	89.630	129233.2	1441.9	
		13.62	72.433	187872.3	2593.7	
		14.62	63.617	249851.8	3927.4	
		15.00	61.720	274719.4	4451.1	
39.00	7.00	-0.28	999.000	0.0	0.0	***6
		0.72	999.000	0.0	0.0	***6
		1.72	999.000	0.0	0.0	***6
		2.72	999.000	0.0	0.0	***6
		3.72	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
39.00	7.00	4.72	999.000	0.0	0.0	***6
		5.72	999.000	0.0	0.0	***6
		6.72	999.000	0.0	0.0	***6
		7.72	999.000	0.0	0.0	***6
		8.72	999.000	0.0	0.0	***6
		9.72	999.000	0.0	0.0	***6
		10.72	145.684	68026.9	466.9	
		11.72	92.216	120806.0	1310.0	
		12.72	73.193	174869.5	2389.1	
		13.72	63.959	232799.5	3639.8	
		14.00	62.194	249697.9	4014.8	
39.00	6.00	-1.17	999.000	0.0	0.0	***6
		-0.17	999.000	0.0	0.0	***6
		0.83	999.000	0.0	0.0	***6
		1.83	999.000	0.0	0.0	***6
		2.83	999.000	0.0	0.0	***6
		3.83	999.000	0.0	0.0	***6
		4.83	999.000	0.0	0.0	***6
		5.83	999.000	0.0	0.0	***6
		6.83	999.000	0.0	0.0	***6
		7.83	999.000	0.0	0.0	***6
		8.83	999.000	0.0	0.0	***6
		9.83	158.006	64512.2	408.3	
		10.83	96.173	111861.5	1163.1	
		11.83	74.553	161594.0	2167.5	
		12.83	64.667	215623.4	3334.3	
		13.00	63.493	225368.4	3549.5	
40.00	15.00	7.33	999.000	0.0	0.0	***6
		8.33	999.000	0.0	0.0	***6
		9.33	999.000	0.0	0.0	***6
		10.33	999.000	0.0	0.0	***6
		11.33	999.000	0.0	0.0	***6
		12.33	999.000	0.0	0.0	***6
		13.33	999.000	0.0	0.0	***6
		14.33	999.000	0.0	0.0	***6
		15.33	999.000	0.0	0.0	***6
		16.33	999.000	0.0	0.0	***6
		17.33	999.000	0.0	0.0	***6
		18.33	999.000	39963.9	0.1	***1
		19.33	85.861	194108.3	2260.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
40.00	15.00	20.33	72.944	291088.2	3990.6	
		21.33	66.831	386629.2	5785.1	
		22.00	63.597	451868.0	7105.2	
40.00	14.00	6.43	999.000	0.0	0.0	***6
		7.43	999.000	0.0	0.0	***6
		8.43	999.000	0.0	0.0	***6
		9.43	999.000	0.0	0.0	***6
		10.43	999.000	0.0	0.0	***6
		11.43	999.000	0.0	0.0	***6
		12.43	999.000	0.0	0.0	***6
		13.43	999.000	0.0	0.0	***6
		14.43	999.000	0.0	0.0	***6
		15.43	999.000	0.0	0.0	***6
		16.43	999.000	0.0	0.0	***6
		17.43	108.645	89533.6	824.1	
		18.43	85.852	189967.5	2212.7	
		19.43	71.750	280736.1	3912.7	
		20.43	65.834	371212.5	5638.6	
		21.00	63.175	423544.8	6704.3	
40.00	13.00	5.54	999.000	0.0	0.0	***6
		6.54	999.000	0.0	0.0	***6
		7.54	999.000	0.0	0.0	***6
		8.54	999.000	0.0	0.0	***6
		9.54	999.000	0.0	0.0	***6
		10.54	999.000	0.0	0.0	***6
		11.54	999.000	0.0	0.0	***6
		12.54	999.000	0.0	0.0	***6
		13.54	999.000	0.0	0.0	***6
		14.54	999.000	0.0	0.0	***6
		15.54	999.000	0.0	0.0	***6
		16.54	115.598	93328.4	807.4	
		17.54	85.939	184778.5	2150.1	
		18.54	71.201	269676.1	3787.5	
		19.54	64.893	355275.9	5474.8	
		20.00	62.782	395750.8	6303.6	
40.00	12.00	4.64	999.000	0.0	0.0	***6
		5.64	999.000	0.0	0.0	***6
		6.64	999.000	0.0	0.0	***6
		7.64	999.000	0.0	0.0	***6
		8.64	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
40.00	12.00	9.64	999.000	0.0	0.0	***6
		10.64	999.000	0.0	0.0	***6
		11.64	999.000	0.0	0.0	***6
		12.64	999.000	0.0	0.0	***6
		13.64	999.000	0.0	0.0	***6
		14.64	999.000	0.0	0.0	***6
		15.64	122.150	95142.1	778.9	
		16.64	86.197	178633.7	2072.4	
		17.64	70.857	257967.8	3640.7	
		18.64	64.016	338867.0	5293.5	
		19.00	62.424	368501.6	5903.2	
40.00	11.00	3.75	999.000	0.0	0.0	***6
		4.75	999.000	0.0	0.0	***6
		5.75	999.000	0.0	0.0	***6
		6.75	999.000	0.0	0.0	***6
		7.75	999.000	0.0	0.0	***6
		8.75	999.000	0.0	0.0	***6
		9.75	999.000	0.0	0.0	***6
		10.75	999.000	0.0	0.0	***6
		11.75	999.000	0.0	0.0	***6
		12.75	999.000	0.0	0.0	***6
		13.75	999.000	0.0	0.0	***6
		14.75	129.098	95298.5	738.2	
		15.75	86.706	171599.0	1979.1	
		16.75	70.687	245670.9	3475.5	
		17.75	63.211	322034.9	5094.6	
		18.00	62.114	341814.2	5503.0	
40.00	10.00	2.85	999.000	0.0	0.0	***6
		3.85	999.000	0.0	0.0	***6
		4.85	999.000	0.0	0.0	***6
		5.85	999.000	0.0	0.0	***6
		6.85	999.000	0.0	0.0	***6
		7.85	999.000	0.0	0.0	***6
		8.85	999.000	0.0	0.0	***6
		9.85	999.000	0.0	0.0	***6
		10.85	999.000	0.0	0.0	***6
		11.85	999.000	0.0	0.0	***6
		12.85	999.000	0.0	0.0	***6
		13.85	137.346	94036.6	684.7	
		14.85	87.589	163768.4	1869.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
40.00	10.00	15.85	70.735	232844.0	3291.8	
		16.85	62.490	304828.9	4878.0	
		17.00	61.865	315707.3	5103.2	
40.00	9.00	1.96	999.000	0.0	0.0	***6
		2.96	999.000	0.0	0.0	***6
		3.96	999.000	0.0	0.0	***6
		4.96	999.000	0.0	0.0	***6
		5.96	999.000	0.0	0.0	***6
		6.96	999.000	0.0	0.0	***6
		7.96	999.000	0.0	0.0	***6
		8.96	999.000	0.0	0.0	***6
		9.96	999.000	0.0	0.0	***6
		10.96	999.000	0.0	0.0	***6
		11.96	999.000	0.0	0.0	***6
		12.96	145.348	91546.3	629.8	
		13.96	89.013	155229.5	1743.9	
		14.96	71.064	219547.1	3089.4	
		15.96	62.358	287299.7	4607.3	
		16.00	62.088	290201.5	4674.0	
40.00	8.00	1.06	999.000	0.0	0.0	***6
		2.06	999.000	0.0	0.0	***6
		3.06	999.000	0.0	0.0	***6
		4.06	999.000	0.0	0.0	***6
		5.06	999.000	0.0	0.0	***6
		6.06	999.000	0.0	0.0	***6
		7.06	999.000	0.0	0.0	***6
		8.06	999.000	0.0	0.0	***6
		9.06	999.000	0.0	0.0	***6
		10.06	999.000	0.0	0.0	***6
		11.06	999.000	0.0	0.0	***6
		12.06	152.591	88052.0	577.0	
		13.06	91.190	146129.7	1602.5	
		14.06	71.751	205910.2	2869.8	
		15.00	63.097	265319.5	4205.0	
40.00	7.00	0.17	999.000	0.0	0.0	***6
		1.17	999.000	0.0	0.0	***6
		2.17	999.000	0.0	0.0	***6
		3.17	999.000	0.0	0.0	***6
		4.17	999.000	0.0	0.0	***6
		5.17	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
40.00	7.00	6.17	999.000	0.0	0.0	***6
		7.17	999.000	0.0	0.0	***6
		8.17	999.000	0.0	0.0	***6
		9.17	999.000	0.0	0.0	***6
		10.17	999.000	0.0	0.0	***6
		12.17	94.532	136475.8	1443.7	
		13.17	72.942	191920.9	2631.1	
		14.00	64.525	241086.7	3736.4	
40.00	6.00	-0.72	999.000	0.0	0.0	***6
		0.28	999.000	0.0	0.0	***6
		1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		11.28	99.725	126341.6	1266.9	
		12.28	74.851	177638.0	2373.2	
		13.00	66.559	217531.8	3268.2	
41.00	15.00	7.77	999.000	0.0	0.0	***6
		8.77	999.000	0.0	0.0	***6
		9.77	999.000	0.0	0.0	***6
		10.77	999.000	0.0	0.0	***6
		11.77	999.000	0.0	0.0	***6
		12.77	999.000	0.0	0.0	***6
		13.77	999.000	0.0	0.0	***6
		14.77	999.000	0.0	0.0	***6
		15.77	999.000	0.0	0.0	***6
		16.77	999.000	0.0	0.0	***6
		17.77	999.000	0.0	0.0	***6
		18.77	121.317	119270.5	983.1	
		19.77	85.349	221683.2	2597.4	
		20.77	70.539	317746.0	4504.6	
		21.77	64.412	414113.6	6429.1	
		22.00	63.306	436171.4	6889.9	
41.00	14.00	6.88	999.000	0.0	0.0	***6
		7.88	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
41.00	14.00	8.88	999.000	0.0	0.0	***6
		9.88	999.000	0.0	0.0	***6
		10.88	999.000	0.0	0.0	***6
		11.88	999.000	0.0	0.0	***6
		12.88	999.000	0.0	0.0	***6
		13.88	999.000	0.0	0.0	***6
		14.88	999.000	0.0	0.0	***6
		15.88	999.000	0.0	0.0	***6
		16.88	999.000	0.0	0.0	***6
		17.88	125.538	120858.4	962.7	
		18.88	85.267	215582.0	2528.3	
		19.88	70.151	305998.2	4362.0	
		20.88	63.583	397514.9	6251.9	
		21.00	63.001	408731.8	6487.7	
41.00	13.00	5.98	999.000	0.0	0.0	***6
		6.98	999.000	0.0	0.0	***6
		7.98	999.000	0.0	0.0	***6
		8.98	999.000	0.0	0.0	***6
		9.98	999.000	0.0	0.0	***6
		10.98	999.000	0.0	0.0	***6
		11.98	999.000	0.0	0.0	***6
		12.98	999.000	0.0	0.0	***6
		13.98	999.000	0.0	0.0	***6
		14.98	999.000	0.0	0.0	***6
		15.98	999.000	0.0	0.0	***6
		16.98	130.096	120959.5	929.8	
		17.98	85.414	208591.7	2442.1	
		18.98	69.896	293618.0	4200.8	
		19.98	62.814	380441.7	6056.7	
		20.00	62.740	381813.5	6085.7	
41.00	12.00	5.09	999.000	0.0	0.0	***6
		6.09	999.000	0.0	0.0	***6
		7.09	999.000	0.0	0.0	***6
		8.09	999.000	0.0	0.0	***6
		9.09	999.000	0.0	0.0	***6
		10.09	999.000	0.0	0.0	***6
		11.09	999.000	0.0	0.0	***6
		12.09	999.000	0.0	0.0	***6
		13.09	999.000	0.0	0.0	***6
		14.09	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
41.00	12.00	15.09	999.000	0.0	0.0	***6
		16.09	135.497	119739.8	883.7	
		17.09	85.859	200786.9	2338.6	
		18.09	69.802	280658.9	4020.8	
		19.00	62.534	355431.5	5683.8	
41.00	11.00	4.19	999.000	0.0	0.0	***6
		5.19	999.000	0.0	0.0	***6
		6.19	999.000	0.0	0.0	***6
		7.19	999.000	0.0	0.0	***6
		8.19	999.000	0.0	0.0	***6
		9.19	999.000	0.0	0.0	***6
		10.19	999.000	0.0	0.0	***6
		11.19	999.000	0.0	0.0	***6
		12.19	999.000	0.0	0.0	***6
		13.19	999.000	0.0	0.0	***6
		14.19	999.000	0.0	0.0	***6
		15.19	142.407	117339.4	824.0	
		16.19	86.696	192238.4	2217.4	
		17.19	69.909	267173.5	3821.7	
		18.00	62.746	329602.3	5253.0	
41.00	10.00	3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	999.000	0.0	0.0	***6
		11.28	999.000	0.0	0.0	***6
		12.28	999.000	0.0	0.0	***6
		13.28	999.000	0.0	0.0	***6
		14.28	149.228	112597.1	754.5	
		15.28	88.566	181753.1	2052.2	
		16.28	70.484	251905.3	3573.9	
		17.00	63.650	304343.9	4781.5	
41.00	9.00	2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
41.00	9.00	7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	999.000	0.0	0.0	***6
		11.28	999.000	0.0	0.0	***6
		12.28	999.000	0.0	0.0	***6
		13.28	171.587	101563.0	591.9	
		14.28	94.158	165291.5	1755.5	
		15.28	72.544	230563.7	3178.2	
		16.00	64.885	279675.8	4310.3	
41.00	8.00	1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	999.000	0.0	0.0	***6
		11.28	999.000	0.0	0.0	***6
		13.28	102.343	149298.7	1458.8	
		14.28	75.387	209781.5	2782.7	
		15.00	66.578	255620.3	3839.4	
41.00	7.00	0.28	999.000	0.0	0.0	***6
		1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	999.000	0.0	0.0	***6
		12.28	111.577	133795.2	1199.1	
		13.28	79.410	189581.4	2387.4	
		14.00	68.928	232201.8	3368.8	
41.00	6.00	-0.72	999.000	0.0	0.0	***6
		0.28	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
41.00	6.00	1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		12.28	85.326	169989.5	1992.2	
		13.00	72.261	209448.1	2898.5	
42.00	15.00	8.22	999.000	0.0	0.0	***6
		9.22	999.000	0.0	0.0	***6
		10.22	999.000	0.0	0.0	***6
		11.22	999.000	0.0	0.0	***6
		12.22	999.000	0.0	0.0	***6
		13.22	999.000	0.0	0.0	***6
		14.22	999.000	0.0	0.0	***6
		15.22	999.000	0.0	0.0	***6
		16.22	999.000	0.0	0.0	***6
		17.22	999.000	0.0	0.0	***6
		18.22	999.000	0.0	0.0	***6
		19.22	129.672	148546.5	1145.6	
		20.22	84.655	247872.5	2928.0	
		21.22	69.467	344144.3	4954.0	
		22.00	63.739	419956.5	6588.7	
42.00	14.00	7.32	999.000	0.0	0.0	***6
		8.32	999.000	0.0	0.0	***6
		9.32	999.000	0.0	0.0	***6
		10.32	999.000	0.0	0.0	***6
		11.32	999.000	0.0	0.0	***6
		12.32	999.000	0.0	0.0	***6
		13.32	999.000	0.0	0.0	***6
		14.32	999.000	0.0	0.0	***6
		15.32	999.000	0.0	0.0	***6
		16.32	999.000	0.0	0.0	***6
		17.32	999.000	0.0	0.0	***6
		18.32	133.614	147018.6	1100.3	
		19.32	85.007	239737.8	2820.2	
		20.32	69.346	330699.5	4768.8	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
42.00	14.00	21.00	63.603	393423.6	6185.6	
42.00	13.00	6.32	999.000	0.0	0.0	***6
		7.32	999.000	0.0	0.0	***6
		8.32	999.000	0.0	0.0	***6
		9.32	999.000	0.0	0.0	***6
		10.32	999.000	0.0	0.0	***6
		11.32	999.000	0.0	0.0	***6
		12.32	999.000	0.0	0.0	***6
		13.32	999.000	0.0	0.0	***6
		14.32	999.000	0.0	0.0	***6
		15.32	999.000	0.0	0.0	***6
		16.32	999.000	0.0	0.0	***6
		17.32	151.547	135668.3	895.2	
		18.32	88.178	222521.7	2523.6	
		19.32	70.493	308247.6	4372.7	
		20.00	63.965	367404.6	5743.9	
42.00	12.00	5.33	999.000	0.0	0.0	***6
		6.33	999.000	0.0	0.0	***6
		7.33	999.000	0.0	0.0	***6
		8.33	999.000	0.0	0.0	***6
		9.33	999.000	0.0	0.0	***6
		10.33	999.000	0.0	0.0	***6
		11.33	999.000	0.0	0.0	***6
		12.33	999.000	0.0	0.0	***6
		13.33	999.000	0.0	0.0	***6
		14.33	999.000	0.0	0.0	***6
		15.33	999.000	0.0	0.0	***6
		16.33	170.086	124626.2	732.7	
		17.33	92.372	205711.6	2227.0	
		18.33	71.989	286280.7	3976.8	
		19.00	64.867	341914.1	5271.0	
42.00	11.00	4.33	999.000	0.0	0.0	***6
		5.33	999.000	0.0	0.0	***6
		6.33	999.000	0.0	0.0	***6
		7.33	999.000	0.0	0.0	***6
		8.33	999.000	0.0	0.0	***6
		9.33	999.000	0.0	0.0	***6
		10.33	999.000	0.0	0.0	***6
		11.33	999.000	0.0	0.0	***6
		12.33	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
42.00	11.00	13.33	999.000	0.0	0.0	***6
		14.33	999.000	0.0	0.0	***6
		16.33	98.069	189320.3	1930.5	
		17.33	73.951	264815.5	3581.0	
		18.00	66.060	316968.2	4798.2	
42.00	10.00	3.33	999.000	0.0	0.0	***6
		4.33	999.000	0.0	0.0	***6
		5.33	999.000	0.0	0.0	***6
		6.33	999.000	0.0	0.0	***6
		7.33	999.000	0.0	0.0	***6
		8.33	999.000	0.0	0.0	***6
		9.33	999.000	0.0	0.0	***6
		10.33	999.000	0.0	0.0	***6
		11.33	999.000	0.0	0.0	***6
		12.33	999.000	0.0	0.0	***6
		13.33	999.000	0.0	0.0	***6
		15.33	106.091	173361.6	1634.1	
		16.33	76.559	243868.8	3185.4	
		17.00	67.641	292583.9	4325.5	
42.00	9.00	2.34	999.000	0.0	0.0	***6
		3.34	999.000	0.0	0.0	***6
		4.34	999.000	0.0	0.0	***6
		5.34	999.000	0.0	0.0	***6
		6.34	999.000	0.0	0.0	***6
		7.34	999.000	0.0	0.0	***6
		8.34	999.000	0.0	0.0	***6
		9.34	999.000	0.0	0.0	***6
		10.34	999.000	0.0	0.0	***6
		11.34	999.000	0.0	0.0	***6
		12.34	999.000	0.0	0.0	***6
		14.34	115.165	157852.3	1370.7	
		15.34	80.092	223460.1	2790.0	
		16.00	69.758	268780.3	3853.1	
42.00	8.00	1.34	999.000	0.0	0.0	***6
		2.34	999.000	0.0	0.0	***6
		3.34	999.000	0.0	0.0	***6
		4.34	999.000	0.0	0.0	***6
		5.34	999.000	0.0	0.0	***6
		6.34	999.000	0.0	0.0	***6
		7.34	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
42.00	8.00	8.34	999.000	0.0	0.0	***6
		9.34	999.000	0.0	0.0	***6
		10.34	999.000	0.0	0.0	***6
		11.34	999.000	0.0	0.0	***6
		14.34	85.016	203611.6	2395.0	
		15.00	72.641	245579.6	3380.7	
42.00	7.00	0.35	999.000	0.0	0.0	***6
		1.35	999.000	0.0	0.0	***6
		2.35	999.000	0.0	0.0	***6
		3.35	999.000	0.0	0.0	***6
		4.35	999.000	0.0	0.0	***6
		5.35	999.000	0.0	0.0	***6
		6.35	999.000	0.0	0.0	***6
		7.35	999.000	0.0	0.0	***6
		8.35	999.000	0.0	0.0	***6
		9.35	999.000	0.0	0.0	***6
		10.35	999.000	0.0	0.0	***6
		13.35	91.715	184347.9	2010.0	
		14.00	76.670	223005.1	2908.6	
42.00	6.00	-0.64	999.000	0.0	0.0	***6
		0.36	999.000	0.0	0.0	***6
		1.36	999.000	0.0	0.0	***6
		2.36	999.000	0.0	0.0	***6
		3.36	999.000	0.0	0.0	***6
		4.36	999.000	0.0	0.0	***6
		5.36	999.000	0.0	0.0	***6
		6.36	999.000	0.0	0.0	***6
		7.36	999.000	0.0	0.0	***6
		8.36	999.000	0.0	0.0	***6
		9.36	999.000	0.0	0.0	***6
		12.36	98.726	165699.1	1678.4	
		13.00	82.522	201083.3	2436.7	

Table of B.A.

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

Center X(m),Y(m)

Y(m)	X(m)	33.00	34.00	35.00	36.00	37.00	38.00
15.00	Fs	85.040	79.427	67.287	71.198	29.039	66.105
	R(m)	22.00	22.00	18.46	22.00	18.06	22.00
14.00	Fs	84.692	78.995	66.684	70.640	36.395	65.557
	R(m)	21.00	21.00	17.49	21.00	17.13	21.00
13.00	Fs	84.359	68.044	66.374	70.094	42.297	65.022
	R(m)	20.00	16.29	16.53	20.00	16.21	20.00
12.00	Fs	84.044	67.390	66.587	69.564	47.980	64.506
	R(m)	19.00	15.31	15.57	19.00	15.31	19.00
11.00	Fs	83.751	66.699	66.688	69.057	61.563	64.013
	R(m)	18.00	14.34	14.62	18.00	14.41	18.00
10.00	Fs	83.484	65.968	66.677	37.060	65.632	63.552
	R(m)	17.00	13.37	13.68	13.07	17.00	17.00
9.00	Fs	82.437	65.198	66.560	44.911	65.180	21.359
	R(m)	13.17	12.41	12.75	12.17	16.00	12.07
8.00	Fs	80.928	64.392	66.345	50.132	64.783	40.866
	R(m)	12.19	11.46	11.84	11.28	15.00	11.17
7.00	Fs	79.392	63.557	66.162	53.984	64.460	56.752
	R(m)	11.22	10.52	10.94	10.38	14.00	10.28
6.00	Fs	77.845	62.717	66.747	58.495	64.242	62.354
	R(m)	10.25	9.60	10.04	9.49	13.00	13.00

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

Center X(m),Y(m)

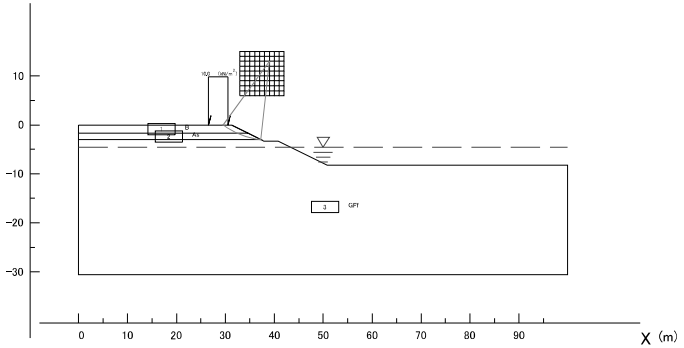
Y(m)	X(m)	39.00	40.00	41.00	42.00
15.00	Fs	64.538	63.597	63.306	63.739
	R(m)	22.00	22.00	22.00	22.00
14.00	Fs	64.039	63.175	63.001	63.603
	R(m)	21.00	21.00	21.00	21.00
13.00	Fs	6.128	62.782	62.740	63.965
	R(m)	16.09	20.00	20.00	20.00
12.00	Fs	26.160	62.424	62.534	64.867
	R(m)	15.20	19.00	19.00	19.00
11.00	Fs	62.675	62.114	62.746	66.060
	R(m)	18.00	18.00	18.00	18.00
10.00	Fs	62.292	61.865	63.650	67.641
	R(m)	17.00	17.00	17.00	17.00
9.00	Fs	61.968	62.088	64.885	69.758
	R(m)	16.00	16.00	16.00	16.00
8.00	Fs	61.720	63.097	66.578	72.641
	R(m)	15.00	15.00	15.00	15.00
7.00	Fs	62.194	64.525	68.928	76.670
	R(m)	14.00	14.00	14.00	14.00
6.00	Fs	63.493	66.559	72.261	82.522
	R(m)	13.00	13.00	13.00	13.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	6.128
Failure circle X(m)	=	39.00
Y(m)	=	13.00
R(m)	=	16.092
Resisting moment(kNm)	=	4249.2
Sliding moment(kNm)	=	693.4
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



WARNING ***1 Points of intersection of an arc and the ground are more than three points. count = 2

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

4. Action02 (seismic)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	5	19.00	18.00	9.00	1.00	0.00	30.00	0.00	0.00	0.0
2	6	18.50	17.50	8.50	0.00	0.00	27.00	0.00	0.00	0.0
3	8	18.00	17.00	8.00	1000.0	0 0.0	030.0	0 0.0	0 0.0	0 0.
0										

// Distribution load that considers partial coefficient //

load No.	Left			Right			Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)			
2	26.55	0.00	5.0	30.55	0.00	5.0	0.000	0.200	0.000

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

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	-4.63	
2	100.00	-4.63	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	15.00	5.10	999.000	0.0	0.0	***6
		6.10	999.000	0.0	0.0	***6
		7.10	999.000	0.0	0.0	***6
		8.10	999.000	0.0	0.0	***6
		9.10	999.000	0.0	0.0	***6
		10.10	999.000	0.0	0.0	***6
		11.10	999.000	0.0	0.0	***6
		12.10	999.000	0.0	0.0	***6
		13.10	999.000	0.0	0.0	***6
		14.10	999.000	0.0	0.0	***6
		15.10	999.000	0.0	0.0	***6
		19.10	46.900	240875.8	5136.0	
		20.10	46.921	365978.3	7799.9	
		21.10	41.729	462133.4	11074.7	
		22.00	37.743	550271.5	14579.3	
33.00	14.00	4.11	999.000	0.0	0.0	***6
		5.11	999.000	0.0	0.0	***6
		6.11	999.000	0.0	0.0	***6
		7.11	999.000	0.0	0.0	***6
		8.11	999.000	0.0	0.0	***6
		9.11	999.000	0.0	0.0	***6
		10.11	999.000	0.0	0.0	***6
		11.11	999.000	0.0	0.0	***6
		12.11	999.000	0.0	0.0	***6
		13.11	999.000	0.0	0.0	***6
		14.11	999.000	0.0	0.0	***6
		18.11	46.496	223223.3	4800.9	
		19.11	46.863	342118.0	7300.4	
		20.11	41.753	433156.7	10374.3	
		21.00	37.841	516334.9	13644.7	
33.00	13.00	3.12	999.000	0.0	0.0	***6
		4.12	999.000	0.0	0.0	***6
		5.12	999.000	0.0	0.0	***6
		6.12	999.000	0.0	0.0	***6
		7.12	999.000	0.0	0.0	***6
		8.12	999.000	0.0	0.0	***6
		9.12	999.000	0.0	0.0	***6
		10.12	999.000	0.0	0.0	***6
		11.12	999.000	0.0	0.0	***6
		12.12	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	13.00	13.12	999.000	0.0	0.0	***6
		17.12	46.086	206067.5	4471.4	
		18.12	46.802	318726.2	6810.0	
		19.12	41.786	404738.6	9686.0	
		20.00	37.957	482991.2	12724.7	
33.00	12.00	2.13	999.000	0.0	0.0	***6
		3.13	999.000	0.0	0.0	***6
		4.13	999.000	0.0	0.0	***6
		5.13	999.000	0.0	0.0	***6
		6.13	999.000	0.0	0.0	***6
		7.13	999.000	0.0	0.0	***6
		8.13	999.000	0.0	0.0	***6
		9.13	999.000	0.0	0.0	***6
		10.13	999.000	0.0	0.0	***6
		11.13	999.000	0.0	0.0	***6
		12.13	999.000	0.0	0.0	***6
		16.13	45.670	189428.0	4147.8	
		17.13	46.626	295105.8	6329.2	
		18.13	41.829	376906.5	9010.7	
		19.00	38.093	450260.4	11820.0	
33.00	11.00	1.14	999.000	0.0	0.0	***6
		2.14	999.000	0.0	0.0	***6
		3.14	999.000	0.0	0.0	***6
		4.14	999.000	0.0	0.0	***6
		5.14	999.000	0.0	0.0	***6
		6.14	999.000	0.0	0.0	***6
		7.14	999.000	0.0	0.0	***6
		8.14	999.000	0.0	0.0	***6
		9.14	999.000	0.0	0.0	***6
		10.14	999.000	0.0	0.0	***6
		11.14	999.000	0.0	0.0	***6
		15.14	45.250	173326.2	3830.4	
		16.14	46.237	270850.9	5857.9	
		17.14	41.884	349691.7	8349.1	
		18.00	38.254	418164.2	10931.2	
33.00	10.00	0.15	999.000	0.0	0.0	***6
		1.15	999.000	0.0	0.0	***6
		2.15	999.000	0.0	0.0	***6
		3.15	999.000	0.0	0.0	***6
		4.15	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	10.00	5.15	999.000	0.0	0.0	***6
		6.15	999.000	0.0	0.0	***6
		7.15	999.000	0.0	0.0	***6
		8.15	999.000	0.0	0.0	***6
		9.15	999.000	0.0	0.0	***6
		10.15	999.000	0.0	0.0	***6
		14.15	44.832	157789.2	3519.6	
		15.15	45.845	247400.4	5396.5	
		16.15	41.953	323133.3	7702.3	
		17.00	38.445	386726.3	10059.3	
33.00	9.00	-0.83	999.000	0.0	0.0	***6
		0.17	999.000	0.0	0.0	***6
		1.17	999.000	0.0	0.0	***6
		2.17	999.000	0.0	0.0	***6
		3.17	999.000	0.0	0.0	***6
		4.17	999.000	0.0	0.0	***6
		5.17	999.000	0.0	0.0	***6
		6.17	999.000	0.0	0.0	***6
		7.17	999.000	0.0	0.0	***6
		8.17	999.000	0.0	0.0	***6
		9.17	999.000	0.0	0.0	***6
		13.17	44.562	143306.5	3215.9	
		14.17	45.453	224797.9	4945.7	
		15.17	42.039	297278.5	7071.5	
		16.00	38.671	355972.9	9205.1	
33.00	8.00	-1.81	999.000	0.0	0.0	***6
		-0.81	999.000	0.0	0.0	***6
		0.19	999.000	0.0	0.0	***6
		1.19	999.000	0.0	0.0	***6
		2.19	999.000	0.0	0.0	***6
		3.19	999.000	0.0	0.0	***6
		4.19	999.000	0.0	0.0	***6
		5.19	999.000	0.0	0.0	***6
		6.19	999.000	0.0	0.0	***6
		7.19	999.000	0.0	0.0	***6
		8.19	999.000	0.0	0.0	***6
		12.19	44.499	129942.7	2920.1	
		13.19	45.068	203098.8	4506.5	
		14.19	42.145	272189.0	6458.4	
		15.00	38.942	325933.6	8369.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	7.00	-2.78	999.000	0.0	0.0	***6
		-1.78	999.000	0.0	0.0	***6
		-0.78	999.000	0.0	0.0	***6
		0.22	999.000	0.0	0.0	***6
		1.22	999.000	0.0	0.0	***6
		2.22	999.000	0.0	0.0	***6
		3.22	999.000	0.0	0.0	***6
		4.22	999.000	0.0	0.0	***6
		5.22	999.000	0.0	0.0	***6
		6.22	999.000	0.0	0.0	***6
		7.22	999.000	0.0	0.0	***6
		11.22	44.457	117071.3	2633.3	
		12.22	44.698	182376.8	4080.2	
		13.22	42.274	247948.1	5865.2	
		14.00	39.267	296640.9	7554.5	
33.00	6.00	-3.75	999.000	0.0	0.0	***6
		-2.75	999.000	0.0	0.0	***6
		-1.75	999.000	0.0	0.0	***6
		-0.75	999.000	0.0	0.0	***6
		0.25	999.000	0.0	0.0	***6
		1.25	999.000	0.0	0.0	***6
		2.25	999.000	0.0	0.0	***6
		3.25	999.000	0.0	0.0	***6
		4.25	999.000	0.0	0.0	***6
		5.25	999.000	0.0	0.0	***6
		6.25	999.000	0.0	0.0	***6
		10.25	44.449	104766.3	2357.0	
		11.25	44.356	162736.5	3668.9	
		12.25	42.431	224675.0	5295.1	
		13.00	39.660	268132.2	6760.7	
34.00	15.00	5.25	999.000	0.0	0.0	***6
		6.25	999.000	0.0	0.0	***6
		7.25	999.000	0.0	0.0	***6
		8.25	999.000	0.0	0.0	***6
		9.25	999.000	0.0	0.0	***6
		10.25	999.000	0.0	0.0	***6
		11.25	999.000	0.0	0.0	***6
		12.25	999.000	0.0	0.0	***6
		13.25	999.000	0.0	0.0	***6
		14.25	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	15.00	15.25	999.000	0.0	0.0	***6
		19.25	48.783	261175.1	5353.9	
		20.25	45.322	367596.7	8110.8	
		21.25	40.259	463562.6	11514.5	
		22.00	37.023	537015.8	14504.9	
34.00	14.00	4.27	999.000	0.0	0.0	***6
		5.27	999.000	0.0	0.0	***6
		6.27	999.000	0.0	0.0	***6
		7.27	999.000	0.0	0.0	***6
		8.27	999.000	0.0	0.0	***6
		9.27	999.000	0.0	0.0	***6
		10.27	999.000	0.0	0.0	***6
		11.27	999.000	0.0	0.0	***6
		12.27	999.000	0.0	0.0	***6
		13.27	999.000	0.0	0.0	***6
		14.27	999.000	0.0	0.0	***6
		18.27	48.370	243390.3	5031.8	
		19.27	45.215	344661.7	7622.8	
		20.27	40.227	435583.9	10828.2	
		21.00	37.097	503842.5	13581.9	
34.00	13.00	3.29	999.000	0.0	0.0	***6
		4.29	999.000	0.0	0.0	***6
		5.29	999.000	0.0	0.0	***6
		6.29	999.000	0.0	0.0	***6
		7.29	999.000	0.0	0.0	***6
		8.29	999.000	0.0	0.0	***6
		9.29	999.000	0.0	0.0	***6
		10.29	999.000	0.0	0.0	***6
		11.29	999.000	0.0	0.0	***6
		12.29	999.000	0.0	0.0	***6
		13.29	999.000	0.0	0.0	***6
		16.29	38.908	108194.8	2780.8	
		17.29	47.948	226123.8	4716.1	
		18.29	45.103	322220.7	7144.1	
		19.29	40.199	408199.2	10154.5	
		20.00	37.190	471253.4	12671.6	
34.00	12.00	2.31	999.000	0.0	0.0	***6
		3.31	999.000	0.0	0.0	***6
		4.31	999.000	0.0	0.0	***6
		5.31	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	12.00	6.31	999.000	0.0	0.0	***6
		7.31	999.000	0.0	0.0	***6
		8.31	999.000	0.0	0.0	***6
		9.31	999.000	0.0	0.0	***6
		10.31	999.000	0.0	0.0	***6
		11.31	999.000	0.0	0.0	***6
		12.31	999.000	0.0	0.0	***6
		15.31	39.229	101985.9	2599.8	
		16.31	47.517	209401.2	4406.9	
		17.31	44.987	300305.9	6675.5	
		18.31	40.175	381446.1	9494.5	
		19.00	37.304	439266.5	11775.5	
34.00	11.00	1.34	999.000	0.0	0.0	***6
		2.34	999.000	0.0	0.0	***6
		3.34	999.000	0.0	0.0	***6
		4.34	999.000	0.0	0.0	***6
		5.34	999.000	0.0	0.0	***6
		6.34	999.000	0.0	0.0	***6
		7.34	999.000	0.0	0.0	***6
		8.34	999.000	0.0	0.0	***6
		9.34	999.000	0.0	0.0	***6
		10.34	999.000	0.0	0.0	***6
		11.34	999.000	0.0	0.0	***6
		14.34	39.561	95866.4	2423.3	
		15.34	47.078	193252.7	4105.0	
		16.34	44.864	278955.7	6217.8	
		17.34	40.158	355370.0	8849.4	
		18.00	37.441	407902.6	10894.5	
34.00	10.00	0.37	999.000	0.0	0.0	***6
		1.37	999.000	0.0	0.0	***6
		2.37	999.000	0.0	0.0	***6
		3.37	999.000	0.0	0.0	***6
		4.37	999.000	0.0	0.0	***6
		5.37	999.000	0.0	0.0	***6
		6.37	999.000	0.0	0.0	***6
		7.37	999.000	0.0	0.0	***6
		8.37	999.000	0.0	0.0	***6
		9.37	999.000	0.0	0.0	***6
		10.37	999.000	0.0	0.0	***6
		13.37	39.904	89853.2	2251.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	10.00	14.37	46.634	177717.8	3810.9	
		15.37	44.735	258219.8	5772.2	
		16.37	40.147	330029.2	8220.6	
		17.00	37.608	377184.5	10029.4	
34.00	9.00	-0.59	999.000	0.0	0.0	***6
		0.41	999.000	0.0	0.0	***6
		1.41	999.000	0.0	0.0	***6
		2.41	999.000	0.0	0.0	***6
		3.41	999.000	0.0	0.0	***6
		4.41	999.000	0.0	0.0	***6
		5.41	999.000	0.0	0.0	***6
		6.41	999.000	0.0	0.0	***6
		7.41	999.000	0.0	0.0	***6
		8.41	999.000	0.0	0.0	***6
		9.41	999.000	0.0	0.0	***6
		12.41	40.258	83970.3	2085.8	
		13.41	46.189	162846.1	3525.6	
		14.41	44.599	238161.6	5340.0	
		15.41	40.144	305498.3	7610.0	
		16.00	37.810	347137.8	9181.1	
34.00	8.00	-1.54	999.000	0.0	0.0	***6
		-0.54	999.000	0.0	0.0	***6
		0.46	999.000	0.0	0.0	***6
		1.46	999.000	0.0	0.0	***6
		2.46	999.000	0.0	0.0	***6
		3.46	999.000	0.0	0.0	***6
		4.46	999.000	0.0	0.0	***6
		5.46	999.000	0.0	0.0	***6
		6.46	999.000	0.0	0.0	***6
		7.46	999.000	0.0	0.0	***6
		8.46	999.000	0.0	0.0	***6
		11.46	40.624	78251.8	1926.2	
		12.46	45.749	148704.5	3250.4	
		13.46	44.456	218866.6	4923.3	
		14.46	40.151	281878.7	7020.5	
		15.00	38.056	317790.8	8350.5	
34.00	7.00	-2.48	999.000	0.0	0.0	***6
		-1.48	999.000	0.0	0.0	***6
		-0.48	999.000	0.0	0.0	***6
		0.52	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	7.00	1.52	999.000	0.0	0.0	***6
		2.52	999.000	0.0	0.0	***6
		3.52	999.000	0.0	0.0	***6
		4.52	999.000	0.0	0.0	***6
		5.52	999.000	0.0	0.0	***6
		6.52	999.000	0.0	0.0	***6
		7.52	999.000	0.0	0.0	***6
		10.52	41.001	72749.0	1774.3	
		11.52	45.322	135386.2	2987.2	
		12.52	44.303	200454.3	4524.6	
		13.52	40.169	259311.6	6455.5	
		14.00	38.358	289175.2	7538.8	
34.00	6.00	-3.40	999.000	0.0	0.0	***6
		-2.40	999.000	0.0	0.0	***6
		-1.40	999.000	0.0	0.0	***6
		-0.40	999.000	0.0	0.0	***6
		0.60	999.000	0.0	0.0	***6
		1.60	999.000	0.0	0.0	***6
		2.60	999.000	0.0	0.0	***6
		3.60	999.000	0.0	0.0	***6
		4.60	999.000	0.0	0.0	***6
		5.60	999.000	0.0	0.0	***6
		6.60	999.000	0.0	0.0	***6
		9.60	41.388	67542.0	1631.9	
		10.60	44.923	123028.8	2738.7	
		11.60	44.141	183100.0	4148.0	
		12.60	40.198	238005.3	5920.8	
		13.00	38.731	261326.5	6747.1	
35.00	15.00	5.46	999.000	0.0	0.0	***6
		6.46	999.000	0.0	0.0	***6
		7.46	999.000	0.0	0.0	***6
		8.46	999.000	0.0	0.0	***6
		9.46	999.000	0.0	0.0	***6
		10.46	999.000	0.0	0.0	***6
		11.46	999.000	0.0	0.0	***6
		12.46	999.000	0.0	0.0	***6
		13.46	999.000	0.0	0.0	***6
		14.46	999.000	0.0	0.0	***6
		15.46	999.000	0.0	0.0	***6
		18.46	39.612	133906.1	3380.5	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	15.00	19.46	49.027	278740.9	5685.5	
		20.46	43.600	374807.9	8596.5	
		21.46	38.688	470774.8	12168.4	
		22.00	36.475	523492.0	14352.0	
35.00	14.00	4.49	999.000	0.0	0.0	***6
		5.49	999.000	0.0	0.0	***6
		6.49	999.000	0.0	0.0	***6
		7.49	999.000	0.0	0.0	***6
		8.49	999.000	0.0	0.0	***6
		9.49	999.000	0.0	0.0	***6
		10.49	999.000	0.0	0.0	***6
		11.49	999.000	0.0	0.0	***6
		12.49	999.000	0.0	0.0	***6
		13.49	999.000	0.0	0.0	***6
		14.49	999.000	0.0	0.0	***6
		17.49	39.867	127751.4	3204.4	
		18.49	48.801	262406.5	5377.1	
		19.49	43.432	352854.7	8124.3	
		20.49	38.593	443887.5	11501.8	
		21.00	36.523	491092.7	13446.1	
35.00	13.00	3.53	999.000	0.0	0.0	***6
		4.53	999.000	0.0	0.0	***6
		5.53	999.000	0.0	0.0	***6
		6.53	999.000	0.0	0.0	***6
		7.53	999.000	0.0	0.0	***6
		8.53	999.000	0.0	0.0	***6
		9.53	999.000	0.0	0.0	***6
		10.53	999.000	0.0	0.0	***6
		11.53	999.000	0.0	0.0	***6
		12.53	999.000	0.0	0.0	***6
		13.53	999.000	0.0	0.0	***6
		16.53	40.318	122283.3	3033.0	
		17.53	48.556	246457.6	5075.8	
		18.53	43.254	331433.0	7662.4	
		19.53	38.496	417644.8	10849.1	
		20.00	36.588	459267.9	12552.4	
35.00	12.00	2.57	999.000	0.0	0.0	***6
		3.57	999.000	0.0	0.0	***6
		4.57	999.000	0.0	0.0	***6
		5.57	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	12.00	6.57	999.000	0.0	0.0	***6
		7.57	999.000	0.0	0.0	***6
		8.57	999.000	0.0	0.0	***6
		9.57	999.000	0.0	0.0	***6
		10.57	999.000	0.0	0.0	***6
		11.57	999.000	0.0	0.0	***6
		12.57	999.000	0.0	0.0	***6
		15.57	41.113	117857.3	2866.6	
		16.57	48.288	230927.6	4782.3	
		17.57	43.066	310585.5	7211.8	
		18.57	38.397	392097.8	10211.7	
		19.00	36.674	428035.9	11671.4	
35.00	11.00	1.62	999.000	0.0	0.0	***6
		2.62	999.000	0.0	0.0	***6
		3.62	999.000	0.0	0.0	***6
		4.62	999.000	0.0	0.0	***6
		5.62	999.000	0.0	0.0	***6
		6.62	999.000	0.0	0.0	***6
		7.62	999.000	0.0	0.0	***6
		8.62	999.000	0.0	0.0	***6
		9.62	999.000	0.0	0.0	***6
		10.62	999.000	0.0	0.0	***6
		11.62	999.000	0.0	0.0	***6
		14.62	41.867	113290.3	2706.0	
		15.62	47.996	215857.7	4497.4	
		16.62	42.866	290365.3	6773.8	
		17.62	38.295	367309.9	9591.5	
		18.00	36.786	397417.3	10803.4	
35.00	10.00	0.68	999.000	0.0	0.0	***6
		1.68	999.000	0.0	0.0	***6
		2.68	999.000	0.0	0.0	***6
		3.68	999.000	0.0	0.0	***6
		4.68	999.000	0.0	0.0	***6
		5.68	999.000	0.0	0.0	***6
		6.68	999.000	0.0	0.0	***6
		7.68	999.000	0.0	0.0	***6
		8.68	999.000	0.0	0.0	***6
		9.68	999.000	0.0	0.0	***6
		10.68	999.000	0.0	0.0	***6
		13.68	42.573	108632.8	2551.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	10.00	14.68	47.672	201296.0	4222.5	
		15.68	42.652	270841.3	6350.0	
		16.68	38.191	343363.2	8990.6	
		17.00	36.931	367434.2	9949.2	
35.00	9.00	-0.25	999.000	0.0	0.0	***6
		0.75	999.000	0.0	0.0	***6
		1.75	999.000	0.0	0.0	***6
		2.75	999.000	0.0	0.0	***6
		3.75	999.000	0.0	0.0	***6
		4.75	999.000	0.0	0.0	***6
		5.75	999.000	0.0	0.0	***6
		6.75	999.000	0.0	0.0	***6
		7.75	999.000	0.0	0.0	***6
		8.75	999.000	0.0	0.0	***6
		9.75	999.000	0.0	0.0	***6
		12.75	43.223	103944.9	2404.8	
		13.75	47.311	187311.2	3959.2	
		14.75	42.423	252103.6	5942.6	
		15.75	38.084	320364.9	8412.0	
		16.00	37.117	338110.8	9109.4	
35.00	8.00	-1.16	999.000	0.0	0.0	***6
		-0.16	999.000	0.0	0.0	***6
		0.84	999.000	0.0	0.0	***6
		1.84	999.000	0.0	0.0	***6
		2.84	999.000	0.0	0.0	***6
		3.84	999.000	0.0	0.0	***6
		4.84	999.000	0.0	0.0	***6
		5.84	999.000	0.0	0.0	***6
		6.84	999.000	0.0	0.0	***6
		7.84	999.000	0.0	0.0	***6
		8.84	999.000	0.0	0.0	***6
		11.84	43.808	99304.3	2266.8	
		12.84	46.909	174002.4	3709.4	
		13.84	42.177	234274.3	5554.6	
		14.84	37.973	298460.7	7859.8	
		15.00	37.348	309473.2	8286.1	
35.00	7.00	-2.06	999.000	0.0	0.0	***6
		-1.06	999.000	0.0	0.0	***6
		-0.06	999.000	0.0	0.0	***6
		0.94	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	7.00	1.94	999.000	0.0	0.0	***6
		2.94	999.000	0.0	0.0	***6
		3.94	999.000	0.0	0.0	***6
		4.94	999.000	0.0	0.0	***6
		5.94	999.000	0.0	0.0	***6
		6.94	999.000	0.0	0.0	***6
		7.94	999.000	0.0	0.0	***6
		10.94	44.325	94568.5	2133.5	
		11.94	46.478	161321.0	3470.9	
		12.94	41.926	217326.2	5183.6	
		13.94	37.868	277639.8	7331.7	
		14.00	37.638	281551.9	7480.6	
35.00	6.00	-2.96	999.000	0.0	0.0	***6
		-1.96	999.000	0.0	0.0	***6
		-0.96	999.000	0.0	0.0	***6
		0.04	999.000	0.0	0.0	***6
		1.04	999.000	0.0	0.0	***6
		2.04	999.000	0.0	0.0	***6
		3.04	999.000	0.0	0.0	***6
		4.04	999.000	0.0	0.0	***6
		5.04	999.000	0.0	0.0	***6
		6.04	999.000	0.0	0.0	***6
		7.04	999.000	0.0	0.0	***6
		10.04	44.876	88589.2	1974.1	
		11.04	46.110	148389.1	3218.2	
		12.04	41.757	200330.6	4797.5	
		13.00	38.002	254381.3	6694.0	
36.00	15.00	5.73	999.000	0.0	0.0	***6
		6.73	999.000	0.0	0.0	***6
		7.73	999.000	0.0	0.0	***6
		8.73	999.000	0.0	0.0	***6
		9.73	999.000	0.0	0.0	***6
		10.73	999.000	0.0	0.0	***6
		11.73	999.000	0.0	0.0	***6
		12.73	999.000	0.0	0.0	***6
		13.73	999.000	0.0	0.0	***6
		14.73	999.000	0.0	0.0	***6
		15.73	999.000	0.0	0.0	***6
		18.73	49.222	182096.4	3699.5	
		19.73	47.392	292022.2	6161.9	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
36.00	15.00	20.73	41.784	387342.4	9270.1	
		21.73	37.144	483605.8	13019.6	
		22.00	36.112	509683.9	14113.8	
36.00	14.00	4.78	999.000	0.0	0.0	***6
		5.78	999.000	0.0	0.0	***6
		6.78	999.000	0.0	0.0	***6
		7.78	999.000	0.0	0.0	***6
		8.78	999.000	0.0	0.0	***6
		9.78	999.000	0.0	0.0	***6
		10.78	999.000	0.0	0.0	***6
		11.78	999.000	0.0	0.0	***6
		12.78	999.000	0.0	0.0	***6
		13.78	999.000	0.0	0.0	***6
		14.78	999.000	0.0	0.0	***6
		17.78	49.553	175370.9	3539.1	
		18.78	47.093	276498.4	5871.3	
		19.78	41.546	366417.4	8819.5	
		20.78	36.978	457883.7	12382.7	
		21.00	36.146	478074.2	13226.1	
36.00	13.00	3.84	999.000	0.0	0.0	***6
		4.84	999.000	0.0	0.0	***6
		5.84	999.000	0.0	0.0	***6
		6.84	999.000	0.0	0.0	***6
		7.84	999.000	0.0	0.0	***6
		8.84	999.000	0.0	0.0	***6
		9.84	999.000	0.0	0.0	***6
		10.84	999.000	0.0	0.0	***6
		11.84	999.000	0.0	0.0	***6
		12.84	999.000	0.0	0.0	***6
		13.84	999.000	0.0	0.0	***6
		16.84	49.826	168619.5	3384.2	
		17.84	46.766	261388.0	5589.3	
		18.84	41.292	346071.4	8381.0	
		19.84	36.803	432869.8	11761.8	
		20.00	36.196	447029.2	12350.3	
36.00	12.00	2.91	999.000	0.0	0.0	***6
		3.91	999.000	0.0	0.0	***6
		4.91	999.000	0.0	0.0	***6
		5.91	999.000	0.0	0.0	***6
		6.91	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
36.00	12.00	7.91	999.000	0.0	0.0	***6
		8.91	999.000	0.0	0.0	***6
		9.91	999.000	0.0	0.0	***6
		10.91	999.000	0.0	0.0	***6
		11.91	999.000	0.0	0.0	***6
		12.91	999.000	0.0	0.0	***6
		15.91	50.034	161877.6	3235.4	
		16.91	46.406	246734.0	5316.8	
		17.91	41.021	326359.4	7955.9	
		18.91	36.620	408630.2	11158.8	
		19.00	36.265	416567.2	11486.8	
36.00	11.00	1.98	999.000	0.0	0.0	***6
		2.98	999.000	0.0	0.0	***6
		3.98	999.000	0.0	0.0	***6
		4.98	999.000	0.0	0.0	***6
		5.98	999.000	0.0	0.0	***6
		6.98	999.000	0.0	0.0	***6
		7.98	999.000	0.0	0.0	***6
		8.98	999.000	0.0	0.0	***6
		9.98	999.000	0.0	0.0	***6
		10.98	999.000	0.0	0.0	***6
		11.98	999.000	0.0	0.0	***6
		14.98	50.166	155190.1	3093.5	
		15.98	46.011	232590.2	5055.1	
		16.98	40.729	307351.1	7546.2	
		17.98	36.426	385248.6	10576.1	
		18.00	36.358	386707.6	10636.0	
36.00	10.00	1.07	999.000	0.0	0.0	***6
		2.07	999.000	0.0	0.0	***6
		3.07	999.000	0.0	0.0	***6
		4.07	999.000	0.0	0.0	***6
		5.07	999.000	0.0	0.0	***6
		6.07	999.000	0.0	0.0	***6
		7.07	999.000	0.0	0.0	***6
		8.07	999.000	0.0	0.0	***6
		9.07	999.000	0.0	0.0	***6
		10.07	999.000	0.0	0.0	***6
		11.07	999.000	0.0	0.0	***6
		13.07	26.046	39111.3	1501.6	
		14.07	50.213	148614.5	2959.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
36.00	10.00	15.07	45.575	219027.7	4805.9	
		16.07	40.416	289136.0	7154.1	
		17.00	36.483	357471.8	9798.4	
36.00	9.00	0.17	999.000	0.0	0.0	***6
		1.17	999.000	0.0	0.0	***6
		2.17	999.000	0.0	0.0	***6
		3.17	999.000	0.0	0.0	***6
		4.17	999.000	0.0	0.0	***6
		5.17	999.000	0.0	0.0	***6
		6.17	999.000	0.0	0.0	***6
		7.17	999.000	0.0	0.0	***6
		8.17	999.000	0.0	0.0	***6
		9.17	999.000	0.0	0.0	***6
		10.17	999.000	0.0	0.0	***6
		12.17	31.680	45850.9	1447.3	
		13.17	50.153	141994.4	2831.2	
		14.17	45.108	205965.3	4566.1	
		15.17	40.089	271648.5	6776.2	
		16.00	36.646	328883.5	8974.7	
36.00	8.00	-0.72	999.000	0.0	0.0	***6
		0.28	999.000	0.0	0.0	***6
		1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		11.28	35.468	48961.5	1380.4	
		12.28	49.968	133953.7	2680.8	
		13.28	44.691	192562.5	4308.8	
		14.28	39.818	254010.6	6379.2	
		15.00	36.859	300969.2	8165.4	
36.00	7.00	-1.62	999.000	0.0	0.0	***6
		-0.62	999.000	0.0	0.0	***6
		0.38	999.000	0.0	0.0	***6
		1.38	999.000	0.0	0.0	***6
		2.38	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
36.00	7.00	3.38	999.000	0.0	0.0	***6
		4.38	999.000	0.0	0.0	***6
		5.38	999.000	0.0	0.0	***6
		6.38	999.000	0.0	0.0	***6
		7.38	999.000	0.0	0.0	***6
		8.38	999.000	0.0	0.0	***6
		10.38	38.273	49692.4	1298.4	
		11.38	49.887	124864.8	2503.0	
		12.38	44.352	178758.0	4030.4	
		13.38	39.628	236141.2	5958.9	
		14.00	37.139	273758.2	7371.3	
36.00	6.00	-2.51	999.000	0.0	0.0	***6
		-1.51	999.000	0.0	0.0	***6
		-0.51	999.000	0.0	0.0	***6
		0.49	999.000	0.0	0.0	***6
		1.49	999.000	0.0	0.0	***6
		2.49	999.000	0.0	0.0	***6
		3.49	999.000	0.0	0.0	***6
		4.49	999.000	0.0	0.0	***6
		5.49	999.000	0.0	0.0	***6
		6.49	999.000	0.0	0.0	***6
		7.49	999.000	0.0	0.0	***6
		9.49	41.499	49838.6	1201.0	
		10.49	49.941	115179.3	2306.3	
		11.49	44.115	164629.9	3731.8	
		12.49	39.538	218105.5	5516.4	
		13.00	37.506	247283.4	6593.2	
37.00	15.00	6.06	999.000	0.0	0.0	***6
		7.06	999.000	0.0	0.0	***6
		8.06	999.000	0.0	0.0	***6
		9.06	999.000	0.0	0.0	***6
		10.06	999.000	0.0	0.0	***6
		11.06	999.000	0.0	0.0	***6
		12.06	999.000	0.0	0.0	***6
		13.06	999.000	0.0	0.0	***6
		14.06	999.000	0.0	0.0	***6
		15.06	999.000	0.0	0.0	***6
		16.06	999.000	0.0	0.0	***6
		18.06	20.182	41856.2	2073.9	
		19.06	51.346	212289.1	4134.5	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	15.00	20.06	45.530	309907.4	6806.6	
		21.06	39.941	404966.9	10139.0	
		22.00	35.942	495568.2	13787.8	
37.00	14.00	5.13	999.000	0.0	0.0	***6
		6.13	999.000	0.0	0.0	***6
		7.13	999.000	0.0	0.0	***6
		8.13	999.000	0.0	0.0	***6
		9.13	999.000	0.0	0.0	***6
		10.13	999.000	0.0	0.0	***6
		11.13	999.000	0.0	0.0	***6
		12.13	999.000	0.0	0.0	***6
		13.13	999.000	0.0	0.0	***6
		14.13	999.000	0.0	0.0	***6
		15.13	999.000	0.0	0.0	***6
		17.13	25.429	51166.8	2012.1	
		18.13	51.078	203933.3	3992.6	
		19.13	45.137	295205.3	6540.2	
		20.13	39.632	385111.2	9717.1	
		21.00	35.974	464764.6	12919.4	
37.00	13.00	4.21	999.000	0.0	0.0	***6
		5.21	999.000	0.0	0.0	***6
		6.21	999.000	0.0	0.0	***6
		7.21	999.000	0.0	0.0	***6
		8.21	999.000	0.0	0.0	***6
		9.21	999.000	0.0	0.0	***6
		10.21	999.000	0.0	0.0	***6
		11.21	999.000	0.0	0.0	***6
		12.21	999.000	0.0	0.0	***6
		13.21	999.000	0.0	0.0	***6
		14.21	999.000	0.0	0.0	***6
		16.21	29.688	58064.9	1955.8	
		17.21	50.745	195759.0	3857.7	
		18.21	44.708	280957.0	6284.2	
		19.21	39.302	365890.1	9309.6	
		20.00	36.022	434516.4	12062.6	
37.00	12.00	3.31	999.000	0.0	0.0	***6
		4.31	999.000	0.0	0.0	***6
		5.31	999.000	0.0	0.0	***6
		6.31	999.000	0.0	0.0	***6
		7.31	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	12.00	8.31	999.000	0.0	0.0	***6
		9.31	999.000	0.0	0.0	***6
		10.31	999.000	0.0	0.0	***6
		11.31	999.000	0.0	0.0	***6
		12.31	999.000	0.0	0.0	***6
		13.31	999.000	0.0	0.0	***6
		15.31	33.807	64433.0	1905.9	
		16.31	50.337	187805.1	3730.9	
		17.31	44.239	267216.5	6040.3	
		18.31	38.949	347372.6	8918.6	
		19.00	36.089	404841.1	11217.8	
37.00	11.00	2.41	999.000	0.0	0.0	***6
		3.41	999.000	0.0	0.0	***6
		4.41	999.000	0.0	0.0	***6
		5.41	999.000	0.0	0.0	***6
		6.41	999.000	0.0	0.0	***6
		7.41	999.000	0.0	0.0	***6
		8.41	999.000	0.0	0.0	***6
		9.41	999.000	0.0	0.0	***6
		10.41	999.000	0.0	0.0	***6
		11.41	999.000	0.0	0.0	***6
		12.41	999.000	0.0	0.0	***6
		14.41	43.447	80887.4	1861.8	
		15.41	49.861	179951.8	3609.1	
		16.41	43.738	253882.5	5804.7	
		17.41	38.580	329468.8	8539.8	
		18.00	36.181	375757.5	10385.4	
37.00	10.00	1.51	999.000	0.0	0.0	***6
		2.51	999.000	0.0	0.0	***6
		3.51	999.000	0.0	0.0	***6
		4.51	999.000	0.0	0.0	***6
		5.51	999.000	0.0	0.0	***6
		6.51	999.000	0.0	0.0	***6
		7.51	999.000	0.0	0.0	***6
		8.51	999.000	0.0	0.0	***6
		9.51	999.000	0.0	0.0	***6
		10.51	999.000	0.0	0.0	***6
		11.51	999.000	0.0	0.0	***6
		13.51	48.586	87682.5	1804.7	
		14.51	49.389	171382.0	3470.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	10.00	15.51	43.275	240139.2	5549.2	
		16.51	38.250	311334.1	8139.4	
		17.00	36.305	347286.5	9565.8	
37.00	9.00	0.62	999.000	0.0	0.0	***6
		1.62	999.000	0.0	0.0	***6
		2.62	999.000	0.0	0.0	***6
		3.62	999.000	0.0	0.0	***6
		4.62	999.000	0.0	0.0	***6
		5.62	999.000	0.0	0.0	***6
		6.62	999.000	0.0	0.0	***6
		7.62	999.000	0.0	0.0	***6
		8.62	999.000	0.0	0.0	***6
		9.62	999.000	0.0	0.0	***6
		10.62	999.000	0.0	0.0	***6
		12.62	51.934	89871.7	1730.5	
		13.62	49.128	162061.5	3298.7	
		14.62	42.871	225924.7	5269.8	
		15.62	37.974	292890.3	7712.9	
		16.00	36.468	319450.8	8759.7	
37.00	8.00	-0.27	999.000	0.0	0.0	***6
		0.73	999.000	0.0	0.0	***6
		1.73	999.000	0.0	0.0	***6
		2.73	999.000	0.0	0.0	***6
		3.73	999.000	0.0	0.0	***6
		4.73	999.000	0.0	0.0	***6
		5.73	999.000	0.0	0.0	***6
		6.73	999.000	0.0	0.0	***6
		7.73	999.000	0.0	0.0	***6
		8.73	999.000	0.0	0.0	***6
		9.73	999.000	0.0	0.0	***6
		11.73	54.322	89014.8	1638.7	
		12.73	49.005	152070.3	3103.2	
		13.73	42.540	211305.7	4967.2	
		14.73	37.762	274193.8	7261.2	
		15.00	36.683	292276.1	7967.6	
37.00	7.00	-1.17	999.000	0.0	0.0	***6
		-0.17	999.000	0.0	0.0	***6
		0.83	999.000	0.0	0.0	***6
		1.83	999.000	0.0	0.0	***6
		2.83	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	7.00	3.83	999.000	0.0	0.0	***6
		4.83	999.000	0.0	0.0	***6
		5.83	999.000	0.0	0.0	***6
		6.83	999.000	0.0	0.0	***6
		7.83	999.000	0.0	0.0	***6
		8.83	999.000	0.0	0.0	***6
		10.83	56.194	85924.6	1529.1	
		11.83	49.010	141501.5	2887.2	
		12.83	42.299	196350.4	4642.0	
		13.83	37.628	255303.3	6785.0	
		14.00	36.966	265790.5	7190.2	
37.00	6.00	-2.06	999.000	0.0	0.0	***6
		-1.06	999.000	0.0	0.0	***6
		-0.06	999.000	0.0	0.0	***6
		0.94	999.000	0.0	0.0	***6
		1.94	999.000	0.0	0.0	***6
		2.94	999.000	0.0	0.0	***6
		3.94	999.000	0.0	0.0	***6
		4.94	999.000	0.0	0.0	***6
		5.94	999.000	0.0	0.0	***6
		6.94	999.000	0.0	0.0	***6
		7.94	999.000	0.0	0.0	***6
		9.94	57.870	81129.5	1401.9	
		10.94	49.206	130452.2	2651.2	
		11.94	42.241	181128.7	4288.0	
		12.94	37.591	236279.6	6285.5	
		13.00	37.339	240026.1	6428.3	
38.00	15.00	6.45	999.000	0.0	0.0	***6
		7.45	999.000	0.0	0.0	***6
		8.45	999.000	0.0	0.0	***6
		9.45	999.000	0.0	0.0	***6
		10.45	999.000	0.0	0.0	***6
		11.45	999.000	0.0	0.0	***6
		12.45	999.000	0.0	0.0	***6
		13.45	999.000	0.0	0.0	***6
		14.45	999.000	0.0	0.0	***6
		15.45	999.000	0.0	0.0	***6
		16.45	999.000	0.0	0.0	***6
		18.45	52.603	125831.7	2392.1	
		19.45	50.176	236362.2	4710.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	15.00	20.45	43.497	332177.1	7636.8	
		21.45	38.254	427546.1	11176.5	
		22.00	35.980	481117.5	13371.7	
38.00	14.00	5.54	999.000	0.0	0.0	***6
		6.54	999.000	0.0	0.0	***6
		7.54	999.000	0.0	0.0	***6
		8.54	999.000	0.0	0.0	***6
		9.54	999.000	0.0	0.0	***6
		10.54	999.000	0.0	0.0	***6
		11.54	999.000	0.0	0.0	***6
		12.54	999.000	0.0	0.0	***6
		13.54	999.000	0.0	0.0	***6
		14.54	999.000	0.0	0.0	***6
		15.54	999.000	0.0	0.0	***6
		17.54	55.726	131425.6	2358.4	
		18.54	49.711	228373.5	4594.0	
		19.54	43.009	318324.5	7401.3	
		20.54	37.889	408798.3	10789.5	
		21.00	36.023	451137.5	12523.6	
38.00	13.00	4.65	999.000	0.0	0.0	***6
		5.65	999.000	0.0	0.0	***6
		6.65	999.000	0.0	0.0	***6
		7.65	999.000	0.0	0.0	***6
		8.65	999.000	0.0	0.0	***6
		9.65	999.000	0.0	0.0	***6
		10.65	999.000	0.0	0.0	***6
		11.65	999.000	0.0	0.0	***6
		12.65	999.000	0.0	0.0	***6
		13.65	999.000	0.0	0.0	***6
		14.65	999.000	0.0	0.0	***6
		16.65	56.510	131540.5	2327.8	
		17.65	49.183	220446.0	4482.1	
		18.65	42.493	304807.3	7173.1	
		19.65	37.508	390575.8	10413.1	
		20.00	36.084	421704.0	11686.8	
38.00	12.00	3.75	999.000	0.0	0.0	***6
		4.75	999.000	0.0	0.0	***6
		5.75	999.000	0.0	0.0	***6
		6.75	999.000	0.0	0.0	***6
		7.75	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	12.00	8.75	999.000	0.0	0.0	***6
		9.75	999.000	0.0	0.0	***6
		10.75	999.000	0.0	0.0	***6
		11.75	999.000	0.0	0.0	***6
		12.75	999.000	0.0	0.0	***6
		13.75	999.000	0.0	0.0	***6
		15.75	57.040	130117.3	2281.1	
		16.75	48.648	211750.3	4352.7	
		17.75	42.009	290826.4	6922.9	
		18.75	37.156	372056.7	10013.4	
		19.00	36.166	392833.4	10861.8	
38.00	11.00	2.86	999.000	0.0	0.0	***6
		3.86	999.000	0.0	0.0	***6
		4.86	999.000	0.0	0.0	***6
		5.86	999.000	0.0	0.0	***6
		6.86	999.000	0.0	0.0	***6
		7.86	999.000	0.0	0.0	***6
		8.86	999.000	0.0	0.0	***6
		9.86	999.000	0.0	0.0	***6
		10.86	999.000	0.0	0.0	***6
		11.86	999.000	0.0	0.0	***6
		12.86	999.000	0.0	0.0	***6
		14.86	57.437	127257.8	2215.6	
		15.86	48.158	202258.4	4199.9	
		16.86	41.572	276318.4	6646.8	
		17.86	36.842	353164.8	9585.8	
		18.00	36.277	364544.4	10049.0	
38.00	10.00	1.96	999.000	0.0	0.0	***6
		2.96	999.000	0.0	0.0	***6
		3.96	999.000	0.0	0.0	***6
		4.96	999.000	0.0	0.0	***6
		5.96	999.000	0.0	0.0	***6
		6.96	999.000	0.0	0.0	***6
		7.96	999.000	0.0	0.0	***6
		8.96	999.000	0.0	0.0	***6
		9.96	999.000	0.0	0.0	***6
		10.96	999.000	0.0	0.0	***6
		11.96	999.000	0.0	0.0	***6
		13.96	57.794	123158.1	2131.0	
		14.96	47.886	192058.5	4010.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	10.00	15.96	41.187	261341.9	6345.2	
		16.96	36.573	333950.0	9131.0	
		17.00	36.422	336856.8	9248.7	
38.00	9.00	1.07	999.000	0.0	0.0	***6
		2.07	999.000	0.0	0.0	***6
		3.07	999.000	0.0	0.0	***6
		4.07	999.000	0.0	0.0	***6
		5.07	999.000	0.0	0.0	***6
		6.07	999.000	0.0	0.0	***6
		7.07	999.000	0.0	0.0	***6
		8.07	999.000	0.0	0.0	***6
		9.07	999.000	0.0	0.0	***6
		10.07	999.000	0.0	0.0	***6
		11.07	999.000	0.0	0.0	***6
		12.07	15.401	10956.1	711.4	
		13.07	58.198	117980.5	2027.2	
		14.07	47.708	181231.5	3798.7	
		15.07	40.866	245956.5	6018.7	
		16.00	36.612	309792.7	8461.6	
38.00	8.00	0.17	999.000	0.0	0.0	***6
		1.17	999.000	0.0	0.0	***6
		2.17	999.000	0.0	0.0	***6
		3.17	999.000	0.0	0.0	***6
		4.17	999.000	0.0	0.0	***6
		5.17	999.000	0.0	0.0	***6
		6.17	999.000	0.0	0.0	***6
		7.17	999.000	0.0	0.0	***6
		8.17	999.000	0.0	0.0	***6
		9.17	999.000	0.0	0.0	***6
		10.17	999.000	0.0	0.0	***6
		11.17	29.160	19430.4	666.3	
		12.17	58.743	111865.6	1904.3	
		13.17	47.657	169856.2	3564.1	
		14.17	40.620	230222.6	5667.7	
		15.00	36.859	283376.7	7688.1	
38.00	7.00	-0.72	999.000	0.0	0.0	***6
		0.28	999.000	0.0	0.0	***6
		1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	7.00	4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	39.738	24189.7	608.7	
		11.28	59.541	104939.2	1762.5	
		12.28	47.777	158010.4	3307.3	
		13.28	40.543	214202.3	5283.3	
		14.00	37.183	257636.2	6928.9	
38.00	6.00	-1.62	999.000	0.0	0.0	***6
		-0.62	999.000	0.0	0.0	***6
		0.38	999.000	0.0	0.0	***6
		1.38	999.000	0.0	0.0	***6
		2.38	999.000	0.0	0.0	***6
		3.38	999.000	0.0	0.0	***6
		4.38	999.000	0.0	0.0	***6
		5.38	999.000	0.0	0.0	***6
		6.38	999.000	0.0	0.0	***6
		7.38	999.000	0.0	0.0	***6
		8.38	999.000	0.0	0.0	***6
		9.38	71.766	39439.2	549.6	
		10.38	60.749	97317.9	1602.0	
		11.38	48.130	145772.0	3028.7	
		12.38	40.724	197960.0	4861.0	
		13.00	37.609	232601.8	6184.8	
39.00	15.00	6.88	999.000	0.0	0.0	***6
		7.88	999.000	0.0	0.0	***6
		8.88	999.000	0.0	0.0	***6
		9.88	999.000	0.0	0.0	***6
		10.88	999.000	0.0	0.0	***6
		11.88	999.000	0.0	0.0	***6
		12.88	999.000	0.0	0.0	***6
		13.88	999.000	0.0	0.0	***6
		14.88	999.000	0.0	0.0	***6
		15.88	999.000	0.0	0.0	***6
		16.88	999.000	0.0	0.0	***6
		18.88	57.491	164039.4	2853.3	
		19.88	48.382	263522.8	5446.8	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
39.00	15.00	20.88	41.552	358582.7	8629.7	
		21.88	36.728	454772.8	12382.2	
		22.00	36.251	466299.5	12863.2	
39.00	14.00	5.99	999.000	0.0	0.0	***6
		6.99	999.000	0.0	0.0	***6
		7.99	999.000	0.0	0.0	***6
		8.99	999.000	0.0	0.0	***6
		9.99	999.000	0.0	0.0	***6
		10.99	999.000	0.0	0.0	***6
		11.99	999.000	0.0	0.0	***6
		12.99	999.000	0.0	0.0	***6
		13.99	999.000	0.0	0.0	***6
		14.99	999.000	0.0	0.0	***6
		15.99	999.000	0.0	0.0	***6
		17.99	57.611	162384.2	2818.6	
		18.99	47.797	254763.3	5330.1	
		19.99	41.078	344447.8	8385.3	
		20.99	36.372	435960.3	11986.2	
		21.00	36.320	437162.1	12036.3	
39.00	13.00	5.09	999.000	0.0	0.0	***6
		6.09	999.000	0.0	0.0	***6
		7.09	999.000	0.0	0.0	***6
		8.09	999.000	0.0	0.0	***6
		9.09	999.000	0.0	0.0	***6
		10.09	999.000	0.0	0.0	***6
		11.09	999.000	0.0	0.0	***6
		12.09	999.000	0.0	0.0	***6
		13.09	999.000	0.0	0.0	***6
		14.09	999.000	0.0	0.0	***6
		15.09	999.000	0.0	0.0	***6
		16.09	4.435	4183.6	943.3	
		17.09	57.668	159402.2	2764.1	
		18.09	47.241	245191.0	5190.3	
		19.09	40.640	329739.0	8113.7	
		20.00	36.411	408562.2	11220.7	
39.00	12.00	4.20	999.000	0.0	0.0	***6
		5.20	999.000	0.0	0.0	***6
		6.20	999.000	0.0	0.0	***6
		7.20	999.000	0.0	0.0	***6
		8.20	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
39.00	12.00	9.20	999.000	0.0	0.0	***6
		10.20	999.000	0.0	0.0	***6
		11.20	999.000	0.0	0.0	***6
		12.20	999.000	0.0	0.0	***6
		13.20	999.000	0.0	0.0	***6
		14.20	999.000	0.0	0.0	***6
		15.20	19.069	17703.6	928.4	
		16.20	57.717	155237.3	2689.6	
		17.20	46.800	234878.6	5018.8	
		18.20	40.242	314508.8	7815.4	
		19.00	36.530	380515.9	10416.6	
39.00	11.00	3.30	999.000	0.0	0.0	***6
		4.30	999.000	0.0	0.0	***6
		5.30	999.000	0.0	0.0	***6
		6.30	999.000	0.0	0.0	***6
		7.30	999.000	0.0	0.0	***6
		8.30	999.000	0.0	0.0	***6
		9.30	999.000	0.0	0.0	***6
		10.30	999.000	0.0	0.0	***6
		11.30	999.000	0.0	0.0	***6
		12.30	999.000	0.0	0.0	***6
		13.30	999.000	0.0	0.0	***6
		14.30	999.000	22303.1	1.1	***1
		15.30	57.814	150015.3	2594.8	
		16.30	46.504	223896.1	4814.5	
		17.30	39.891	298810.2	7490.6	
		18.00	36.682	353041.1	9624.4	
39.00	10.00	2.41	999.000	0.0	0.0	***6
		3.41	999.000	0.0	0.0	***6
		4.41	999.000	0.0	0.0	***6
		5.41	999.000	0.0	0.0	***6
		6.41	999.000	0.0	0.0	***6
		7.41	999.000	0.0	0.0	***6
		8.41	999.000	0.0	0.0	***6
		9.41	999.000	0.0	0.0	***6
		10.41	999.000	0.0	0.0	***6
		11.41	999.000	0.0	0.0	***6
		12.41	999.000	0.0	0.0	***6
		13.41	81.402	71113.9	873.6	
		14.41	58.012	143848.7	2479.6	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
39.00	10.00	15.41	46.302	212312.4	4585.4	
		16.41	39.595	282696.6	7139.7	
		17.00	36.876	326157.0	8844.7	
39.00	9.00	1.51	999.000	0.0	0.0	***6
		2.51	999.000	0.0	0.0	***6
		3.51	999.000	0.0	0.0	***6
		4.51	999.000	0.0	0.0	***6
		5.51	999.000	0.0	0.0	***6
		6.51	999.000	0.0	0.0	***6
		7.51	999.000	0.0	0.0	***6
		8.51	999.000	0.0	0.0	***6
		9.51	999.000	0.0	0.0	***6
		10.51	999.000	0.0	0.0	***6
		11.51	999.000	0.0	0.0	***6
		12.51	86.254	71583.0	829.9	
		13.51	58.379	136840.3	2344.0	
		14.51	46.215	200194.3	4331.8	
		15.51	39.362	266222.4	6763.4	
		16.00	37.125	299884.8	8077.7	
39.00	8.00	0.62	999.000	0.0	0.0	***6
		1.62	999.000	0.0	0.0	***6
		2.62	999.000	0.0	0.0	***6
		3.62	999.000	0.0	0.0	***6
		4.62	999.000	0.0	0.0	***6
		5.62	999.000	0.0	0.0	***6
		6.62	999.000	0.0	0.0	***6
		7.62	999.000	0.0	0.0	***6
		8.62	999.000	0.0	0.0	***6
		9.62	999.000	0.0	0.0	***6
		10.62	999.000	0.0	0.0	***6
		11.62	91.356	70439.8	771.1	
		12.62	58.997	129086.9	2188.0	
		13.62	46.277	187608.9	4054.1	
		14.62	39.290	249443.7	6348.7	
		15.00	37.444	274248.5	7324.2	
39.00	7.00	-0.28	999.000	0.0	0.0	***6
		0.72	999.000	0.0	0.0	***6
		1.72	999.000	0.0	0.0	***6
		2.72	999.000	0.0	0.0	***6
		3.72	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
39.00	7.00	4.72	999.000	0.0	0.0	***6
		5.72	999.000	0.0	0.0	***6
		6.72	999.000	0.0	0.0	***6
		7.72	999.000	0.0	0.0	***6
		8.72	999.000	0.0	0.0	***6
		9.72	999.000	0.0	0.0	***6
		10.72	96.121	67976.0	707.2	
		11.72	59.966	120670.2	2012.3	
		12.72	46.532	174624.0	3752.8	
		13.72	39.410	232418.1	5897.5	
		14.00	37.972	249274.1	6564.7	
39.00	6.00	-1.17	999.000	0.0	0.0	***6
		-0.17	999.000	0.0	0.0	***6
		0.83	999.000	0.0	0.0	***6
		1.83	999.000	0.0	0.0	***6
		2.83	999.000	0.0	0.0	***6
		3.83	999.000	0.0	0.0	***6
		4.83	999.000	0.0	0.0	***6
		5.83	999.000	0.0	0.0	***6
		6.83	999.000	0.0	0.0	***6
		7.83	999.000	0.0	0.0	***6
		8.83	999.000	0.0	0.0	***6
		9.83	102.448	64467.7	629.3	
		10.83	61.436	111737.7	1818.8	
		11.83	47.036	161368.2	3430.7	
		12.83	39.685	215270.7	5424.5	
		13.00	38.759	224991.4	5805.0	
40.00	15.00	7.33	999.000	0.0	0.0	***6
		8.33	999.000	0.0	0.0	***6
		9.33	999.000	0.0	0.0	***6
		10.33	999.000	0.0	0.0	***6
		11.33	999.000	0.0	0.0	***6
		12.33	999.000	0.0	0.0	***6
		13.33	999.000	0.0	0.0	***6
		14.33	999.000	0.0	0.0	***6
		15.33	999.000	0.0	0.0	***6
		16.33	999.000	0.0	0.0	***6
		17.33	999.000	0.0	0.0	***6
		18.33	999.000	39963.9	4.8	***1
		19.33	57.501	193892.6	3372.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
40.00	15.00	20.33	46.448	290691.4	6258.4	
		21.33	39.980	386009.9	9655.0	
		22.00	36.791	451075.9	12260.5	
40.00	14.00	6.43	999.000	0.0	0.0	***6
		7.43	999.000	0.0	0.0	***6
		8.43	999.000	0.0	0.0	***6
		9.43	999.000	0.0	0.0	***6
		10.43	999.000	0.0	0.0	***6
		11.43	999.000	0.0	0.0	***6
		12.43	999.000	0.0	0.0	***6
		13.43	999.000	0.0	0.0	***6
		14.43	999.000	0.0	0.0	***6
		15.43	999.000	0.0	0.0	***6
		16.43	999.000	0.0	0.0	***6
		17.43	78.024	89453.9	1146.5	
		18.43	57.337	189754.0	3309.4	
		19.43	45.938	280347.1	6102.7	
		20.43	39.585	370608.3	9362.3	
		21.00	36.907	422801.1	11455.9	
40.00	13.00	5.54	999.000	0.0	0.0	***6
		6.54	999.000	0.0	0.0	***6
		7.54	999.000	0.0	0.0	***6
		8.54	999.000	0.0	0.0	***6
		9.54	999.000	0.0	0.0	***6
		10.54	999.000	0.0	0.0	***6
		11.54	999.000	0.0	0.0	***6
		12.54	999.000	0.0	0.0	***6
		13.54	999.000	0.0	0.0	***6
		14.54	999.000	0.0	0.0	***6
		15.54	999.000	0.0	0.0	***6
		16.54	81.418	93248.6	1145.3	
		17.54	57.218	184568.6	3225.7	
		18.54	45.594	269296.6	5906.4	
		19.54	39.227	354689.0	9041.9	
		20.00	37.052	395055.2	10662.2	
40.00	12.00	4.64	999.000	0.0	0.0	***6
		5.64	999.000	0.0	0.0	***6
		6.64	999.000	0.0	0.0	***6
		7.64	999.000	0.0	0.0	***6
		8.64	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
40.00	12.00	9.64	999.000	0.0	0.0	***6
		10.64	999.000	0.0	0.0	***6
		11.64	999.000	0.0	0.0	***6
		12.64	999.000	0.0	0.0	***6
		13.64	999.000	0.0	0.0	***6
		14.64	999.000	0.0	0.0	***6
		15.64	84.305	95063.3	1127.6	
		16.64	57.177	178428.9	3120.7	
		17.64	45.334	257599.7	5682.3	
		18.64	38.911	338299.5	8694.2	
		19.00	37.232	367854.2	9880.1	
40.00	11.00	3.75	999.000	0.0	0.0	***6
		4.75	999.000	0.0	0.0	***6
		5.75	999.000	0.0	0.0	***6
		6.75	999.000	0.0	0.0	***6
		7.75	999.000	0.0	0.0	***6
		8.75	999.000	0.0	0.0	***6
		9.75	999.000	0.0	0.0	***6
		10.75	999.000	0.0	0.0	***6
		11.75	999.000	0.0	0.0	***6
		12.75	999.000	0.0	0.0	***6
		13.75	999.000	0.0	0.0	***6
		14.75	87.114	95221.8	1093.1	
		15.75	57.231	171400.7	2994.9	
		16.75	45.157	245316.2	5432.5	
		17.75	38.643	321489.1	8319.5	
		18.00	37.456	341214.9	9109.7	
40.00	10.00	2.85	999.000	0.0	0.0	***6
		3.85	999.000	0.0	0.0	***6
		4.85	999.000	0.0	0.0	***6
		5.85	999.000	0.0	0.0	***6
		6.85	999.000	0.0	0.0	***6
		7.85	999.000	0.0	0.0	***6
		8.85	999.000	0.0	0.0	***6
		9.85	999.000	0.0	0.0	***6
		10.85	999.000	0.0	0.0	***6
		11.85	999.000	0.0	0.0	***6
		12.85	999.000	0.0	0.0	***6
		13.85	90.230	93963.1	1041.4	
		14.85	57.438	163578.4	2847.9	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
40.00	10.00	15.85	45.083	232504.6	5157.3	
		16.85	38.431	304307.1	7918.2	
		17.00	37.736	315156.1	8351.5	
40.00	9.00	1.96	999.000	0.0	0.0	***6
		2.96	999.000	0.0	0.0	***6
		3.96	999.000	0.0	0.0	***6
		4.96	999.000	0.0	0.0	***6
		5.96	999.000	0.0	0.0	***6
		6.96	999.000	0.0	0.0	***6
		7.96	999.000	0.0	0.0	***6
		8.96	999.000	0.0	0.0	***6
		9.96	999.000	0.0	0.0	***6
		10.96	999.000	0.0	0.0	***6
		11.96	999.000	0.0	0.0	***6
		12.96	93.500	91477.3	978.4	
		13.96	57.868	155049.3	2679.4	
		14.96	45.135	219225.0	4857.1	
		15.96	38.380	286804.2	7472.8	
		16.00	38.162	289698.2	7591.2	
40.00	8.00	1.06	999.000	0.0	0.0	***6
		2.06	999.000	0.0	0.0	***6
		3.06	999.000	0.0	0.0	***6
		4.06	999.000	0.0	0.0	***6
		5.06	999.000	0.0	0.0	***6
		6.06	999.000	0.0	0.0	***6
		7.06	999.000	0.0	0.0	***6
		8.06	999.000	0.0	0.0	***6
		9.06	999.000	0.0	0.0	***6
		10.06	999.000	0.0	0.0	***6
		11.06	999.000	0.0	0.0	***6
		12.06	97.018	87988.7	906.9	
		13.06	58.587	145960.9	2491.4	
		14.06	45.339	205607.2	4534.9	
		15.00	38.814	264864.0	6824.0	
40.00	7.00	0.17	999.000	0.0	0.0	***6
		1.17	999.000	0.0	0.0	***6
		2.17	999.000	0.0	0.0	***6
		3.17	999.000	0.0	0.0	***6
		4.17	999.000	0.0	0.0	***6
		5.17	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
40.00	7.00	6.17	999.000	0.0	0.0	***6
		7.17	999.000	0.0	0.0	***6
		8.17	999.000	0.0	0.0	***6
		9.17	999.000	0.0	0.0	***6
		10.17	999.000	0.0	0.0	***6
		12.17	59.741	136320.0	2281.9	
		13.17	45.752	191639.2	4188.6	
		14.00	39.646	240678.8	6070.7	
40.00	6.00	-0.72	999.000	0.0	0.0	***6
		0.28	999.000	0.0	0.0	***6
		1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		11.28	61.535	126200.8	2050.9	
		12.28	46.448	177379.6	3818.9	
		13.00	40.730	217171.5	5331.9	
41.00	15.00	7.77	999.000	0.0	0.0	***6
		8.77	999.000	0.0	0.0	***6
		9.77	999.000	0.0	0.0	***6
		10.77	999.000	0.0	0.0	***6
		11.77	999.000	0.0	0.0	***6
		12.77	999.000	0.0	0.0	***6
		13.77	999.000	0.0	0.0	***6
		14.77	999.000	0.0	0.0	***6
		15.77	999.000	0.0	0.0	***6
		16.77	999.000	0.0	0.0	***6
		17.77	999.000	0.0	0.0	***6
		18.77	83.667	119172.9	1424.4	
		19.77	56.532	221427.3	3916.8	
		20.77	44.986	317285.7	7053.0	
		21.77	38.756	413405.1	10666.8	
		22.00	37.657	435400.9	11562.2	
41.00	14.00	6.88	999.000	0.0	0.0	***6
		7.88	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
41.00	14.00	8.88	999.000	0.0	0.0	***6
		9.88	999.000	0.0	0.0	***6
		10.88	999.000	0.0	0.0	***6
		11.88	999.000	0.0	0.0	***6
		12.88	999.000	0.0	0.0	***6
		13.88	999.000	0.0	0.0	***6
		14.88	999.000	0.0	0.0	***6
		15.88	999.000	0.0	0.0	***6
		16.88	999.000	0.0	0.0	***6
		17.88	85.182	120760.9	1417.7	
		18.88	56.293	215330.1	3825.2	
		19.88	44.699	305548.1	6835.7	
		20.88	38.435	396824.7	10324.5	
		21.00	37.847	408009.9	10780.5	
41.00	13.00	5.98	999.000	0.0	0.0	***6
		6.98	999.000	0.0	0.0	***6
		7.98	999.000	0.0	0.0	***6
		8.98	999.000	0.0	0.0	***6
		9.98	999.000	0.0	0.0	***6
		10.98	999.000	0.0	0.0	***6
		11.98	999.000	0.0	0.0	***6
		12.98	999.000	0.0	0.0	***6
		13.98	999.000	0.0	0.0	***6
		14.98	999.000	0.0	0.0	***6
		15.98	999.000	0.0	0.0	***6
		16.98	86.729	120863.1	1393.6	
		17.98	56.157	208345.4	3710.1	
		18.98	44.477	293180.2	6591.8	
		19.98	38.153	379772.3	9954.0	
		20.00	38.077	381140.2	10009.8	
41.00	12.00	5.09	999.000	0.0	0.0	***6
		6.09	999.000	0.0	0.0	***6
		7.09	999.000	0.0	0.0	***6
		8.09	999.000	0.0	0.0	***6
		9.09	999.000	0.0	0.0	***6
		10.09	999.000	0.0	0.0	***6
		11.09	999.000	0.0	0.0	***6
		12.09	999.000	0.0	0.0	***6
		13.09	999.000	0.0	0.0	***6
		14.09	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
41.00	12.00	15.09	999.000	0.0	0.0	***6
		16.09	88.518	119645.8	1351.7	
		17.09	56.155	200547.8	3571.4	
		18.09	44.332	280235.4	6321.3	
		19.00	38.355	354806.7	9250.5	
41.00	11.00	4.19	999.000	0.0	0.0	***6
		5.19	999.000	0.0	0.0	***6
		6.19	999.000	0.0	0.0	***6
		7.19	999.000	0.0	0.0	***6
		8.19	999.000	0.0	0.0	***6
		9.19	999.000	0.0	0.0	***6
		10.19	999.000	0.0	0.0	***6
		11.19	999.000	0.0	0.0	***6
		12.19	999.000	0.0	0.0	***6
		13.19	999.000	0.0	0.0	***6
		14.19	999.000	0.0	0.0	***6
		15.19	90.775	117249.0	1291.6	
		16.19	56.321	192008.2	3409.2	
		17.19	44.279	266766.5	6024.7	
		18.00	38.762	329026.0	8488.3	
41.00	10.00	3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	999.000	0.0	0.0	***6
		11.28	999.000	0.0	0.0	***6
		12.28	999.000	0.0	0.0	***6
		13.28	999.000	0.0	0.0	***6
		14.28	94.186	112513.8	1194.6	
		15.28	57.041	181536.3	3182.6	
		16.28	44.495	251520.2	5652.7	
		17.00	39.365	303816.0	7717.9	
41.00	9.00	2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
41.00	9.00	7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	999.000	0.0	0.0	***6
		11.28	999.000	0.0	0.0	***6
		12.28	999.000	0.0	0.0	***6
		13.28	106.739	101497.7	950.9	
		14.28	59.888	165101.8	2756.9	
		15.28	45.659	230217.6	5042.1	
		16.00	40.114	279196.3	6960.1	
41.00	8.00	1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	999.000	0.0	0.0	***6
		11.28	999.000	0.0	0.0	***6
		13.28	63.725	149136.3	2340.3	
		14.28	47.149	209474.2	4442.8	
		15.00	41.057	255189.2	6215.5	
41.00	7.00	0.28	999.000	0.0	0.0	***6
		1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		10.28	999.000	0.0	0.0	***6
		12.28	68.474	133660.2	1952.0	
		13.28	49.100	189312.8	3855.6	
		14.00	42.267	231818.8	5484.7	
41.00	6.00	-0.72	999.000	0.0	0.0	***6
		0.28	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
41.00	6.00	1.28	999.000	0.0	0.0	***6
		2.28	999.000	0.0	0.0	***6
		3.28	999.000	0.0	0.0	***6
		4.28	999.000	0.0	0.0	***6
		5.28	999.000	0.0	0.0	***6
		6.28	999.000	0.0	0.0	***6
		7.28	999.000	0.0	0.0	***6
		8.28	999.000	0.0	0.0	***6
		9.28	999.000	0.0	0.0	***6
		12.28	51.737	169759.3	3281.2	
		13.00	43.853	209113.2	4768.5	
42.00	15.00	8.22	999.000	0.0	0.0	***6
		9.22	999.000	0.0	0.0	***6
		10.22	999.000	0.0	0.0	***6
		11.22	999.000	0.0	0.0	***6
		12.22	999.000	0.0	0.0	***6
		13.22	999.000	0.0	0.0	***6
		14.22	999.000	0.0	0.0	***6
		15.22	999.000	0.0	0.0	***6
		16.22	999.000	0.0	0.0	***6
		17.22	999.000	0.0	0.0	***6
		18.22	999.000	0.0	0.0	***6
		19.22	85.873	148427.6	1728.5	
		20.22	55.426	247573.2	4466.7	
		21.22	44.024	343616.2	7805.2	
		22.00	38.936	419218.2	10766.8	
42.00	14.00	7.32	999.000	0.0	0.0	***6
		8.32	999.000	0.0	0.0	***6
		9.32	999.000	0.0	0.0	***6
		10.32	999.000	0.0	0.0	***6
		11.32	999.000	0.0	0.0	***6
		12.32	999.000	0.0	0.0	***6
		13.32	999.000	0.0	0.0	***6
		14.32	999.000	0.0	0.0	***6
		15.32	999.000	0.0	0.0	***6
		16.32	999.000	0.0	0.0	***6
		17.32	999.000	0.0	0.0	***6
		18.32	87.099	146901.9	1686.6	
		19.32	55.408	239445.5	4321.5	
		20.32	43.878	330185.6	7525.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
42.00	14.00	21.00	39.238	392734.1	10009.0	
42.00	13.00	6.32	999.000	0.0	0.0	***6
		7.32	999.000	0.0	0.0	***6
		8.32	999.000	0.0	0.0	***6
		9.32	999.000	0.0	0.0	***6
		10.32	999.000	0.0	0.0	***6
		11.32	999.000	0.0	0.0	***6
		12.32	999.000	0.0	0.0	***6
		13.32	999.000	0.0	0.0	***6
		14.32	999.000	0.0	0.0	***6
		15.32	999.000	0.0	0.0	***6
		16.32	999.000	0.0	0.0	***6
		17.32	96.016	135569.5	1412.0	
		18.32	57.253	222256.6	3882.0	
		19.32	44.636	307773.0	6895.1	
		20.00	39.681	366763.9	9242.7	
42.00	12.00	5.33	999.000	0.0	0.0	***6
		6.33	999.000	0.0	0.0	***6
		7.33	999.000	0.0	0.0	***6
		8.33	999.000	0.0	0.0	***6
		9.33	999.000	0.0	0.0	***6
		10.33	999.000	0.0	0.0	***6
		11.33	999.000	0.0	0.0	***6
		12.33	999.000	0.0	0.0	***6
		13.33	999.000	0.0	0.0	***6
		14.33	999.000	0.0	0.0	***6
		15.33	999.000	0.0	0.0	***6
		16.33	106.946	124545.3	1164.6	
		17.33	59.554	205473.7	3450.2	
		18.33	45.553	285845.3	6275.0	
		19.00	40.287	341322.3	8472.2	
42.00	11.00	4.33	999.000	0.0	0.0	***6
		5.33	999.000	0.0	0.0	***6
		6.33	999.000	0.0	0.0	***6
		7.33	999.000	0.0	0.0	***6
		8.33	999.000	0.0	0.0	***6
		9.33	999.000	0.0	0.0	***6
		10.33	999.000	0.0	0.0	***6
		11.33	999.000	0.0	0.0	***6
		12.33	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
42.00	11.00	13.33	999.000	0.0	0.0	***6
		14.33	999.000	0.0	0.0	***6
		16.33	62.482	189109.6	3026.6	
		17.33	46.674	264419.2	5665.2	
		18.00	41.023	316425.1	7713.4	
42.00	10.00	3.33	999.000	0.0	0.0	***6
		4.33	999.000	0.0	0.0	***6
		5.33	999.000	0.0	0.0	***6
		6.33	999.000	0.0	0.0	***6
		7.33	999.000	0.0	0.0	***6
		8.33	999.000	0.0	0.0	***6
		9.33	999.000	0.0	0.0	***6
		10.33	999.000	0.0	0.0	***6
		11.33	999.000	0.0	0.0	***6
		12.33	999.000	0.0	0.0	***6
		13.33	999.000	0.0	0.0	***6
		15.33	66.313	173178.1	2611.5	
		16.33	48.067	243511.4	5066.0	
		17.00	41.926	292089.6	6966.7	
42.00	9.00	2.34	999.000	0.0	0.0	***6
		3.34	999.000	0.0	0.0	***6
		4.34	999.000	0.0	0.0	***6
		5.34	999.000	0.0	0.0	***6
		6.34	999.000	0.0	0.0	***6
		7.34	999.000	0.0	0.0	***6
		8.34	999.000	0.0	0.0	***6
		9.34	999.000	0.0	0.0	***6
		10.34	999.000	0.0	0.0	***6
		11.34	999.000	0.0	0.0	***6
		12.34	999.000	0.0	0.0	***6
		14.34	70.975	157696.1	2221.9	
		15.34	49.830	223141.5	4478.1	
		16.00	43.052	268334.7	6232.8	
42.00	8.00	1.34	999.000	0.0	0.0	***6
		2.34	999.000	0.0	0.0	***6
		3.34	999.000	0.0	0.0	***6
		4.34	999.000	0.0	0.0	***6
		5.34	999.000	0.0	0.0	***6
		6.34	999.000	0.0	0.0	***6
		7.34	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
42.00	8.00	8.34	999.000	0.0	0.0	***6
		9.34	999.000	0.0	0.0	***6
		10.34	999.000	0.0	0.0	***6
		11.34	999.000	0.0	0.0	***6
		14.34	52.111	203331.5	3901.9	
		15.00	44.481	245182.4	5512.1	
42.00	7.00	0.35	999.000	0.0	0.0	***6
		1.35	999.000	0.0	0.0	***6
		2.35	999.000	0.0	0.0	***6
		3.35	999.000	0.0	0.0	***6
		4.35	999.000	0.0	0.0	***6
		5.35	999.000	0.0	0.0	***6
		6.35	999.000	0.0	0.0	***6
		7.35	999.000	0.0	0.0	***6
		8.35	999.000	0.0	0.0	***6
		9.35	999.000	0.0	0.0	***6
		10.35	999.000	0.0	0.0	***6
		13.35	55.070	184106.5	3343.1	
		14.00	46.335	222656.2	4805.4	
42.00	6.00	-0.64	999.000	0.0	0.0	***6
		0.36	999.000	0.0	0.0	***6
		1.36	999.000	0.0	0.0	***6
		2.36	999.000	0.0	0.0	***6
		3.36	999.000	0.0	0.0	***6
		4.36	999.000	0.0	0.0	***6
		5.36	999.000	0.0	0.0	***6
		6.36	999.000	0.0	0.0	***6
		7.36	999.000	0.0	0.0	***6
		8.36	999.000	0.0	0.0	***6
		9.36	999.000	0.0	0.0	***6
		12.36	58.596	165496.3	2824.4	
		13.00	48.811	200782.5	4113.5	

Table of B.A.

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

Center X(m),Y(m)

Y(m)	X(m)	33.00	34.00	35.00	36.00	37.00	38.00
15.00	Fs	37.743	37.023	36.475	36.112	20.182	35.980
	R(m)	22.00	22.00	22.00	22.00	18.06	22.00
14.00	Fs	37.841	37.097	36.523	36.146	25.429	36.023
	R(m)	21.00	21.00	21.00	21.00	17.13	21.00
13.00	Fs	37.957	37.190	36.588	36.196	29.688	36.084
	R(m)	20.00	20.00	20.00	20.00	16.21	20.00
12.00	Fs	38.093	37.304	36.674	36.265	33.807	36.166
	R(m)	19.00	19.00	19.00	19.00	15.31	19.00
11.00	Fs	38.254	37.441	36.786	36.358	36.181	36.277
	R(m)	18.00	18.00	18.00	18.00	18.00	18.00
10.00	Fs	38.445	37.608	36.931	26.046	36.305	36.422
	R(m)	17.00	17.00	17.00	13.07	17.00	17.00
9.00	Fs	38.671	37.810	37.117	31.680	36.468	15.401
	R(m)	16.00	16.00	16.00	12.17	16.00	12.07
8.00	Fs	38.942	38.056	37.348	35.468	36.683	29.160
	R(m)	15.00	15.00	15.00	11.28	15.00	11.17
7.00	Fs	39.267	38.358	37.638	37.139	36.966	37.183
	R(m)	14.00	14.00	14.00	14.00	14.00	14.00
6.00	Fs	39.660	38.731	38.002	37.506	37.339	37.609
	R(m)	13.00	13.00	13.00	13.00	13.00	13.00

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

Center X(m),Y(m)

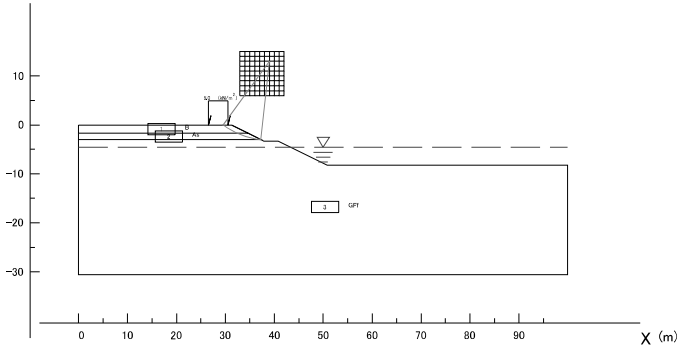
Y(m)	X(m)	39.00	40.00	41.00	42.00
15.00	Fs	36.251	36.791	37.657	38.936
	R(m)	22.00	22.00	22.00	22.00
14.00	Fs	36.320	36.907	37.847	39.238
	R(m)	21.00	21.00	21.00	21.00
13.00	Fs	4.435	37.052	38.077	39.681
	R(m)	16.09	20.00	20.00	20.00
12.00	Fs	19.069	37.232	38.355	40.287
	R(m)	15.20	19.00	19.00	19.00
11.00	Fs	36.682	37.456	38.762	41.023
	R(m)	18.00	18.00	18.00	18.00
10.00	Fs	36.876	37.736	39.365	41.926
	R(m)	17.00	17.00	17.00	17.00
9.00	Fs	37.125	38.162	40.114	43.052
	R(m)	16.00	16.00	16.00	16.00
8.00	Fs	37.444	38.814	41.057	44.481
	R(m)	15.00	15.00	15.00	15.00
7.00	Fs	37.972	39.646	42.267	46.335
	R(m)	14.00	14.00	14.00	14.00
6.00	Fs	38.759	40.730	43.853	48.811
	R(m)	13.00	13.00	13.00	13.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	4.435
Failure circle X(m)	=	39.00
Y(m)	=	13.00
R(m)	=	16.092
Resisting moment(kNm)	=	4183.6
Sliding moment(kNm)	=	943.3
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



WARNING ***1 Points of intersection of an arc and the ground are more than three points. count = 2

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

Test of Embankment Stability

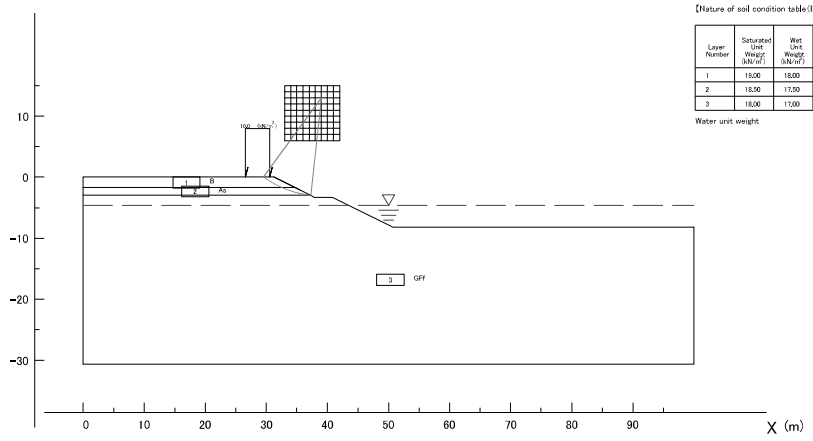
Action number = 1

Action name : normal

Examination at earthquake : It doesn't do.

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	6.128	≧ 1.0 (OK)
Center of arc	X	=	39.00	(m)
	Y	=	13.00	(m)
Radius	R	=	16.092	(m)
Resisting moment	M_R	=	4249.2	(kNm)
Sliding moment	M_D	=	693.4	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	19.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.50	17.50	27.00	0.00	0.00	0.000	0.000
3	18.00	17.00	30.00	1000.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)

Safety Factor (Ordinary Condition)

Test of Embankment Stability

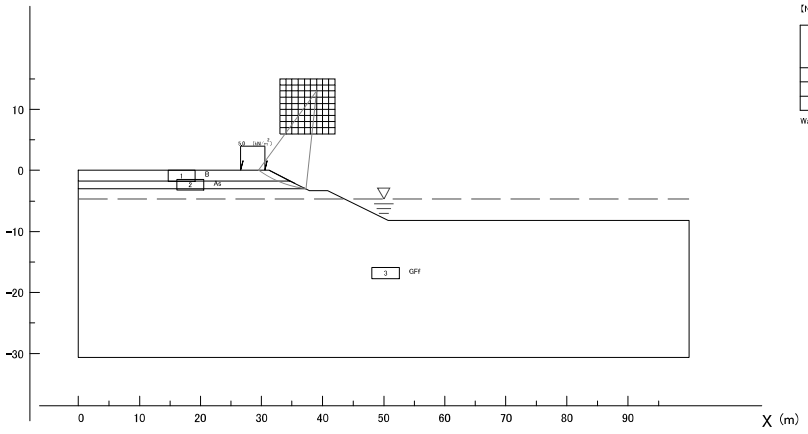
Action number = 2

Action name : seismic

Examination at earthquake : It does.

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	4.435	≧ 1.0 (OK)
Center of arc	X	=	39.00	(m)
	Y	=	13.00	(m)
Radius	R	=	16.092	(m)
Resisting moment	M_R	=	4183.6	(kNm)
Sliding moment	M_D	=	943.3	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	19.00	18.00	30.00	1.00	0.00	0.200	0.000
2	18.50	17.50	27.00	0.00	0.00	0.200	0.000
3	18.00	17.00	30.00	1000.00	0.00	0.200	0.000

Water unit weight = 10.00 (kN/m³)

Safety Factor (Seismic Condition)

1.2.1 SLOPE STABILITY　ANALYSIS

1.2.1.1　Normal and Seismic Conditions

(3)　L6+340

Circular Slip Surface

L+6340

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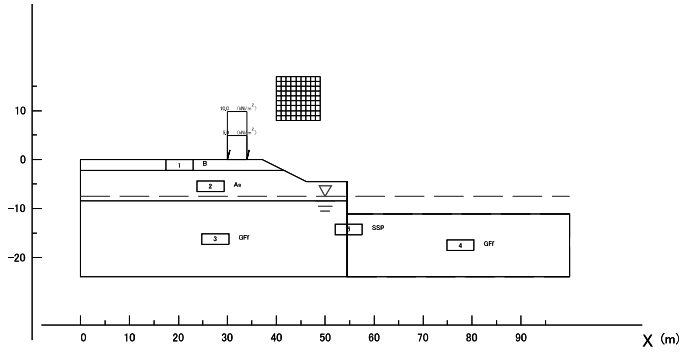
1. Input data list

// Design section //



// Design level of reliability design method //

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

// Combination of action //

// Setting of action //

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

// Partial coefficient concerning analytical technique γ_α //

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

// Partial coefficient concerning W,C,φ γw,γc,γtanφ //

No.	Action 1			Action 2											
	γw	γc	γtanφ	γw	γc	γtanφ	γw	γc	γtanφ	γw	γc	γtanφ
1	1.00	1.00	1.00	1.00	1.00	1.00						
2	1.00	1.00	1.00	1.00	1.00	1.00						
3	1.00	1.00	1.00	1.00	1.00	1.00						
4	1.00	1.00	1.00	1.00	1.00	1.00						
5	1.00	1.00	1.00	1.00	1.00	1.00						

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

$$W_d' = \gamma_w W_k'$$

$$C_d = \gamma_c C_k$$

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

M : Resistance moment

γ_w : Partial coefficient concerning weight

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

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

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

γ_c : Partial coefficient concerning Cohesion

C_d : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (value for design) (kN/m²)

C_k : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (characteristic value) (kN/m²)

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

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

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

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

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

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

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

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

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

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

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

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

K : Resistance power coefficient

r : Radius of slipping circular arc

F : Distribution load i

FR : Slipping line orthogonalization direction load value of load i

FO : Slipping line direction load value of load i

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

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

K_{hp} : The horizontal seismic intensity

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

ϕ : Internal friction angle of soil

// Partial coefficient to residual water level //

Action number	rRWL
1	1.00
2	1.00

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

γ_{RWL} : Partial coefficient concerning residual water level

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

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

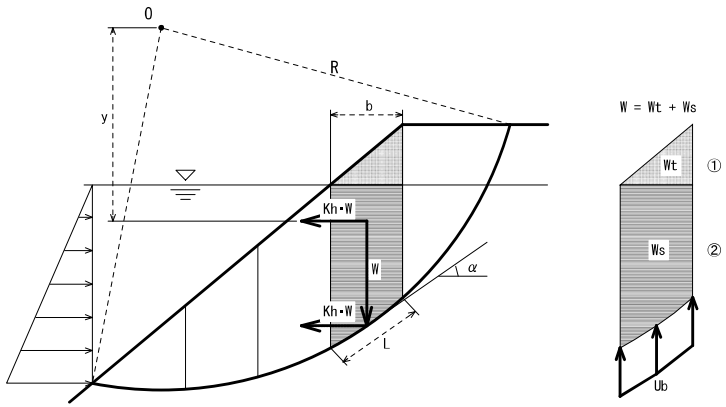
(DATA 01.)　// ANALYSIS //

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

Expression

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

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



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

(DATA 02.)　// CONTROL //

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

(DATA 04.) // SEISMIC LOAD //

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


(DATA 06.) // NODAL POINT //

No.	Coordinate		Y-coordinate
	x (m)	y (m)	before settlement (m)
1	0.00	0.00	0.00
2	30.01	0.00	0.00
3	34.01	0.00	0.00
4	37.13	0.00	0.00
5	41.58	-2.22	0.00
6	0.00	-2.22	0.00
7	0.00	-7.51	0.00
8	0.00	-8.47	0.00
9	54.38	-8.47	0.00
10	54.38	-4.50	0.00
11	46.13	-4.50	0.00
12	54.53	-4.50	0.00
13	54.53	-11.09	0.00
14	54.53	-23.98	0.00
15	54.38	-23.98	0.00
16	100.00	-11.09	0.00
17	100.00	-23.98	0.00
18	0.00	-23.98	0.00

(DATA 07.) // WATER LEVEL //

Unit weight of water (kN/m³) = 10.00

Action No.	Water level line number
1	1
2	1

Water level line number: 1

No.	Coordinate	
	X (m)	Y (m)
1	0.00	-7.51
2	100.00	-7.51

Water level line number: 2

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

(DATA 08.) // LAYER //

No.	material property No.	The name of the strata
1	5	B
2	6	As
3	8	GFf
4	8	GFf
5	2	SSP

No.	Num of Node	Node numbers composing a layer	Slip existence
1	6	1 6 5 4 3 2	Slip
2	7	5 6 7 8 9 10 11	Slip
3	4	8 18 15 9	Slip
4	4	13 14 17 16	Not Slip
5	6	9 15 14 13 12 10	Slip

(DATA 09.1) // MATERIAL PROPERTIES //

No.	Nature of soil division	Saturated weight (kN/m³)	Wet weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
2	SSP	77.00	77.00	******	0.00	0.00	0.00	0.000	0.0
5	B	19.00	18.00	1.00	0.00	30.00	0.00	0.000	0.0
6	As	18.50	17.50	0.00	0.00	32.00	0.00	0.000	0.0
8	GFf	18.00	17.00	******	0.00	30.00	0.00	0.000	0.0

(DATA 09.2) // Characteristic of soil //

No.	Action Number									
	Act 1	Act 2								
1	5	5								
2	6	6								
3	8	8								
4	8	8								
5	2	2								

(DATA 11.) // GRID POINT //

No.	Slip direction	Double cutting	GX (m)	GY (m)	X-point	Y-point	X-pitch (m)	Y-pitch (m)	Dx/Dy	NEXCO Radius
1	Downstream	Rigt lump	40.00	17.00	10	10	1.00	1.00	0.000	0.000

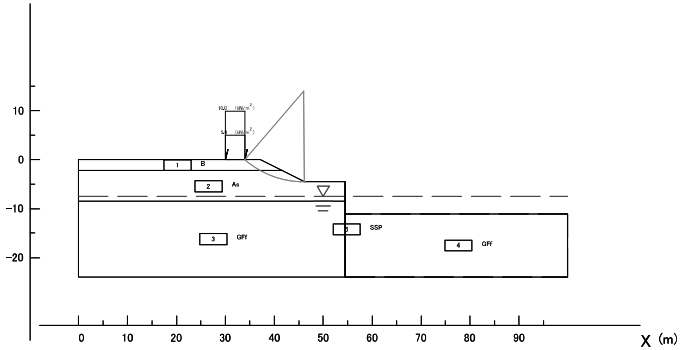
2. Check list

// Check of circular arc //

Action No.	Action name	Bearing force Action ratio	Judgment
1	normal	1.642	OK
2	seismic	1.001	OK

Action No.	Bearing force Action ratio	Partial coefficient r_a	Center of slipping circular arc X (m)	Center of slipping circular arc Y (m)	Radius of circular arc(m)	Resistance Moment (kNm)	Sliding Moment (kNm)
1	1.642	1.00	46.00	14.00	18.487	3322.1	2023.4
2	1.001	1.00	46.00	14.00	18.487	3077.0	3074.9

// Check Result chart //



3. Action01 (normal)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle ϕ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	5	19.00	18.00	9.00	1.00	0.00	30.00	0.00	0.00	0.0
2	6	18.50	17.50	8.50	0.00	0.00	32.00	0.00	0.00	0.0
3	8	18.00	17.00	8.00	1000.0	0 0.0	030.0	0 0.0	0 0.0	0 0.
0	4	8 18.0	0 17.0	0 8.0	01000.	00 0.	0030.	00 0.	00 0.	00 0
0.0	5	2 77.	00 77.	00 67.	001000	0.00	0.00	0.00	0.00	0.00
0.0										

// Distribution load that considers partial coefficient //

load No.	Left X (m)	Left Y (m)	Left Load Value(kN)	Right X (m)	Right Y (m)	Right Load Value(kN)	Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
1	30.01	0.00	10.0	34.01	0.00	10.0	0.000	0.000	0.000

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

No.	Coordinate X (m)	Coordinate Y (m)	Residual water level
1	0.00	-7.51	
2	100.00	-7.51	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
40.00	17.00	18.24	3.050	763.2	250.2
		19.24	2.522	2573.0	1020.1
40.00	16.00	17.26	3.048	707.8	232.3
		18.26	2.476	2391.9	966.0
40.00	15.00	16.27	3.052	654.6	214.5
		17.27	2.431	2217.0	912.0
40.00	14.00	15.29	3.066	603.4	196.8
		16.29	2.387	2048.5	858.4
40.00	13.00	15.31	2.345	1887.6	805.0
		16.31	2.397	4095.2	1708.3
40.00	12.00	14.34	2.305	1733.9	752.1
		15.34	2.354	3771.9	1602.3
40.00	11.00	13.37	2.268	1586.8	699.8
		14.37	2.311	3460.8	1497.3
40.00	10.00	12.40	2.232	1446.7	648.1
		13.40	2.270	3162.8	1393.3
40.00	9.00	11.45	2.200	1314.4	597.3
		12.45	2.231	2879.2	1290.7
		13.45	2.321	5097.2	2195.9
40.00	8.00	-11.50	999.000	0.0	0.0
		-10.50	999.000	0.0	0.0
		10.50	2.173	1190.5	547.8
		11.50	2.194	2611.4	1190.1
		12.50	2.287	4640.8	2029.6
41.00	17.00	18.43	2.909	747.3	256.9
		19.43	2.300	2538.1	1103.6
41.00	16.00	17.46	2.911	699.9	240.4
		18.46	2.261	2378.8	1052.1
41.00	15.00	17.49	2.223	2225.2	1001.1
		18.49	2.275	4799.7	2110.0
41.00	14.00	16.53	2.185	2077.7	950.8
		17.53	2.234	4484.4	2006.9
41.00	13.00	15.56	2.149	1936.7	901.3
		16.56	2.195	4181.0	1905.1
41.00	12.00	14.61	2.113	1802.5	852.9
		15.61	2.156	3890.2	1804.6
41.00	11.00	13.66	2.080	1675.8	805.7
		14.66	2.118	3613.1	1706.0
41.00	10.00	12.72	2.049	1557.4	760.1
		13.72	2.082	3351.1	1609.6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
41.00	10.00	14.72	2.171	5864.6	2701.2
41.00	9.00	11.80	2.021	1448.3	716.7
		12.80	2.049	3105.8	1516.1
		13.80	2.139	5438.7	2542.6
41.00	8.00	-11.11	999.000	0.0	0.0
		10.89	1.997	1349.9	676.0
		11.89	2.019	2879.8	1426.5
		12.89	2.110	5042.6	2389.5
42.00	17.00	19.68	2.129	2588.0	1215.8
		20.68	2.180	5551.6	2546.4
42.00	16.00	18.72	2.093	2447.1	1168.9
		19.72	2.143	5245.1	2447.6
42.00	15.00	17.77	2.059	2312.6	1123.2
		18.77	2.106	4950.2	2350.2
42.00	14.00	16.82	2.025	2185.0	1078.8
		17.82	2.070	4667.6	2254.7
42.00	13.00	15.88	1.993	2064.8	1036.1
		16.88	2.035	4398.2	2161.3
42.00	12.00	14.95	1.962	1952.9	995.5
		15.95	2.001	4143.3	2070.5
		16.95	2.087	7168.8	3435.5
42.00	11.00	14.03	1.932	1850.1	957.4
		15.03	1.969	3904.4	1983.1
		16.03	2.055	6747.6	3282.7
42.00	10.00	13.12	1.905	1757.8	922.6
		14.12	1.939	3683.5	1899.8
		15.12	2.027	6354.2	3135.2
42.00	9.00	12.23	1.882	1669.3	887.2
		13.23	1.912	3471.2	1815.8
		14.23	2.001	5977.1	2986.7
42.00	8.00	11.33	1.863	1566.5	840.7
		12.33	1.887	3241.4	1717.6
		13.33	1.978	5580.5	2820.9
		14.33	2.164	8794.2	4063.9
43.00	17.00	19.98	1.989	2712.5	1363.9
		20.98	2.037	5763.8	2829.9
43.00	16.00	19.04	1.957	2592.0	1324.3
		20.04	2.003	5490.2	2740.4
43.00	15.00	18.11	1.926	2479.0	1286.8
		19.11	1.971	5229.7	2653.4

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
43.00	14.00	17.18	1.897	2374.4	1251.9
		18.18	1.939	4983.2	2569.5
43.00	13.00	16.26	1.868	2278.9	1220.0
		17.26	1.909	4752.3	2489.4
		18.26	2.024	8206.7	4054.7
43.00	12.00	15.36	1.841	2193.9	1191.7
		16.36	1.880	4538.6	2413.7
		17.36	2.004	7830.6	3907.9
43.00	11.00	14.46	1.816	2112.2	1163.1
		15.46	1.853	4332.1	2337.3
		16.46	1.986	7467.1	3759.3
43.00	10.00	13.57	1.794	2015.1	1123.1
		14.57	1.828	4106.1	2246.1
		15.57	1.970	7077.8	3593.5
43.00	9.00	13.67	1.805	3860.7	2139.1
		14.67	1.954	6662.5	3409.8
		15.67	2.201	10506.9	4773.2
43.00	8.00	12.78	1.784	3597.3	2015.9
		13.78	1.940	6222.8	3208.2
		14.78	2.186	9817.7	4491.2
44.00	17.00	20.34	1.874	2916.7	1556.4
		21.34	1.920	6104.1	3179.9
44.00	16.00	19.41	1.846	2820.0	1527.7
		20.41	1.890	5867.3	3103.8
44.00	15.00	18.50	1.819	2732.7	1502.6
		19.50	1.862	5645.6	3031.9
		20.50	2.056	9925.6	4826.9
44.00	14.00	17.59	1.793	2655.9	1481.6
		18.59	1.835	5440.8	2964.9
		19.59	2.044	9567.7	4680.6
44.00	13.00	16.70	1.768	2582.2	1460.5
		17.70	1.811	5244.9	2896.7
		18.70	2.034	9219.3	4532.0
44.00	12.00	15.80	1.745	2492.1	1427.7
		16.80	1.791	5035.6	2811.2
		17.80	2.025	8839.3	4366.1
44.00	11.00	14.91	1.726	2385.4	1382.3
		15.91	1.776	4808.3	2707.8
		16.91	2.015	8427.3	4182.3
44.00	10.00	15.02	1.764	4561.6	2586.5

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
44.00	10.00	16.02	2.006	7984.8	3980.6
		17.02	2.291	12520.4	5464.6
44.00	9.00	14.12	1.755	4294.9	2447.3
		15.12	1.998	7513.8	3761.0
		16.12	2.280	11774.2	5164.5
44.00	8.00	13.23	1.750	4008.6	2290.2
		14.23	1.991	7016.5	3523.5
		15.23	2.270	10999.7	4846.6
45.00	17.00	20.73	1.779	3209.7	1803.9
		21.73	1.841	6629.3	3601.4
45.00	16.00	19.83	1.755	3142.0	1790.7
		20.83	1.830	6471.0	3536.6
		21.83	2.129	11612.3	5453.3
45.00	15.00	18.94	1.731	3077.0	1777.6
		19.94	1.823	6323.1	3468.4
		20.94	2.126	11280.3	5304.7
45.00	14.00	18.04	1.709	2995.1	1752.7
		19.04	1.819	6151.9	3382.9
		20.04	2.123	10911.2	5138.7
45.00	13.00	17.15	1.689	2895.7	1714.8
		18.15	1.816	5954.9	3279.4
		19.15	2.120	10504.5	4954.8
45.00	12.00	17.25	1.815	5731.2	3158.0
		18.25	2.117	10061.6	4753.0
45.00	11.00	16.36	1.816	5481.0	3018.7
		17.36	2.114	9584.1	4533.3
		18.36	2.952	18073.1	6123.0
45.00	10.00	15.46	1.819	5204.8	2861.5
		16.46	2.112	9074.1	4295.7
		17.46	2.957	17170.4	5806.9
45.00	9.00	14.57	1.825	4903.7	2686.4
		15.57	2.112	8534.0	4040.2
		16.57	2.965	16233.4	5475.6
45.00	8.00	13.67	1.837	4579.3	2493.4
		14.67	2.115	7966.6	3766.8
		15.67	2.672	13702.9	5129.0
		16.67	15.940	105852.9	6640.8
46.00	17.00	21.17	1.701	3595.1	2113.2
		22.17	1.895	7655.5	4040.2
		23.17	2.870	17426.1	6072.2

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
46.00	16.00	20.28	1.680	3522.1	2096.6
		21.28	1.902	7520.8	3954.5
		22.28	2.870	16946.0	5904.2
46.00	15.00	19.38	1.660	3431.0	2066.8
		20.38	1.910	7353.8	3851.0
		21.38	2.872	16424.5	5718.8
46.00	14.00	18.49	1.642	3322.1	2023.4
		19.49	1.918	7154.0	3729.5
		20.49	2.876	15863.8	5516.0
46.00	13.00	18.59	1.928	6921.7	3590.1
		19.59	2.883	15265.8	5295.5
		20.59	2.955	21461.9	7262.1
46.00	12.00	17.70	1.939	6657.4	3432.8
		18.70	2.893	14632.9	5057.5
		19.70	2.953	20478.4	6934.1
46.00	11.00	16.80	1.953	6362.4	3257.7
		17.80	2.909	13968.0	4802.0
		18.80	2.954	19453.5	6584.7
46.00	10.00	15.91	1.970	6037.9	3064.6
		16.91	2.931	13274.0	4529.5
		17.91	2.961	18397.0	6213.9
46.00	9.00	15.01	1.993	5685.8	2853.6
		16.01	2.961	12554.9	4240.4
		17.01	2.974	17316.3	5822.1
		18.01	23.022	180976.8	7860.9
46.00	8.00	15.12	2.871	11300.8	3935.6
		16.12	2.998	16218.6	5409.8
		17.12	24.784	181638.0	7328.9
47.00	17.00	21.62	1.664	4051.4	2435.1
		22.62	2.046	9050.3	4422.5
		23.62	2.917	19227.3	6590.6
47.00	16.00	20.72	1.681	4023.1	2393.9
		21.72	2.064	8875.3	4301.0
		22.72	2.917	18656.0	6396.5
47.00	15.00	20.83	2.082	8662.2	4161.5
		21.83	2.919	18045.2	6182.5
47.00	14.00	19.93	2.317	9277.0	4004.0
		20.93	2.925	17396.8	5948.3
		21.93	2.826	23718.2	8392.2
47.00	13.00	19.04	2.749	10521.8	3827.6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
47.00	13.00	20.04	2.935	16712.9	5693.6
		21.04	2.814	22642.6	8047.0
47.00	12.00	18.14	2.969	10786.2	3633.1
		19.14	2.952	15995.8	5418.1
		20.14	2.805	21537.5	7677.3
47.00	11.00	17.25	3.015	10314.0	3421.1
		18.25	2.977	15248.0	5121.6
		19.25	2.802	20408.3	7283.0
47.00	10.00	17.35	3.013	14472.3	4804.1
		18.35	2.806	19259.9	6863.9
		19.35	26.612	250333.9	9407.0
47.00	9.00	16.46	3.062	13672.0	4465.5
		17.46	2.819	18097.2	6419.7
		18.46	27.783	245721.6	8844.3
47.00	8.00	15.57	3.128	12844.7	4106.7
		16.57	12.652	75298.1	5951.6
		17.57	28.981	239210.0	8253.9
		18.57	29.874	330440.3	11061.1
48.00	17.00	22.06	1.846	4993.4	2705.4
		23.06	2.975	14187.2	4769.6
		24.06	2.859	20868.8	7299.0
48.00	16.00	22.17	2.988	13806.8	4620.8
		23.17	2.855	20210.6	7078.3
48.00	15.00	21.27	3.007	13389.0	4453.4
		22.27	2.855	19514.9	6835.6
		23.27	2.640	25731.2	9747.2
48.00	14.00	20.38	3.032	12935.7	4267.0
		21.38	2.859	18783.9	6570.6
		22.38	2.618	24586.6	9389.8
48.00	13.00	19.49	3.065	12448.6	4061.1
		20.49	2.868	18019.5	6282.6
		21.49	6.322	56937.7	9006.0
48.00	12.00	18.59	3.111	11930.2	3835.4
		19.59	2.881	17203.6	5971.4
		20.59	13.184	113322.2	8595.7
		21.59	26.957	316885.2	11755.4
48.00	11.00	18.70	2.898	16332.7	5636.5
		19.70	16.909	137943.4	8158.2
		20.70	27.418	307137.6	11202.2
48.00	10.00	17.80	2.923	15429.7	5278.8

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
48.00	10.00	18.80	19.768	152106.1	7694.7
		19.80	27.925	296551.0	10619.5
48.00	9.00	16.91	2.961	14502.9	4897.3
		17.91	22.210	159995.3	7203.9
		18.91	28.505	285218.8	10006.0
		19.91	26.512	353632.8	13338.7
48.00	8.00	17.01	24.450	163443.3	6684.8
		18.01	29.189	273220.0	9360.4
		19.01	26.876	337358.9	12552.3
49.00	17.00	23.51	2.962	15588.8	5262.2
		24.51	2.740	22346.2	8154.6
49.00	16.00	22.62	2.972	15127.8	5090.7
		23.62	2.728	21563.3	7905.6
		24.62	14.079	158838.1	11281.6
49.00	15.00	21.72	2.987	14631.4	4898.7
		22.72	2.714	20717.8	7632.6
		23.72	17.363	189513.3	10914.8
49.00	14.00	20.83	3.009	14101.7	4685.8
		21.83	2.703	19828.0	7335.4
		22.83	19.842	208750.0	10520.6
49.00	13.00	19.93	3.042	13540.6	4451.4
		20.93	2.695	18903.3	7013.4
		21.93	21.869	220835.8	10098.1
		22.93	24.817	341321.2	13753.5
49.00	12.00	20.04	2.693	17952.8	6667.3
		21.04	23.619	227890.8	9648.5
		22.04	25.072	330584.2	13185.6
49.00	11.00	19.14	2.697	16981.0	6296.3
		20.14	25.192	231024.0	9170.6
		21.14	25.356	319138.8	12586.1
49.00	10.00	18.25	2.711	15992.0	5898.9
		19.25	26.573	230196.5	8662.8
		20.25	25.687	307044.5	11953.2
		21.25	23.874	377240.6	15801.1
49.00	9.00	18.36	27.507	223488.3	8124.7
		19.36	26.083	294379.7	11286.4
		20.36	24.051	360566.1	14991.4
49.00	8.00	17.46	28.546	215686.2	7555.7
		18.46	26.567	281217.5	10585.1
		19.46	24.294	343615.6	14144.0

Table of B.A

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

Center X(m),Y(m)

Y(m)	X(m)	40.00	41.00	42.00	43.00	44.00	45.00
17.00	Fs	2.522	2.300	2.129	1.989	1.874	1.779
	R(m)	19.24	19.43	19.68	19.98	20.34	20.73
16.00	Fs	2.476	2.261	2.093	1.957	1.846	1.755
	R(m)	18.26	18.46	18.72	19.04	19.41	19.83
15.00	Fs	2.431	2.223	2.059	1.926	1.819	1.731
	R(m)	17.27	17.49	17.77	18.11	18.50	18.94
14.00	Fs	2.387	2.185	2.025	1.897	1.793	1.709
	R(m)	16.29	16.53	16.82	17.18	17.59	18.04
13.00	Fs	2.345	2.149	1.993	1.868	1.768	1.689
	R(m)	15.31	15.56	15.88	16.26	16.70	17.15
12.00	Fs	2.305	2.113	1.962	1.841	1.745	1.815
	R(m)	14.34	14.61	14.95	15.36	15.80	17.25
11.00	Fs	2.268	2.080	1.932	1.816	1.726	1.816
	R(m)	13.37	13.66	14.03	14.46	14.91	16.36
10.00	Fs	2.232	2.049	1.905	1.794	1.764	1.819
	R(m)	12.40	12.72	13.12	13.57	15.02	15.46
9.00	Fs	2.200	2.021	1.882	1.805	1.755	1.825
	R(m)	11.45	11.80	12.23	13.67	14.12	14.57
8.00	Fs	2.173	1.997	1.863	1.784	1.750	1.837
	R(m)	10.50	10.89	11.33	12.78	13.23	13.67

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

Center X(m),Y(m)

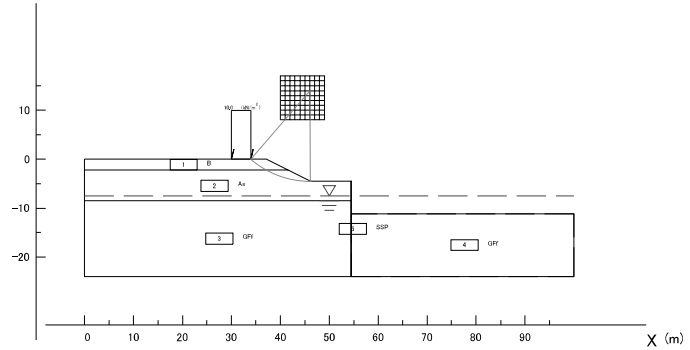
Y(m)	X(m)	46.00	47.00	48.00	49.00
17.00	Fs	1.701	1.664	1.846	2.740
	R(m)	21.17	21.62	22.06	24.51
16.00	Fs	1.680	1.681	2.855	2.728
	R(m)	20.28	20.72	23.17	23.62
15.00	Fs	1.660	2.082	2.640	2.714
	R(m)	19.38	20.83	23.27	22.72
14.00	Fs	1.642	2.317	2.618	2.703
	R(m)	18.49	19.93	22.38	21.83
13.00	Fs	1.928	2.749	2.868	2.695
	R(m)	18.59	19.04	20.49	20.93
12.00	Fs	1.939	2.805	2.881	2.693
	R(m)	17.70	20.14	19.59	20.04
11.00	Fs	1.953	2.802	2.898	2.697
	R(m)	16.80	19.25	18.70	19.14
10.00	Fs	1.970	2.806	2.923	2.711
	R(m)	15.91	18.35	17.80	18.25
9.00	Fs	1.993	2.819	2.961	24.051
	R(m)	15.01	17.46	16.91	20.36
8.00	Fs	2.871	3.128	24.450	24.294
	R(m)	15.12	15.57	17.01	19.46

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	1.642
Failure circle X(m)	=	46.00
Y(m)	=	14.00
R(m)	=	18.487
Resisting moment(kNm)	=	3322.1
Sliding moment(kNm)	=	2023.4
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



4. Action02 (seismic)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	5	19.00	18.00	9.00	1.00	0.00	30.00	0.00	0.00	0.0
2	6	18.50	17.50	8.50	0.00	0.00	32.00	0.00	0.00	0.0
3	8	18.00	17.00	8.00	1000.0	0 0.0	030.0	0 0.0	0 0.0	0 0.
0	4	8 18.0	0 17.0	0 8.0	01000.	00 0.	0030.	00 0.	00 0.	00 0
0.0	5	2 77.	00 77.	00 67.	001000	0.00	0.00	0.00	0.00	0.00
0.0										

// Distribution load that considers partial coefficient //

Load No.	Left			Right			Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)			
2	30.01	0.00	5.0	34.01	0.00	5.0	0.000	0.200	0.000

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

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	-7.51	
2	100.00	-7.51	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
40.00	17.00	18.24	1.624	738.8	454.8
		19.24	1.435	2481.3	1729.4
40.00	16.00	17.26	1.608	684.4	425.5
		18.26	1.415	2304.1	1627.9
40.00	15.00	16.27	1.592	632.0	396.9
		17.27	1.396	2133.2	1528.4
40.00	14.00	15.29	1.576	581.8	369.1
		16.29	1.376	1968.5	1431.0
40.00	13.00	15.31	1.356	1811.4	1335.8
		16.31	1.372	3926.1	2861.7
40.00	12.00	14.34	1.337	1661.5	1243.0
		15.34	1.354	3611.9	2666.9
40.00	11.00	13.37	1.317	1518.1	1152.8
		14.37	1.336	3309.9	2476.8
40.00	10.00	12.40	1.297	1381.8	1065.6
		13.40	1.318	3020.9	2292.0
40.00	9.00	11.45	1.276	1252.9	981.6
		12.45	1.300	2746.0	2113.1
		13.45	1.329	4867.1	3661.9
40.00	8.00	-11.50	999.000	0.0	0.0
		-10.50	999.000	0.0	0.0
		10.50	1.256	1132.5	901.5
		11.50	1.281	2486.9	1941.0
		12.50	1.314	4426.3	3368.6
41.00	17.00	18.43	1.526	718.8	470.9
		19.43	1.339	2432.7	1816.3
41.00	16.00	17.46	1.509	672.1	445.4
		18.46	1.321	2277.0	1723.1
41.00	15.00	17.49	1.303	2127.0	1632.3
		18.49	1.321	4585.4	3471.1
41.00	14.00	16.53	1.284	1983.0	1544.1
		17.53	1.304	4279.0	3281.7
41.00	13.00	15.56	1.265	1845.3	1458.8
		16.56	1.286	3984.3	3097.2
41.00	12.00	14.61	1.245	1714.4	1376.7
		15.61	1.269	3702.1	2918.0
41.00	11.00	13.66	1.225	1590.8	1298.1
		14.66	1.251	3433.3	2744.9
41.00	10.00	12.72	1.206	1475.3	1223.8
		13.72	1.233	3179.4	2578.8

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
41.00	10.00	14.72	1.266	5574.3	4402.3
41.00	9.00	11.80	1.186	1368.9	1154.4
		12.80	1.215	2941.9	2420.7
		13.80	1.251	5163.1	4126.0
41.00	8.00	-11.11	999.000	0.0	0.0
		10.89	1.167	1272.9	1091.1
		11.89	1.198	2723.3	2272.5
		12.89	1.237	4781.2	3864.5
42.00	17.00	19.68	1.261	2465.4	1955.7
		20.68	1.280	5287.9	4130.2
42.00	16.00	18.72	1.243	2327.5	1873.0
		19.72	1.264	4989.8	3947.7
42.00	15.00	17.77	1.224	2196.0	1793.5
		18.77	1.247	4703.1	3770.3
42.00	14.00	16.82	1.206	2071.1	1717.5
		17.82	1.231	4428.4	3598.5
42.00	13.00	15.88	1.187	1953.5	1645.6
		16.88	1.214	4166.8	3433.1
42.00	12.00	14.95	1.168	1843.9	1578.2
		15.95	1.197	3919.3	3274.8
		16.95	1.230	6794.8	5524.3
42.00	11.00	14.03	1.150	1743.2	1516.3
		15.03	1.180	3687.5	3124.7
		16.03	1.215	6387.7	5255.3
42.00	10.00	13.12	1.131	1652.5	1460.8
		14.12	1.164	3473.2	2984.3
		15.12	1.202	6007.8	5000.1
42.00	9.00	12.23	1.113	1565.7	1406.1
		13.23	1.148	3267.5	2846.2
		14.23	1.188	5644.2	4749.2
42.00	8.00	11.33	1.096	1465.8	1336.9
		12.33	1.133	3045.8	2689.2
		13.33	1.176	5263.1	4475.8
		14.33	1.249	8338.8	6677.1
43.00	17.00	19.98	1.192	2568.3	2154.7
		20.98	1.216	5462.0	4492.1
43.00	16.00	19.04	1.175	2449.9	2085.8
		20.04	1.200	5195.7	4329.1
43.00	15.00	18.11	1.157	2338.9	2021.3
		19.11	1.184	4942.0	4172.8

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
43.00	14.00	17.18	1.140	2235.9	1962.0
		18.18	1.169	4702.2	4024.0
43.00	13.00	16.26	1.122	2141.7	1908.5
		17.26	1.153	4477.4	3883.7
		18.26	1.200	7758.4	6464.4
43.00	12.00	15.36	1.105	2057.6	1862.0
		16.36	1.138	4269.4	3753.2
		17.36	1.190	7395.7	6215.4
43.00	11.00	14.46	1.088	1976.7	1816.4
		15.46	1.123	4068.5	3624.5
		16.46	1.180	7045.7	5968.8
43.00	10.00	13.57	1.072	1881.6	1755.4
		14.57	1.108	3849.9	3475.7
		15.57	1.171	6672.0	5697.7
43.00	9.00	13.67	1.093	3613.5	3306.0
		14.67	1.162	6274.2	5401.4
		15.67	1.259	9967.2	7918.4
43.00	8.00	12.78	1.079	3360.9	3115.3
		13.78	1.152	5854.0	5080.4
		14.78	1.251	9306.4	7441.6
44.00	17.00	20.34	1.133	2745.4	2423.4
		21.34	1.160	5756.0	4960.5
44.00	16.00	19.41	1.117	2649.6	2372.9
		20.41	1.146	5524.7	4822.6
44.00	15.00	18.50	1.100	2562.7	2328.8
		19.50	1.131	5308.2	4693.5
		20.50	1.210	9388.9	7756.8
44.00	14.00	17.59	1.085	2485.9	2292.2
		18.59	1.117	5108.0	4574.5
		19.59	1.204	9044.4	7514.2
44.00	13.00	16.70	1.069	2412.0	2256.6
		17.70	1.103	4916.8	4457.4
		18.70	1.198	8709.5	7272.4
44.00	12.00	15.80	1.053	2323.1	2205.2
		16.80	1.091	4714.0	4319.6
		17.80	1.191	8345.0	7004.2
44.00	11.00	14.91	1.038	2218.9	2136.8
		15.91	1.081	4495.4	4159.3
		16.91	1.185	7950.5	6708.8
44.00	10.00	15.02	1.071	4259.2	3975.8

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
44.00	10.00	16.02	1.179	7527.6	6386.8
		17.02	1.288	11898.3	9238.8
44.00	9.00	14.12	1.063	4005.0	3769.0
		15.12	1.172	7078.0	6038.8
		16.12	1.281	11182.5	8726.8
44.00	8.00	13.23	1.055	3733.3	3539.1
		14.23	1.166	6604.2	5665.4
		15.23	1.275	10440.4	8188.9
45.00	17.00	20.73	1.083	3004.6	2775.3
		21.73	1.120	6226.1	5559.1
45.00	16.00	19.83	1.068	2935.8	2749.3
		20.83	1.113	6072.1	5457.2
		21.83	1.234	11000.5	8911.4
45.00	15.00	18.94	1.053	2869.8	2724.6
		19.94	1.107	5928.8	5355.5
		20.94	1.231	10682.1	8674.8
45.00	14.00	18.04	1.039	2788.0	2683.6
		19.04	1.102	5764.3	5229.9
		20.04	1.228	10328.5	8410.0
45.00	13.00	17.15	1.025	2690.1	2625.1
		18.15	1.098	5575.8	5079.1
		19.15	1.225	9939.4	8116.2
45.00	12.00	17.25	1.094	5362.7	4902.9
		18.25	1.221	9515.9	7794.0
45.00	11.00	16.36	1.090	5125.1	4701.3
		17.36	1.217	9059.9	7443.8
		18.36	1.632	17369.4	10640.5
45.00	10.00	15.46	1.087	4863.4	4474.5
		16.46	1.213	8573.4	7066.3
		17.46	1.635	16499.6	10091.9
45.00	9.00	14.57	1.084	4578.9	4222.9
		15.57	1.210	8058.8	6662.3
		16.57	1.639	15597.5	9518.6
45.00	8.00	13.67	1.083	4273.0	3946.9
		14.67	1.206	7518.9	6232.6
		15.67	1.469	13103.7	8922.3
		16.67	8.677	105069.2	12109.5
46.00	17.00	21.17	1.040	3348.5	3218.5
		22.17	1.136	7195.1	6334.9
		23.17	1.643	16739.2	10188.4

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
46.00	16.00	20.28	1.027	3274.6	3188.7
		21.28	1.136	7067.1	6220.9
		22.28	1.640	16274.4	9926.3
46.00	15.00	19.38	1.014	3183.9	3141.0
		20.38	1.136	6908.6	6079.7
		21.38	1.637	15770.3	9633.8
46.00	14.00	18.49	1.001	3077.0	3074.9
		19.49	1.137	6719.4	5911.1
		20.49	1.636	15228.9	9311.2
46.00	13.00	18.59	1.137	6499.6	5715.1
		19.59	1.636	14652.4	8958.9
		20.59	1.608	20614.3	12822.1
46.00	12.00	17.70	1.138	6250.0	5492.1
		18.70	1.637	14043.0	8577.7
		19.70	1.604	19664.4	12260.4
46.00	11.00	16.80	1.139	5971.5	5242.3
		17.80	1.641	13403.7	8168.2
		18.80	1.601	18675.6	11667.0
46.00	10.00	15.91	1.141	5665.5	4966.2
		16.91	1.647	12737.4	7731.5
		17.91	1.599	17657.6	11042.7
46.00	9.00	15.01	1.144	5334.0	4664.3
		16.01	1.657	12047.9	7269.0
		17.01	1.600	16618.1	10388.4
		18.01	12.640	180034.2	14243.7
46.00	8.00	15.12	1.596	10825.5	6782.5
		16.12	1.604	15564.1	9705.4
		17.12	13.549	180753.2	13341.1
47.00	17.00	21.62	1.016	3760.9	3700.3
		22.62	1.190	8539.0	7175.6
		23.62	1.629	18464.2	11336.2
47.00	16.00	20.72	1.020	3734.2	3662.3
		21.72	1.194	8374.6	7014.8
		22.72	1.625	17910.9	11021.4
47.00	15.00	20.83	1.198	8174.1	6824.9
		21.83	1.623	17320.2	10674.4
47.00	14.00	19.93	1.333	8803.5	6606.1
		20.93	1.622	16694.4	10295.3
		21.93	1.539	22725.7	14769.2
47.00	13.00	19.04	1.583	10064.8	6358.2

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
47.00	13.00	20.04	1.622	16035.5	9884.4
		21.04	1.529	21685.1	14178.1
47.00	12.00	18.14	1.701	10347.7	6081.9
		19.14	1.625	15345.7	9442.2
		20.14	1.521	20618.1	13552.1
47.00	11.00	17.25	1.713	9896.0	5778.2
		18.25	1.631	14627.8	8969.0
		19.25	1.515	19529.7	12891.8
47.00	10.00	17.35	1.640	13884.4	8465.7
		18.35	1.511	18425.1	12197.6
		19.35	14.932	249197.2	16688.5
47.00	9.00	16.46	1.654	13118.9	7933.0
		17.46	1.509	17309.1	11470.3
		18.46	15.542	244645.7	15741.0
47.00	8.00	15.57	1.672	12328.9	7373.8
		16.57	6.960	74559.7	10712.2
		17.57	16.138	238198.1	14760.2
		18.57	16.815	329105.1	19572.2
48.00	17.00	22.06	1.087	4664.4	4290.0
		23.06	1.690	13622.5	8062.1
		24.06	1.585	20007.7	12622.3
48.00	16.00	22.17	1.688	13254.9	7853.1
		23.17	1.581	19370.2	12255.3
48.00	15.00	21.27	1.688	12852.2	7613.8
		22.27	1.577	18697.8	11854.7
		23.27	1.451	24569.0	16933.0
48.00	14.00	20.38	1.691	12416.0	7344.4
		21.38	1.575	17992.5	11420.7
		22.38	1.438	23460.5	16316.7
48.00	13.00	19.49	1.696	11948.3	7045.1
		20.49	1.575	17256.7	10953.4
		21.49	3.566	55850.9	15663.7
48.00	12.00	18.59	1.705	11451.5	6716.1
		19.59	1.576	16471.9	10453.9
		20.59	7.498	112277.9	14973.7
		21.59	15.537	315470.2	20304.4
48.00	11.00	18.70	1.576	15634.9	9922.9
		19.70	9.612	136944.8	14247.2
		20.70	15.795	305782.6	19359.5
48.00	10.00	17.80	1.578	14768.6	9361.9

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment
X (m)	Y (m)	R (m)		(kNm)	(kNm)
48.00	10.00	18.80	11.207	151156.3	13487.4
		19.80	16.065	295259.3	18378.7
48.00	9.00	16.91	1.583	13881.2	8770.4
		17.91	12.534	159097.6	12693.5
		18.91	16.358	283993.9	17361.2
		19.91	15.422	352032.4	22826.4
48.00	8.00	17.01	13.704	162601.0	11865.1
		18.01	16.685	272065.5	16306.2
		19.01	15.604	335844.2	21523.5
49.00	17.00	23.51	1.651	14952.6	9055.6
		24.51	1.526	21370.4	14002.9
49.00	16.00	22.62	1.648	14506.8	8800.1
		23.62	1.517	20611.3	13584.3
		24.62	8.176	157486.2	19262.3
49.00	15.00	21.72	1.648	14027.9	8513.2
		22.72	1.507	19792.3	13132.0
		23.72	10.107	188198.5	18621.2
49.00	14.00	20.83	1.650	13518.2	8195.1
		21.83	1.497	18931.9	12645.7
		22.83	11.564	207475.7	17942.2
49.00	13.00	19.93	1.654	12979.5	7845.8
		20.93	1.488	18039.3	12125.3
		21.93	12.749	219605.4	17225.1
		22.93	14.660	339673.8	23169.8
49.00	12.00	20.04	1.480	17123.8	11573.0
		21.04	13.762	226707.4	16473.4
		22.04	14.822	328998.4	22196.8
49.00	11.00	19.14	1.473	16190.0	10988.2
		20.14	14.656	229891.0	15685.8
		21.14	14.992	317618.1	21185.3
49.00	10.00	18.25	1.470	15241.9	10369.5
		19.25	15.417	229117.5	14861.4
		20.25	15.178	305592.5	20134.1
		21.25	14.305	375356.5	26239.0
49.00	9.00	18.36	15.890	222467.5	14000.5
		19.36	15.386	293000.3	19043.6
		20.36	14.410	358770.1	24897.3
49.00	8.00	17.46	16.386	214727.2	13104.0
		18.46	15.625	279914.5	17914.5
		19.46	14.541	341911.9	23514.3

Table of B.A.

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

Center X(m),Y(m)

Y(m)	X(m)	40.00	41.00	42.00	43.00	44.00	45.00
17.00	Fs	1.435	1.339	1.261	1.192	1.133	1.083
	R(m)	19.24	19.43	19.68	19.98	20.34	20.73
16.00	Fs	1.415	1.321	1.243	1.175	1.117	1.068
	R(m)	18.26	18.46	18.72	19.04	19.41	19.83
15.00	Fs	1.396	1.303	1.224	1.157	1.100	1.053
	R(m)	17.27	17.49	17.77	18.11	18.50	18.94
14.00	Fs	1.376	1.284	1.206	1.140	1.085	1.039
	R(m)	16.29	16.53	16.82	17.18	17.59	18.04
13.00	Fs	1.356	1.265	1.187	1.122	1.069	1.025
	R(m)	15.31	15.56	15.88	16.26	16.70	17.15
12.00	Fs	1.337	1.245	1.168	1.105	1.053	1.094
	R(m)	14.34	14.61	14.95	15.36	15.80	17.25
11.00	Fs	1.317	1.225	1.150	1.088	1.038	1.090
	R(m)	13.37	13.66	14.03	14.46	14.91	16.36
10.00	Fs	1.297	1.206	1.131	1.072	1.071	1.087
	R(m)	12.40	12.72	13.12	13.57	15.02	15.46
9.00	Fs	1.276	1.186	1.113	1.093	1.063	1.084
	R(m)	11.45	11.80	12.23	13.67	14.12	14.57
8.00	Fs	1.256	1.167	1.096	1.079	1.055	1.083
	R(m)	10.50	10.89	11.33	12.78	13.23	13.67

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

Center X(m),Y(m)

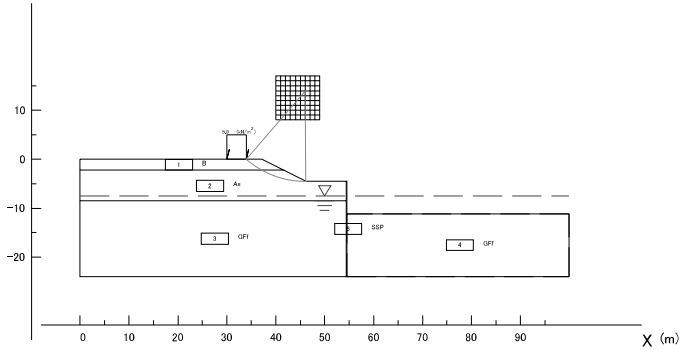
Y(m)	X(m)	46.00	47.00	48.00	49.00
17.00	Fs	1.040	1.016	1.087	1.526
	R(m)	21.17	21.62	22.06	24.51
16.00	Fs	1.027	1.020	1.581	1.517
	R(m)	20.28	20.72	23.17	23.62
15.00	Fs	1.014	1.198	1.451	1.507
	R(m)	19.38	20.83	23.27	22.72
14.00	Fs	1.001	1.333	1.438	1.497
	R(m)	18.49	19.93	22.38	21.83
13.00	Fs	1.137	1.529	1.575	1.488
	R(m)	18.59	21.04	20.49	20.93
12.00	Fs	1.138	1.521	1.576	1.480
	R(m)	17.70	20.14	19.59	20.04
11.00	Fs	1.139	1.515	1.576	1.473
	R(m)	16.80	19.25	18.70	19.14
10.00	Fs	1.141	1.511	1.578	1.470
	R(m)	15.91	18.35	17.80	18.25
9.00	Fs	1.144	1.509	1.583	14.410
	R(m)	15.01	17.46	16.91	20.36
8.00	Fs	1.596	1.672	13.704	14.541
	R(m)	15.12	15.57	17.01	19.46

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio		
	=	1.001
Failure circle X(m)	=	46.00
Y(m)	=	14.00
R(m)	=	18.487
Resisting moment(kNm)	=	3077.0
Sliding moment(kNm)	=	3074.9
Partial coefficient concerning analytical technique		
	=	1.0

// Check Result chart //



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

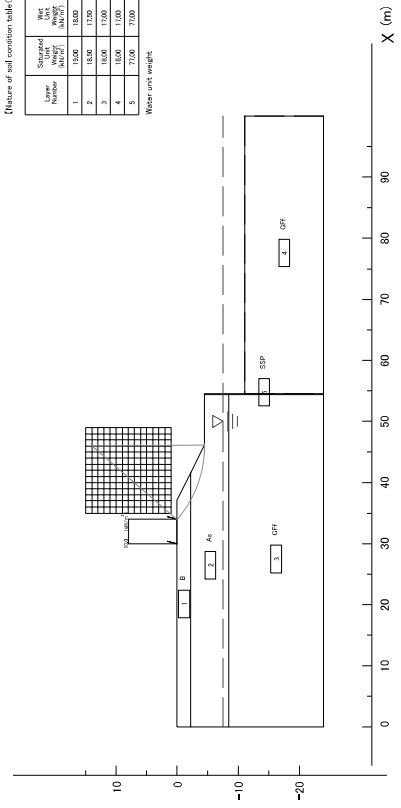
Scale : 1/ 792

Required Bearing force Action ratio	F S =	1.000	≧ 1.0 (OK)
Bearing force Action ratio	=	1.642	
Center of arc	X =	46.00	(m)
	Y =	14.00	(m)
Radius	R =	18.487	(m)
Resisting moment	MR =	3322.1	(kNm)
Sliding moment	MD =	2023.4	(kNm)
Partial coefficient concerning	γ α =	1.00	

[Nature of soil condition table(Input value)]

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Fiction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	19.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	17.00	32.00	0.00	0.00	0.000	0.000
3	18.00	17.00	30.00	1000.00	0.00	0.000	0.000
4	18.00	17.00	30.00	1000.00	0.00	0.000	0.000
5	77.00	77.00	0.00	1000.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



Safety Factor (Ordinary Condition)

Test of Embankment Stability

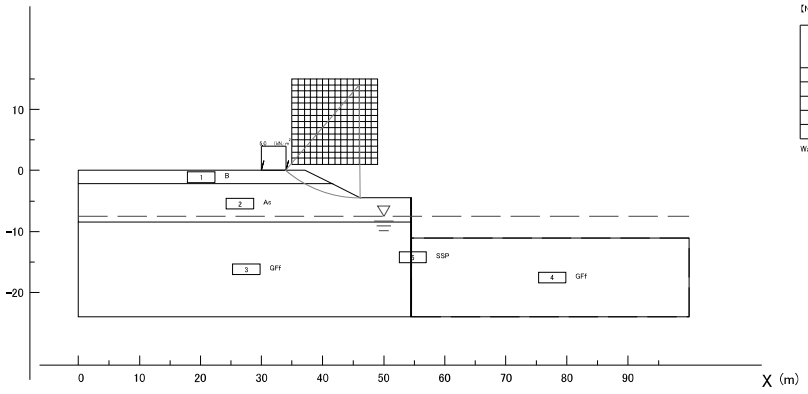
Action number = 2

Action name : seismic

Examination at earthquake : It does.

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	1.001	≧ 1.0 (OK)
Center of arc	X	=	46.00	(m)
	Y	=	14.00	(m)
Radius	R	=	18.487	(m)
Resisting moment	M_R	=	3077.0	(kNm)
Sliding moment	M_D	=	3074.9	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.200	0.000
2	18.50	17.50	32.00	0.00	0.00	0.200	0.000
3	18.00	17.00	30.00	1000.00	0.00	0.200	0.000
4	18.00	17.00	30.00	1000.00	0.00	0.200	0.000
5	77.00	77.00	0.00	1000.00	0.00	0.200	0.000

Water unit weight = 10.00 (kN/m³)

Safety Factor (Seismic Condition)

1.2.1 SLOPE STABILITY　ANALYSIS

1.2.1.1　Normal and Seismic Conditions

(4)　L7+820

Circular Slip Surface

L7+820

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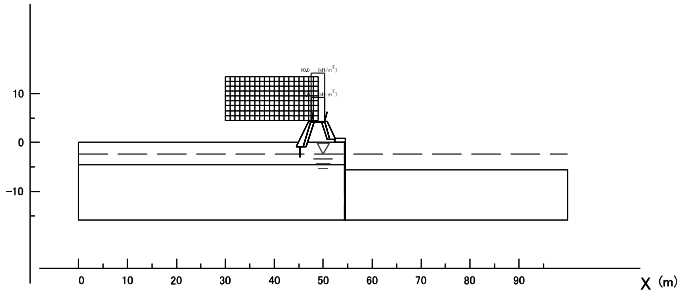
1. Input data list

// Design section //



// Design level of reliability design method //

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

// Combination of action //

// Setting of action //

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

// Partial coefficient concerning analytical technique γ_α //

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

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

No.	Action 1			Action 2										
	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$
1	1.00	1.00	1.00	1.00	1.00	1.00						
2	1.00	1.00	1.00	1.00	1.00	1.00						
3	1.00	1.00	1.00	1.00	1.00	1.00						
4	1.00	1.00	1.00	1.00	1.00	1.00						
5	1.00	1.00	1.00	1.00	1.00	1.00						
6	1.00	1.00	1.00	1.00	1.00	1.00						
7	1.00	1.00	1.00	1.00	1.00	1.00						
8	1.00	1.00	1.00	1.00	1.00	1.00						
9	1.00	1.00	1.00	1.00	1.00	1.00						
10	1.00	1.00	1.00	1.00	1.00	1.00						
11	1.00	1.00	1.00	1.00	1.00	1.00						
12	1.00	1.00	1.00	1.00	1.00	1.00						

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

$$W_d' = \gamma_w W_k'$$

$$C_d = \gamma_c C_k$$

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

M : Resistance moment

γ_w : Partial coefficient concerning weight

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

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

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

γ_c : Partial coefficient concerning Cohesion

C_d : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (value for design) (kN/m²)

C_k : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (characteristic value) (kN/m²)

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

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

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

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

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

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

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

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

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

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

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

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

K : Resistance power coefficient

r : Radius of slipping circular arc

F : Distribution load i

FR : Slipping line orthogonalization direction load value of load i

FO : Slipping line direction load value of load i

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

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

K_{hp} : The horizontal seismic intensity

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

ϕ : Internal friction angle of soil

// Partial coefficient to residual water level //

Action number	rRWL
1	1.00
2	1.00

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

γ_{RWL} : Partial coefficient concerning residual water level

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

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

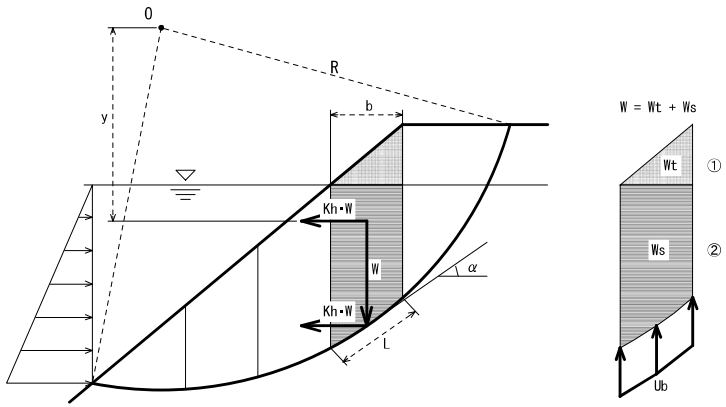
(DATA 01.)　// ANALYSIS //

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

Expression

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

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



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

(DATA 02.)　// CONTROL //

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

(DATA 04.) // SEISMIC LOAD //

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


(DATA 06.) // NODAL POINT //

No.	Coordinate		Y-coordinate
	x (m)	y (m)	before settlement (m)
1	0.00	0.00	0.00
2	44.89	0.00	0.00
3	44.51	-0.75	0.00
4	44.51	-0.90	0.00
5	45.93	-0.90	0.00
6	46.56	-0.90	0.00
7	48.06	4.12	0.00
8	47.44	4.12	0.00
9	47.05	4.32	0.00
10	47.50	4.32	0.00
11	50.28	4.32	0.00
12	50.73	4.32	0.00
13	49.72	4.12	0.00
14	50.34	4.12	0.00
15	50.77	0.60	0.00
16	51.40	0.60	0.00
17	52.34	0.60	0.00
18	52.34	0.80	0.00
19	52.49	0.80	0.00
20	54.49	0.80	0.00
21	54.49	0.00	0.00
22	54.34	0.00	0.00
23	52.34	0.00	0.00
24	54.33	-4.50	0.00
25	54.49	-5.62	0.00
26	100.00	-5.62	0.00
27	100.00	-15.86	0.00
28	54.49	-15.86	0.00
29	54.34	-15.86	0.00
30	0.00	-15.86	0.00
31	0.00	-4.50	0.00
32	46.83	0.00	0.00
33	45.22	-0.90	0.00
34	45.22	-2.90	0.00
35	45.37	-2.90	0.00
36	45.37	-0.90	0.00

(DATA 07.) // WATER LEVEL //

Unit weight of water (kN/m³) = 10.00

Action No.	Water level line number
1	1
2	1

Water level line number: 1

No.	Coordinate	
	X (m)	Y (m)
1	0.00	-2.30
2	100.00	-2.30

Water level line number: 2

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

(DATA 08.) // LAYER //

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

No.	material property No.	The name of the strata
8	5	B
9	6	As
10	7	Dc
11	7	Dc
12	2	SSP

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

(DATA 09.1) // MATERIAL PROPERTIES //

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

(DATA 09.2)　// Characteristic of soil //

No.	Action Number									
	Act 1	Act 2								
1	1	1								
2	1	1								
3	1	1								
4	2	2								
5	3	3								
6	3	3								
7	4	4								
8	5	5								
9	6	6								
10	7	7								
11	7	7								
12	2	2								

(DATA 11.)　// GRID POINT //

No.	Slip direction	Double cutting	GX (m)	GY (m)	X-point	Y-point	X-pitch (m)	Y-pitch (m)	Dx/Dy	NEXCO Radius
1	Upstream	Left lump	30.00	13.50	20	10	1.00	1.00	0.000	0.000

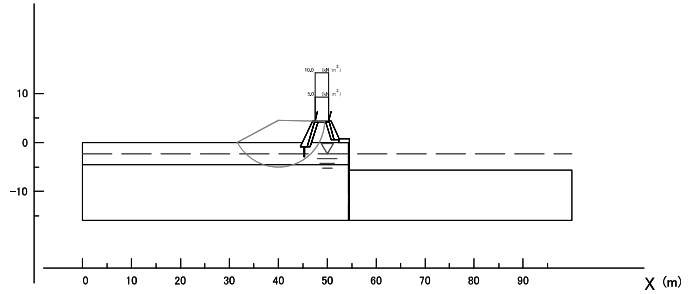
2. Check list

// Check of circular arc //

Action No.	Action name	Bearing force Action ratio	Judgment
1	normal	3.690	OK
2	seismic	1.886	OK

Action No.	Bearing force Action ratio	Partial coefficient r_a	Center of slipping circular arc X (m)	Center of slipping circular arc Y (m)	Radius of circular arc(m)	Resistance Moment (kNm)	Sliding Moment (kNm)
1	3.690	1.00	40.00	4.50	9.500	8593.7	2329.1
2	1.886	1.00	40.00	4.50	9.500	8366.5	4435.0

// Check Result chart //



3. Action01 (normal)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	1	24.00	24.00	14.00	1000.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.
0	2	1 24.0	0 24.0	0 14.0	01000.	00 0.	00 0.	00 0.	00 0.	00 0
0.0	3	1 24.	00 24.	00 14.	001000	0.00	0.00	0.00	0.00	0.00
0.0	4	2 77	0.00 7	0.00 6	0.0010	0.00	0.00	0.00	0.00	0.00
0.0	5	3 2	0.00 1	9.00 1	0.00	0.00	0.003	5.00	0.00	0.00
0.0	6	3 2	0.00 1	9.00 1	0.00	0.00	0.003	5.00	0.00	0.00
0.0	7	4 2	4.00 2	4.00 1	4.00	1.00	0.003	0.00	0.00	0.00
0.0	8	5 1	9.00 1	8.00	9.00	1.00	0.003	0.00	0.00	0.00
0.0	9	6 1	8.50 1	7.50	8.50	0.00	0.002	7.00	0.00	0.00
0.0	10	7 1	9.00 1	8.00	9.0010	0.00	0.00	0.00	0.00	0.00
0.0	11	7 1	9.00 1	8.00	9.0010	0.00	0.00	0.00	0.00	0.00
0.0	12	2 7	7.00 7	7.00 6	7.0010	00.00	0.00	0.00	0.00	0.00
0.	0									

// Distribution load that considers partial coefficient //

	Left			Right			Resisting	H.seismic	P.seismic
load No.	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)	coefficient of load	intensity Khp	intensity Kvp
1	47.50	4.32	10.0	50.28	4.32	10.0	0.000	0.000	0.000

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

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	-2.30	
2	100.00	-2.30	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
30.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	999.000	904.7	0.0	
		15.50	999.000	2771.2	-0.0	
		16.50	999.000	5156.1	0.0	
		17.50	999.000	7727.2	0.0	
		18.50	999.000	21702.8	0.0	
30.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	999.000	811.3	0.0	
		14.50	-1823800.250	2499.5	-0.0	
		15.50	999.000	4674.2	-0.0	
		16.50	999.000	7036.4	0.0	
		17.50	999.000	19912.7	0.0	
30.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	999.000	721.3	0.0	
		13.50	999.000	2237.3	-0.0	
		14.50	999.000	4208.3	0.0	
		15.50	999.000	6367.6	0.0	
		16.50	999.000	18175.0	0.0	
30.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	999.000	635.0	0.0	
		12.50	999.000	1985.1	-0.0	
		13.50	999.000	3759.1	0.0	
		14.50	-3232485.000	5721.6	-0.0	
		15.50	999.000	16491.4	0.0	
30.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	999.000	552.4	0.0	
		11.50	999.000	1743.1	0.0	
		12.50	999.000	3327.2	-0.0	
		13.50	999.000	5099.2	0.0	
		14.50	-9019524.000	14863.7	-0.0	
30.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	999.000	473.7	0.0	
		10.50	999.000	1511.9	0.0	
		11.50	999.000	2913.4	0.0	
		12.50	999.000	4501.4	0.0	
		13.50	999.000	13293.9	-0.0	
30.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	999.000	399.1	0.0	
		9.50	999.000	1291.9	-0.0	
		10.50	999.000	2518.4	0.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
30.00	7.50	11.50	999.000	3929.3	-0.0	
		12.50	999.000	11784.3	-0.0	
30.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	-0.0	
		8.50	999.000	1083.9	0.0	
		9.50	999.000	2143.2	0.0	
		10.50	999.000	3384.0	-0.0	
		11.50	999.000	10337.3	0.0	
30.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	-0.0	
		7.50	999.000	888.4	0.0	
		8.50	999.000	1788.9	-0.0	
		9.50	999.000	2867.0	0.0	
		10.50	999.000	8956.0	-0.0	
30.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	
		7.50	999.000	1457.0	-0.0	
		8.50	999.000	2380.0	0.0	
		9.50	999.000	7643.5	-0.0	
31.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	999.000	904.7	0.0	
		15.50	999.000	2771.2	-0.0	
		16.50	999.000	5156.1	0.0	
		17.50	999.000	7727.2	0.0	
31.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	999.000	811.3	0.0	
		14.50	-1823800.250	2499.5	-0.0	
		15.50	999.000	4674.2	-0.0	
		16.50	999.000	7036.4	0.0	
		17.50	999.000	19912.7	0.0	
31.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	999.000	721.3	0.0	
		13.50	999.000	2237.3	-0.0	
		14.50	999.000	4208.3	0.0	
		15.50	999.000	6367.6	0.0	
		16.50	999.000	18175.0	0.0	
31.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	999.000	635.0	0.0	
		12.50	999.000	1985.1	-0.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
31.00	10.50	13.50	999.000	3759.1	0.0	
		14.50	-3232485.000	5721.6	-0.0	
		15.50	999.000	16491.4	0.0	
31.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	999.000	552.4	0.0	
		11.50	999.000	1743.1	0.0	
		12.50	999.000	3327.2	-0.0	
		13.50	999.000	5099.2	0.0	
		14.50	-9019524.000	14863.7	-0.0	
31.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	999.000	473.7	0.0	
		10.50	999.000	1511.9	0.0	
		11.50	999.000	2913.4	0.0	
		12.50	999.000	4501.4	0.0	
		13.50	999.000	13293.9	-0.0	
31.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	999.000	399.1	0.0	
		9.50	999.000	1291.9	-0.0	
		10.50	999.000	2518.4	0.0	
		11.50	999.000	3929.3	-0.0	
		12.50	999.000	11784.3	-0.0	
31.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	-0.0	
		8.50	999.000	1083.9	0.0	
		9.50	999.000	2143.2	0.0	
		10.50	999.000	3384.0	-0.0	
		11.50	999.000	10337.3	0.0	
31.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	-0.0	
		7.50	999.000	888.4	0.0	
		8.50	999.000	1788.9	-0.0	
		9.50	999.000	2867.0	0.0	
		10.50	999.000	8956.0	-0.0	
31.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	
		7.50	999.000	1457.0	-0.0	
		8.50	999.000	2380.0	0.0	
		9.50	999.000	7643.5	-0.0	
32.00	13.50	13.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
32.00	13.50	14.50	999.000	904.7	0.0	
		15.50	999.000	2771.2	-0.0	
		16.50	999.000	5156.1	0.0	
		17.50	999.000	7727.2	0.0	
32.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	999.000	811.3	0.0	
		14.50	-1823800.250	2499.5	-0.0	
		15.50	999.000	4674.2	-0.0	
32.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	999.000	721.3	0.0	
		13.50	999.000	2237.3	-0.0	
		14.50	999.000	4208.3	0.0	
		15.50	999.000	6367.6	0.0	
32.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	999.000	635.0	0.0	
		12.50	999.000	1985.1	-0.0	
		13.50	999.000	3759.1	0.0	
		14.50	-3232485.000	5721.6	-0.0	
		15.50	999.000	16491.4	0.0	
32.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	999.000	552.4	0.0	
		11.50	999.000	1743.1	0.0	
		12.50	999.000	3327.2	-0.0	
		13.50	999.000	5099.2	0.0	
		14.50	-9019524.000	14863.7	-0.0	
32.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	999.000	473.7	0.0	
		10.50	999.000	1511.9	0.0	
		11.50	999.000	2913.4	0.0	
		12.50	999.000	4501.4	0.0	
		13.50	999.000	13293.9	-0.0	
32.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	999.000	399.1	0.0	
		9.50	999.000	1291.9	-0.0	
		10.50	999.000	2518.4	0.0	
		11.50	999.000	3929.3	-0.0	
		12.50	999.000	11784.3	-0.0	
32.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	-0.0	
		8.50	999.000	1083.9	0.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
32.00	6.50	9.50	999.000	2143.2	0.0	
		10.50	999.000	3384.0	-0.0	
		11.50	999.000	10337.3	0.0	
32.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	-0.0	
		7.50	999.000	888.4	0.0	
		8.50	999.000	1788.9	-0.0	
		9.50	999.000	2867.0	0.0	
		10.50	999.000	8956.0	-0.0	
32.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	
		7.50	999.000	1457.0	-0.0	
		8.50	999.000	2380.0	0.0	
		9.50	999.000	7643.5	-0.0	
33.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	999.000	904.7	0.0	
		15.50	999.000	2771.2	-0.0	
		16.50	999.000	5156.1	0.0	
33.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	999.000	811.3	0.0	
		14.50	-1823800.250	2499.5	-0.0	
		15.50	999.000	4674.2	-0.0	
33.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	999.000	721.3	0.0	
		13.50	999.000	2237.3	-0.0	
		14.50	999.000	4208.3	0.0	
		15.50	999.000	6367.6	0.0	
33.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	999.000	635.0	0.0	
		12.50	999.000	1985.1	-0.0	
		13.50	999.000	3759.1	0.0	
		14.50	-3232485.000	5721.6	-0.0	
33.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	999.000	552.4	0.0	
		11.50	999.000	1743.1	0.0	
		12.50	999.000	3327.2	-0.0	
		13.50	999.000	5099.2	0.0	
		14.50	-9019524.000	14863.7	-0.0	
33.00	8.50	8.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	8.50	9.50	999.000	473.7	0.0	
		10.50	999.000	1511.9	0.0	
		11.50	999.000	2913.4	0.0	
		12.50	999.000	4501.4	0.0	
		13.50	999.000	13293.9	-0.0	
33.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	999.000	399.1	0.0	
		9.50	999.000	1291.9	-0.0	
		10.50	999.000	2518.4	0.0	
		11.50	999.000	3929.3	-0.0	
		12.50	999.000	11784.3	-0.0	
33.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	-0.0	
		8.50	999.000	1083.9	0.0	
		9.50	999.000	2143.2	0.0	
		10.50	999.000	3384.0	-0.0	
		11.50	999.000	10337.3	0.0	
33.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	-0.0	
		7.50	999.000	888.4	0.0	
		8.50	999.000	1788.9	-0.0	
		9.50	999.000	2867.0	0.0	
		10.50	999.000	8956.0	-0.0	
33.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	
		7.50	999.000	1457.0	-0.0	
		8.50	999.000	2380.0	0.0	
		9.50	999.000	7643.5	-0.0	
34.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	999.000	904.7	0.0	
		15.50	999.000	2771.2	-0.0	
34.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	999.000	811.3	0.0	
		14.50	-1823800.250	2499.5	-0.0	
34.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	999.000	721.3	0.0	
		13.50	999.000	2237.3	-0.0	
		14.50	999.000	4208.3	0.0	
34.00	10.50	10.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	10.50	11.50	999.000	635.0	0.0	
		12.50	999.000	1985.1	-0.0	
		13.50	999.000	3759.1	0.0	
34.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	999.000	552.4	0.0	
		11.50	999.000	1743.1	0.0	
		12.50	999.000	3327.2	-0.0	
		13.50	999.000	5099.2	0.0	
34.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	999.000	473.7	0.0	
		10.50	999.000	1511.9	0.0	
		11.50	999.000	2913.4	0.0	
		12.50	999.000	4501.4	0.0	
		13.50	999.000	13293.9	-0.0	
34.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	999.000	399.1	0.0	
		9.50	999.000	1291.9	-0.0	
		10.50	999.000	2518.4	0.0	
		11.50	999.000	3929.3	-0.0	
		12.50	999.000	11784.3	-0.0	
34.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	-0.0	
		8.50	999.000	1083.9	0.0	
		9.50	999.000	2143.2	0.0	
		10.50	999.000	3384.0	-0.0	
		11.50	999.000	10337.3	0.0	
34.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	-0.0	
		7.50	999.000	888.4	0.0	
		8.50	999.000	1788.9	-0.0	
		9.50	999.000	2867.0	0.0	
		10.50	999.000	8956.0	-0.0	
34.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	
		7.50	999.000	1457.0	-0.0	
		8.50	999.000	2380.0	0.0	
		9.50	999.000	7643.5	-0.0	
35.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	999.000	904.7	0.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	999.000	811.3	0.0	
		14.50	-1823800.250	2499.5	-0.0	
35.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	999.000	721.3	0.0	
		13.50	999.000	2237.3	-0.0	
35.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	999.000	635.0	0.0	
		12.50	999.000	1985.1	-0.0	
		13.50	999.000	3759.1	0.0	
35.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	999.000	552.4	0.0	
		11.50	999.000	1743.1	0.0	
		12.50	999.000	3327.2	-0.0	
35.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	999.000	473.7	0.0	
		10.50	999.000	1511.9	0.0	
		11.50	999.000	2913.4	0.0	
		12.50	999.000	4501.4	0.0	
35.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	999.000	399.1	0.0	
		9.50	999.000	1291.9	-0.0	
		10.50	999.000	2518.4	0.0	
		11.50	999.000	3929.3	-0.0	
35.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	-0.0	
		8.50	999.000	1083.9	0.0	
		9.50	999.000	2143.2	0.0	
		10.50	999.000	3384.0	-0.0	
		11.50	999.000	10337.3	0.0	
35.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	-0.0	
		7.50	999.000	888.4	0.0	
		8.50	999.000	1788.9	-0.0	
		9.50	999.000	2867.0	0.0	
		10.50	999.000	8956.0	-0.0	
35.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	
		7.50	999.000	1457.0	-0.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	4.50	8.50	999.000	2380.0	0.0	
		9.50	999.000	7643.5	-0.0	
36.00	13.50	13.50	999.000	0.0	0.0	***6
36.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	999.000	811.3	0.0	
36.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	999.000	721.3	0.0	
36.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	999.000	635.0	0.0	
		12.50	999.000	1985.1	-0.0	
36.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	999.000	552.4	0.0	
		11.50	999.000	1743.1	0.0	
36.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	999.000	473.7	0.0	
		10.50	999.000	1511.9	0.0	
		11.50	999.000	2913.4	0.0	
36.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	999.000	399.1	0.0	
		9.50	999.000	1291.9	-0.0	
		10.50	999.000	2518.4	0.0	
36.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	0.0	
		8.50	999.000	1083.9	0.0	
		9.50	999.000	2143.2	0.0	
		10.50	999.000	3384.0	-0.0	
36.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	0.0	
		7.50	999.000	888.4	0.0	
		8.50	999.000	1788.9	-0.0	
		9.50	999.000	2867.0	0.0	
36.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	
		7.50	999.000	1457.0	-0.0	
		8.50	999.000	2380.0	0.0	
		9.50	999.000	7643.5	-0.0	
37.00	13.50	13.50	999.000	0.0	0.0	***6
37.00	12.50	0.00	0.001	0.0	0.0	***5
37.00	11.50	11.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	999.000	635.0	0.0	
37.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	999.000	552.4	0.0	
37.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	999.000	473.7	0.0	
		10.50	999.000	1511.9	0.0	
37.00	7.50	0.00	0.001	0.0	0.0	***5
37.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	0.0	
		8.50	999.000	1083.9	0.0	
		9.50	999.000	2143.2	0.0	
37.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	0.0	
		7.50	999.000	888.4	0.0	
		8.50	999.000	1788.9	-0.0	
		9.50	999.000	2867.0	0.0	
37.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	
		7.50	999.000	1457.0	-0.0	
		8.50	999.000	2380.0	0.0	
38.00	13.50	12.89	999.000	0.0	0.0	***6
38.00	12.50	0.00	0.001	0.0	0.0	***5
38.00	11.50	11.50	999.000	0.0	0.0	***6
38.00	10.50	10.50	999.000	0.0	0.0	***6
38.00	9.50	9.50	999.000	0.0	0.0	***6
38.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	999.000	473.7	0.0	
38.00	7.50	0.00	0.001	0.0	0.0	***5
38.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	0.0	
		8.50	999.000	1083.9	0.0	
38.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	0.0	
		7.50	999.000	888.4	0.0	
		8.50	999.000	1788.9	-0.0	
38.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	4.50	7.50	999.000	1457.0	0.0	
39.00	13.50	12.21	999.000	0.0	0.0	***6
39.00	12.50	0.00	0.001	0.0	0.0	***5
39.00	11.50	10.79	999.000	0.0	0.0	***6
39.00	10.50	10.15	999.000	0.0	0.0	***6
39.00	9.50	9.50	999.000	0.0	0.0	***6
39.00	8.50	8.50	999.000	0.0	0.0	***6
39.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	999.000	399.1	0.0	
39.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	999.000	329.0	0.0	
39.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	0.0	
		7.50	999.000	888.4	0.0	
39.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		6.50	999.000	706.5	0.0	
40.00	13.50	11.57	999.000	0.0	0.0	***6
40.00	12.50	10.80	999.000	0.0	0.0	***6
40.00	11.50	10.06	999.000	0.0	0.0	***6
40.00	10.50	9.38	999.000	0.0	0.0	***6
40.00	9.50	8.75	999.000	0.0	0.0	***6
40.00	8.50	8.20	999.000	0.0	0.0	***6
40.00	7.50	7.50	999.000	0.0	0.0	***6
40.00	6.50	6.50	999.000	0.0	0.0	***6
40.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	999.000	263.5	0.0	
40.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	999.000	203.1	0.0	
		9.50	3.690	8593.7	2329.1	
41.00	13.50	10.99	999.000	0.0	0.0	***6
41.00	12.50	10.17	999.000	0.0	0.0	***6
41.00	11.50	9.39	999.000	0.0	0.0	***6
41.00	10.50	8.65	999.000	0.0	0.0	***6
41.00	9.50	7.96	999.000	0.0	0.0	***6
41.00	8.50	7.35	999.000	0.0	0.0	***6
41.00	7.50	6.83	999.000	0.0	0.0	***6
41.00	6.50	6.39	999.000	0.0	0.0	***6
41.00	5.50	5.50	999.000	0.0	0.0	***6
41.00	4.50	4.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
42.00	13.50	10.48	999.000	0.0	0.0	***6
42.00	12.50	0.00	0.001	0.0	0.0	***5
42.00	11.50	0.00	0.001	0.0	0.0	***5
42.00	10.50	7.98	999.000	0.0	0.0	***6
42.00	9.50	7.23	999.000	0.0	0.0	***6
42.00	8.50	6.56	999.000	0.0	0.0	***6
42.00	7.50	0.00	0.001	0.0	0.0	***5
42.00	6.50	5.49	999.000	0.0	0.0	***6
42.00	5.50	5.04	999.000	0.0	0.0	***6
42.00	4.50	4.50	999.000	0.0	0.0	***6
43.00	13.50	10.03	999.000	0.0	0.0	***6
43.00	12.50	9.13	999.000	0.0	0.0	***6
43.00	11.50	8.24	999.000	0.0	0.0	***6
43.00	10.50	7.39	999.000	0.0	0.0	***6
43.00	9.50	6.58	999.000	0.0	0.0	***6
43.00	8.50	5.82	999.000	0.0	0.0	***6
43.00	7.50	0.00	0.001	0.0	0.0	***5
43.00	6.50	4.60	999.000	0.0	0.0	***6
43.00	5.50	4.15	999.000	0.0	0.0	***6
43.00	4.50	3.70	999.000	0.0	0.0	***6
44.00	13.50	9.67	999.000	0.0	0.0	***6
44.00	12.50	8.73	999.000	0.0	0.0	***6
44.00	11.50	7.80	999.000	0.0	0.0	***6
44.00	10.50	6.89	999.000	0.0	0.0	***6
44.00	9.50	6.01	999.000	0.0	0.0	***6
44.00	8.50	5.17	999.000	0.0	0.0	***6
44.00	7.50	0.00	0.001	0.0	0.0	***5
44.00	6.50	3.75	999.000	0.0	0.0	***6
44.00	5.50	3.26	999.000	0.0	0.0	***6
44.00	4.50	2.81	999.000	0.0	0.0	***6
45.00	13.50	9.41	999.000	0.0	0.0	***6
45.00	12.50	8.43	999.000	0.0	0.0	***6
45.00	11.50	7.47	999.000	0.0	0.0	***6
45.00	10.50	6.51	999.000	0.0	0.0	***6
45.00	9.50	5.57	999.000	0.0	0.0	***6
45.00	8.50	4.66	999.000	0.0	0.0	***6
45.00	7.50	0.00	0.001	0.0	0.0	***5
45.00	6.50	2.99	999.000	0.0	0.0	***6
45.00	5.50	2.37	999.000	0.0	0.0	***6
45.00	4.50	1.91	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
46.00	13.50	9.24	999.000	0.0	0.0	***6
46.00	12.50	8.25	999.000	0.0	0.0	***6
46.00	11.50	7.26	999.000	0.0	0.0	***6
46.00	10.50	6.27	999.000	0.0	0.0	***6
46.00	9.50	5.29	999.000	0.0	0.0	***6
46.00	8.50	4.31	999.000	0.0	0.0	***6
46.00	7.50	3.35	999.000	0.0	0.0	***6
46.00	6.50	0.00	0.001	0.0	0.0	***5
46.00	5.50	1.58	999.000	0.0	0.0	***6
46.00	4.50	0.00	0.001	0.0	0.0	***5
47.00	13.50	9.18	999.000	0.0	0.0	***6
47.00	12.50	0.00	0.001	0.0	0.0	***5
47.00	11.50	0.00	0.001	0.0	0.0	***5
47.00	10.50	6.18	999.000	0.0	0.0	***6
47.00	9.50	5.18	999.000	0.0	0.0	***6
47.00	8.50	4.18	999.000	0.0	0.0	***6
47.00	7.50	0.00	0.001	0.0	0.0	***5
47.00	6.50	2.18	999.000	0.0	0.0	***6
47.00	5.50	1.18	999.000	0.0	0.0	***6
47.00	4.50	0.00	0.001	0.0	0.0	***5
48.00	13.50	9.18	999.000	0.0	0.0	***6
48.00	12.50	0.00	0.001	0.0	0.0	***5
48.00	11.50	0.00	0.001	0.0	0.0	***5
48.00	10.50	6.18	999.000	0.0	0.0	***6
48.00	9.50	5.18	999.000	0.0	0.0	***6
48.00	8.50	4.18	999.000	0.0	0.0	***6
48.00	7.50	0.00	0.001	0.0	0.0	***5
48.00	6.50	2.18	999.000	0.0	0.0	***6
48.00	5.50	1.18	999.000	0.0	0.0	***6
48.00	4.50	0.18	999.000	0.0	0.0	***6
49.00	13.50	9.18	999.000	0.0	0.0	***6
49.00	12.50	0.00	0.001	0.0	0.0	***5
49.00	11.50	7.18	999.000	0.0	0.0	***6
49.00	10.50	6.18	999.000	0.0	0.0	***6
49.00	9.50	5.18	999.000	0.0	0.0	***6
49.00	8.50	4.18	999.000	0.0	0.0	***6
49.00	7.50	3.18	999.000	0.0	0.0	***6
49.00	6.50	2.18	999.000	0.0	0.0	***6
49.00	5.50	1.18	999.000	0.0	0.0	***6
49.00	4.50	0.18	999.000	0.0	0.0	***6

Table of B.A.

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

Center X(m),Y(m)

Y(m)	X(m)	30.00	31.00	32.00	33.00	34.00	35.00
13.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
12.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
11.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
10.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
9.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
8.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
7.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
6.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
5.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
4.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00

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

Center X(m),Y(m)

Y(m)	X(m)	36.00	37.00	38.00	39.00	40.00	41.00
13.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
12.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
11.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
10.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
9.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
8.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
7.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
6.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
5.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
4.50	Fs	999.000	999.000	999.000	999.000	3.690	999.000
	R(m)	0.00	0.00	0.00	0.00	9.50	0.00

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

Center X(m),Y(m)

Y(m)	X(m)	42.00	43.00	44.00	45.00	46.00	47.00
13.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
12.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
11.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
10.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
9.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
8.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
7.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
6.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
5.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
4.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00

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

Center X(m),Y(m)

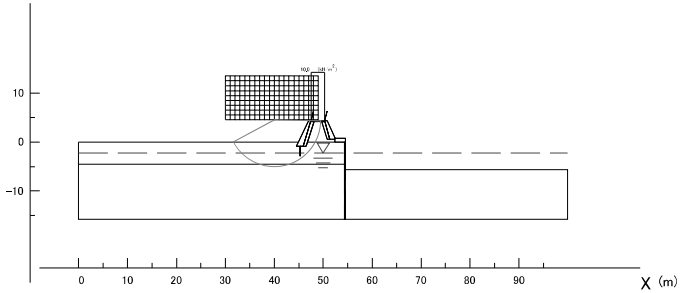
Y(m)	X(m)	48.00	49.00
13.50	Fs	999.000	999.000
	R(m)	0.00	0.00
12.50	Fs	999.000	999.000
	R(m)	0.00	0.00
11.50	Fs	999.000	999.000
	R(m)	0.00	0.00
10.50	Fs	999.000	999.000
	R(m)	0.00	0.00
9.50	Fs	999.000	999.000
	R(m)	0.00	0.00
8.50	Fs	999.000	999.000
	R(m)	0.00	0.00
7.50	Fs	999.000	999.000
	R(m)	0.00	0.00
6.50	Fs	999.000	999.000
	R(m)	0.00	0.00
5.50	Fs	999.000	999.000
	R(m)	0.00	0.00
4.50	Fs	999.000	999.000
	R(m)	0.00	0.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	3.690
Failure circle X(m)	=	40.00
Y(m)	=	4.50
R(m)	=	9.500
Resisting moment(kNm)	=	8593.7
Sliding moment(kNm)	=	2329.1
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



WARNING ***5 There are no arc contacting with base line.
count = 21

WARNING ***6 An arc does not cut the ground,
or An arc cuts the side of a model. count =179

4. Action02 (seismic)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	1	24.00	24.00	14.00	1000.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.
0	2	1 24.0	0 24.0	0 14.0	01000.	00 0.	00 0.	00 0.	00 0.	00 0
0.0	3	1 24.	00 24.	00 14.	001000	0.00	0.00	0.00	0.00	0.00
0.0	4	2 77	0.00 7	0.00 6	0.0010	0.00	0.00	0.00	0.00	0.00
0.0	5	3 2	0.00 1	9.00 1	0.00	0.00	0.003	5.00	0.00	0.00
0.0	6	3 2	0.00 1	9.00 1	0.00	0.00	0.003	5.00	0.00	0.00
0.0	7	4 2	4.00 2	4.00 1	4.00	1.00	0.003	0.00	0.00	0.00
0.0	8	5 1	9.00 1	8.00	9.00	1.00	0.003	0.00	0.00	0.00
0.0	9	6 1	8.50 1	7.50	8.50	0.00	0.002	7.00	0.00	0.00
0.0	10	7 1	9.00 1	8.00	9.0010	0.00	0.00	0.00	0.00	0.00
0.0	11	7 1	9.00 1	8.00	9.0010	0.00	0.00	0.00	0.00	0.00
0.0	12	2 7	7.00 7	7.00 6	7.0010	00.00	0.00	0.00	0.00	0.00
0.	0									

// Distribution load that considers partial coefficient //

	Left			Right			Resisting	H.seismic	P.seismic
load No.	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)	coefficient of load	intensity Khp	intensity Kvp
2	47.50	4.32	5.0	50.28	4.32	5.0	0.000	0.200	0.000

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

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	-2.30	
2	100.00	-2.30	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
30.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	2.548	904.7	355.1	
		15.50	2.548	2771.2	1087.7	
		16.50	2.377	5156.1	2169.4	
		17.50	2.132	7727.2	3624.0	
		18.50	3.969	21702.8	5468.0	
30.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	2.548	811.3	318.5	
		14.50	2.548	2499.5	981.1	
		15.50	2.376	4674.2	1967.1	
		16.50	2.131	7036.4	3301.8	
		17.50	3.980	19912.7	5003.6	
30.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	2.548	721.3	283.1	
		13.50	2.548	2237.3	878.2	
		14.50	2.376	4208.3	1771.5	
		15.50	2.130	6367.6	2989.8	
		16.50	3.992	18175.0	4553.3	
30.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	2.548	635.0	249.2	
		12.50	2.548	1985.1	779.2	
		13.50	2.375	3759.1	1582.9	
		14.50	2.128	5721.6	2688.3	
		15.50	4.005	16491.4	4117.4	
30.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	2.548	552.4	216.8	
		11.50	2.548	1743.1	684.2	
		12.50	2.374	3327.2	1401.5	
		13.50	2.127	5099.2	2397.9	
		14.50	4.021	14863.7	3696.6	
30.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	2.548	473.7	185.9	
		10.50	2.548	1511.9	593.5	
		11.50	2.373	2913.4	1227.7	
		12.50	2.125	4501.4	2118.7	
		13.50	4.039	13293.9	3291.3	
30.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	2.548	399.1	156.7	
		9.50	2.548	1291.9	507.1	
		10.50	2.372	2518.4	1061.8	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
30.00	7.50	11.50	2.122	3929.3	1851.5	
		12.50	4.060	11784.3	2902.3	
30.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
		8.50	2.548	1083.9	425.4	
		9.50	2.370	2143.2	904.1	
		10.50	2.119	3384.0	1596.7	
		11.50	4.086	10337.3	2530.2	
30.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
		8.50	2.369	1788.9	755.3	
		9.50	2.116	2867.0	1355.0	
		10.50	4.116	8956.0	2175.8	
30.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	
		7.50	2.366	1457.0	615.7	
		8.50	2.112	2380.0	1127.1	
		9.50	4.154	7643.5	1840.1	
31.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	2.548	904.7	355.1	
		15.50	2.548	2771.2	1087.7	
		16.50	2.377	5156.1	2169.4	
		17.50	2.132	7727.2	3624.0	
31.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	2.548	811.3	318.5	
		14.50	2.548	2499.5	981.1	
		15.50	2.376	4674.2	1967.1	
		16.50	2.131	7036.4	3301.8	
		17.50	3.980	19912.7	5003.6	
31.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	2.548	721.3	283.1	
		13.50	2.548	2237.3	878.2	
		14.50	2.376	4208.3	1771.5	
		15.50	2.130	6367.6	2989.8	
		16.50	3.992	18175.0	4553.3	
31.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	2.548	635.0	249.2	
		12.50	2.548	1985.1	779.2	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
31.00	10.50	13.50	2.375	3759.1	1582.9	
		14.50	2.128	5721.6	2688.3	
		15.50	4.005	16491.4	4117.4	
31.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	2.548	552.4	216.8	
		11.50	2.548	1743.1	684.2	
		12.50	2.374	3327.2	1401.5	
		13.50	2.127	5099.2	2397.9	
		14.50	4.021	14863.7	3696.6	
31.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	2.548	473.7	185.9	
		10.50	2.548	1511.9	593.5	
		11.50	2.373	2913.4	1227.7	
		12.50	2.125	4501.4	2118.7	
		13.50	4.039	13293.9	3291.3	
31.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	2.548	399.1	156.7	
		9.50	2.548	1291.9	507.1	
		10.50	2.372	2518.4	1061.8	
		11.50	2.122	3929.3	1851.5	
		12.50	4.060	11784.3	2902.3	
31.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
		8.50	2.548	1083.9	425.4	
		9.50	2.370	2143.2	904.1	
		10.50	2.119	3384.0	1596.7	
		11.50	4.086	10337.3	2530.2	
31.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
		8.50	2.369	1788.9	755.3	
		9.50	2.116	2867.0	1355.0	
		10.50	4.116	8956.0	2175.8	
31.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	
		7.50	2.366	1457.0	615.7	
		8.50	2.112	2380.0	1127.1	
		9.50	4.154	7643.5	1840.1	
32.00	13.50	13.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
32.00	13.50	14.50	2.548	904.7	355.1	
		15.50	2.548	2771.2	1087.7	
		16.50	2.377	5156.1	2169.4	
		17.50	2.132	7727.2	3624.0	
32.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	2.548	811.3	318.5	
		14.50	2.548	2499.5	981.1	
		15.50	2.376	4674.2	1967.1	
32.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	2.548	721.3	283.1	
		13.50	2.548	2237.3	878.2	
		14.50	2.376	4208.3	1771.5	
		15.50	2.130	6367.6	2989.8	
32.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	2.548	635.0	249.2	
		12.50	2.548	1985.1	779.2	
		13.50	2.375	3759.1	1582.9	
		14.50	2.128	5721.6	2688.3	
		15.50	4.005	16491.4	4117.4	
32.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	2.548	552.4	216.8	
		11.50	2.548	1743.1	684.2	
		12.50	2.374	3327.2	1401.5	
		13.50	2.127	5099.2	2397.9	
		14.50	4.021	14863.7	3696.6	
32.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	2.548	473.7	185.9	
		10.50	2.548	1511.9	593.5	
		11.50	2.373	2913.4	1227.7	
		12.50	2.125	4501.4	2118.7	
		13.50	4.039	13293.9	3291.3	
32.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	2.548	399.1	156.7	
		9.50	2.548	1291.9	507.1	
		10.50	2.372	2518.4	1061.8	
		11.50	2.122	3929.3	1851.5	
		12.50	4.060	11784.3	2902.3	
32.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
		8.50	2.548	1083.9	425.4	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
32.00	6.50	9.50	2.370	2143.2	904.1	
		10.50	2.119	3384.0	1596.7	
		11.50	4.086	10337.3	2530.2	
32.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
		8.50	2.369	1788.9	755.3	
		9.50	2.116	2867.0	1355.0	
		10.50	4.116	8956.0	2175.8	
32.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	
		7.50	2.366	1457.0	615.7	
		8.50	2.112	2380.0	1127.1	
		9.50	4.154	7643.5	1840.1	
33.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	2.548	904.7	355.1	
		15.50	2.548	2771.2	1087.7	
		16.50	2.377	5156.1	2169.4	
33.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	2.548	811.3	318.5	
		14.50	2.548	2499.5	981.1	
		15.50	2.376	4674.2	1967.1	
33.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	2.548	721.3	283.1	
		13.50	2.548	2237.3	878.2	
		14.50	2.376	4208.3	1771.5	
		15.50	2.130	6367.6	2989.8	
33.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	2.548	635.0	249.2	
		12.50	2.548	1985.1	779.2	
		13.50	2.375	3759.1	1582.9	
		14.50	2.128	5721.6	2688.3	
33.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	2.548	552.4	216.8	
		11.50	2.548	1743.1	684.2	
		12.50	2.374	3327.2	1401.5	
		13.50	2.127	5099.2	2397.9	
		14.50	4.021	14863.7	3696.6	
33.00	8.50	8.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
33.00	8.50	9.50	2.548	473.7	185.9	
		10.50	2.548	1511.9	593.5	
		11.50	2.373	2913.4	1227.7	
		12.50	2.125	4501.4	2118.7	
		13.50	4.039	13293.9	3291.3	
33.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	2.548	399.1	156.7	
		9.50	2.548	1291.9	507.1	
		10.50	2.372	2518.4	1061.8	
		11.50	2.122	3929.3	1851.5	
		12.50	4.060	11784.3	2902.3	
33.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
		8.50	2.548	1083.9	425.4	
		9.50	2.370	2143.2	904.1	
		10.50	2.119	3384.0	1596.7	
		11.50	4.086	10337.3	2530.2	
33.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
		8.50	2.369	1788.9	755.3	
		9.50	2.116	2867.0	1355.0	
		10.50	4.116	8956.0	2175.8	
33.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	
		7.50	2.366	1457.0	615.7	
		8.50	2.112	2380.0	1127.1	
		9.50	4.154	7643.5	1840.1	
34.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	2.548	904.7	355.1	
		15.50	2.548	2771.2	1087.7	
34.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	2.548	811.3	318.5	
		14.50	2.548	2499.5	981.1	
34.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	2.548	721.3	283.1	
		13.50	2.548	2237.3	878.2	
		14.50	2.376	4208.3	1771.5	
34.00	10.50	10.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
34.00	10.50	11.50	2.548	635.0	249.2	
		12.50	2.548	1985.1	779.2	
		13.50	2.375	3759.1	1582.9	
34.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	2.548	552.4	216.8	
		11.50	2.548	1743.1	684.2	
		12.50	2.374	3327.2	1401.5	
		13.50	2.127	5099.2	2397.9	
34.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	2.548	473.7	185.9	
		10.50	2.548	1511.9	593.5	
		11.50	2.373	2913.4	1227.7	
		12.50	2.125	4501.4	2118.7	
		13.50	4.039	13293.9	3291.3	
34.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	2.548	399.1	156.7	
		9.50	2.548	1291.9	507.1	
		10.50	2.372	2518.4	1061.8	
		11.50	2.122	3929.3	1851.5	
		12.50	4.060	11784.3	2902.3	
34.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
		8.50	2.548	1083.9	425.4	
		9.50	2.370	2143.2	904.1	
		10.50	2.119	3384.0	1596.7	
		11.50	4.086	10337.3	2530.2	
34.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
		8.50	2.369	1788.9	755.3	
		9.50	2.116	2867.0	1355.0	
		10.50	4.116	8956.0	2175.8	
34.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	
		7.50	2.366	1457.0	615.7	
		8.50	2.112	2380.0	1127.1	
		9.50	4.154	7643.5	1840.1	
35.00	13.50	13.50	999.000	0.0	0.0	***6
		14.50	2.548	904.7	355.1	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	2.548	811.3	318.5	
		14.50	2.548	2499.5	981.1	
35.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	2.548	721.3	283.1	
		13.50	2.548	2237.3	878.2	
35.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	2.548	635.0	249.2	
		12.50	2.548	1985.1	779.2	
		13.50	2.375	3759.1	1582.9	
35.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	2.548	552.4	216.8	
		11.50	2.548	1743.1	684.2	
		12.50	2.374	3327.2	1401.5	
35.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	2.548	473.7	185.9	
		10.50	2.548	1511.9	593.5	
		11.50	2.373	2913.4	1227.7	
		12.50	2.125	4501.4	2118.7	
35.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	2.548	399.1	156.7	
		9.50	2.548	1291.9	507.1	
		10.50	2.372	2518.4	1061.8	
		11.50	2.122	3929.3	1851.5	
35.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
		8.50	2.548	1083.9	425.4	
		9.50	2.370	2143.2	904.1	
		10.50	2.119	3384.0	1596.7	
		11.50	4.086	10337.3	2530.2	
35.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
		8.50	2.369	1788.9	755.3	
		9.50	2.116	2867.0	1355.0	
		10.50	4.116	8956.0	2175.8	
35.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	
		7.50	2.366	1457.0	615.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
35.00	4.50	8.50	2.112	2380.0	1127.1	
		9.50	4.154	7643.5	1840.1	
36.00	13.50	13.50	999.000	0.0	0.0	***6
36.00	12.50	12.50	999.000	0.0	0.0	***6
		13.50	2.548	811.3	318.5	
36.00	11.50	11.50	999.000	0.0	0.0	***6
		12.50	2.548	721.3	283.1	
36.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	2.548	635.0	249.2	
		12.50	2.548	1985.1	779.2	
36.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	2.548	552.4	216.8	
		11.50	2.548	1743.1	684.2	
36.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	2.548	473.7	185.9	
		10.50	2.548	1511.9	593.5	
		11.50	2.373	2913.4	1227.7	
36.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	2.548	399.1	156.7	
		9.50	2.548	1291.9	507.1	
		10.50	2.372	2518.4	1061.8	
36.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
		8.50	2.548	1083.9	425.4	
		9.50	2.370	2143.2	904.1	
		10.50	2.119	3384.0	1596.7	
36.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
		8.50	2.369	1788.9	755.3	
		9.50	2.116	2867.0	1355.0	
36.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	
		7.50	2.366	1457.0	615.7	
		8.50	2.112	2380.0	1127.1	
		9.50	4.154	7643.5	1840.1	
37.00	13.50	13.50	999.000	0.0	0.0	***6
37.00	12.50	0.00	0.001	0.0	0.0	***5
37.00	11.50	11.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
37.00	10.50	10.50	999.000	0.0	0.0	***6
		11.50	2.548	635.0	249.2	
37.00	9.50	9.50	999.000	0.0	0.0	***6
		10.50	2.548	552.4	216.8	
37.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	2.548	473.7	185.9	
		10.50	2.548	1511.9	593.5	
37.00	7.50	0.00	0.001	0.0	0.0	***5
37.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
		8.50	2.548	1083.9	425.4	
		9.50	2.370	2143.2	904.1	
37.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
		8.50	2.369	1788.9	755.3	
		9.50	2.116	2867.0	1355.0	
37.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	
		7.50	2.366	1457.0	615.7	
		8.50	2.112	2380.0	1127.1	
38.00	13.50	12.89	999.000	0.0	0.0	***6
38.00	12.50	0.00	0.001	0.0	0.0	***5
38.00	11.50	11.50	999.000	0.0	0.0	***6
38.00	10.50	10.50	999.000	0.0	0.0	***6
38.00	9.50	9.50	999.000	0.0	0.0	***6
38.00	8.50	8.50	999.000	0.0	0.0	***6
		9.50	2.548	473.7	185.9	
38.00	7.50	0.00	0.001	0.0	0.0	***5
38.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
		8.50	2.548	1083.9	425.4	
38.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
		8.50	2.369	1788.9	755.3	
38.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
38.00	4.50	7.50	2.366	1457.0	615.7	
39.00	13.50	12.21	999.000	0.0	0.0	***6
39.00	12.50	0.00	0.001	0.0	0.0	***5
39.00	11.50	10.79	999.000	0.0	0.0	***6
39.00	10.50	10.15	999.000	0.0	0.0	***6
39.00	9.50	9.50	999.000	0.0	0.0	***6
39.00	8.50	8.50	999.000	0.0	0.0	***6
39.00	7.50	7.50	999.000	0.0	0.0	***6
		8.50	2.548	399.1	156.7	
39.00	6.50	6.50	999.000	0.0	0.0	***6
		7.50	2.548	329.0	129.1	
39.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
		7.50	2.548	888.4	348.7	
39.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		6.50	2.548	706.5	277.3	
40.00	13.50	11.57	999.000	0.0	0.0	***6
40.00	12.50	10.80	999.000	0.0	0.0	***6
40.00	11.50	10.06	999.000	0.0	0.0	***6
40.00	10.50	9.38	999.000	0.0	0.0	***6
40.00	9.50	8.75	999.000	0.0	0.0	***6
40.00	8.50	8.20	999.000	0.0	0.0	***6
40.00	7.50	7.50	999.000	0.0	0.0	***6
40.00	6.50	6.50	999.000	0.0	0.0	***6
40.00	5.50	5.50	999.000	0.0	0.0	***6
		6.50	2.548	263.5	103.4	
40.00	4.50	4.50	999.000	0.0	0.0	***6
		5.50	2.548	203.1	79.7	
		9.50	1.886	8366.5	4435.0	
41.00	13.50	10.99	999.000	0.0	0.0	***6
41.00	12.50	10.17	999.000	0.0	0.0	***6
41.00	11.50	9.39	999.000	0.0	0.0	***6
41.00	10.50	8.65	999.000	0.0	0.0	***6
41.00	9.50	7.96	999.000	0.0	0.0	***6
41.00	8.50	7.35	999.000	0.0	0.0	***6
41.00	7.50	6.83	999.000	0.0	0.0	***6
41.00	6.50	6.39	999.000	0.0	0.0	***6
41.00	5.50	5.50	999.000	0.0	0.0	***6
41.00	4.50	4.50	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
42.00	13.50	10.48	999.000	0.0	0.0	***6
42.00	12.50	0.00	0.001	0.0	0.0	***5
42.00	11.50	0.00	0.001	0.0	0.0	***5
42.00	10.50	7.98	999.000	0.0	0.0	***6
42.00	9.50	7.23	999.000	0.0	0.0	***6
42.00	8.50	6.56	999.000	0.0	0.0	***6
42.00	7.50	0.00	0.001	0.0	0.0	***5
42.00	6.50	5.49	999.000	0.0	0.0	***6
42.00	5.50	5.04	999.000	0.0	0.0	***6
42.00	4.50	4.50	999.000	0.0	0.0	***6
43.00	13.50	10.03	999.000	0.0	0.0	***6
43.00	12.50	9.13	999.000	0.0	0.0	***6
43.00	11.50	8.24	999.000	0.0	0.0	***6
43.00	10.50	7.39	999.000	0.0	0.0	***6
43.00	9.50	6.58	999.000	0.0	0.0	***6
43.00	8.50	5.82	999.000	0.0	0.0	***6
43.00	7.50	0.00	0.001	0.0	0.0	***5
43.00	6.50	4.60	999.000	0.0	0.0	***6
43.00	5.50	4.15	999.000	0.0	0.0	***6
43.00	4.50	3.70	999.000	0.0	0.0	***6
44.00	13.50	9.67	999.000	0.0	0.0	***6
44.00	12.50	8.73	999.000	0.0	0.0	***6
44.00	11.50	7.80	999.000	0.0	0.0	***6
44.00	10.50	6.89	999.000	0.0	0.0	***6
44.00	9.50	6.01	999.000	0.0	0.0	***6
44.00	8.50	5.17	999.000	0.0	0.0	***6
44.00	7.50	0.00	0.001	0.0	0.0	***5
44.00	6.50	3.75	999.000	0.0	0.0	***6
44.00	5.50	3.26	999.000	0.0	0.0	***6
44.00	4.50	2.81	999.000	0.0	0.0	***6
45.00	13.50	9.41	999.000	0.0	0.0	***6
45.00	12.50	8.43	999.000	0.0	0.0	***6
45.00	11.50	7.47	999.000	0.0	0.0	***6
45.00	10.50	6.51	999.000	0.0	0.0	***6
45.00	9.50	5.57	999.000	0.0	0.0	***6
45.00	8.50	4.66	999.000	0.0	0.0	***6
45.00	7.50	0.00	0.001	0.0	0.0	***5
45.00	6.50	2.99	999.000	0.0	0.0	***6
45.00	5.50	2.37	999.000	0.0	0.0	***6
45.00	4.50	1.91	999.000	0.0	0.0	***6

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
46.00	13.50	9.24	999.000	0.0	0.0	***6
46.00	12.50	8.25	999.000	0.0	0.0	***6
46.00	11.50	7.26	999.000	0.0	0.0	***6
46.00	10.50	6.27	999.000	0.0	0.0	***6
46.00	9.50	5.29	999.000	0.0	0.0	***6
46.00	8.50	4.31	999.000	0.0	0.0	***6
46.00	7.50	3.35	999.000	0.0	0.0	***6
46.00	6.50	0.00	0.001	0.0	0.0	***5
46.00	5.50	1.58	999.000	0.0	0.0	***6
46.00	4.50	0.00	0.001	0.0	0.0	***5
47.00	13.50	9.18	999.000	0.0	0.0	***6
47.00	12.50	0.00	0.001	0.0	0.0	***5
47.00	11.50	0.00	0.001	0.0	0.0	***5
47.00	10.50	6.18	999.000	0.0	0.0	***6
47.00	9.50	5.18	999.000	0.0	0.0	***6
47.00	8.50	4.18	999.000	0.0	0.0	***6
47.00	7.50	0.00	0.001	0.0	0.0	***5
47.00	6.50	2.18	999.000	0.0	0.0	***6
47.00	5.50	1.18	999.000	0.0	0.0	***6
47.00	4.50	0.00	0.001	0.0	0.0	***5
48.00	13.50	9.18	999.000	0.0	0.0	***6
48.00	12.50	0.00	0.001	0.0	0.0	***5
48.00	11.50	0.00	0.001	0.0	0.0	***5
48.00	10.50	6.18	999.000	0.0	0.0	***6
48.00	9.50	5.18	999.000	0.0	0.0	***6
48.00	8.50	4.18	999.000	0.0	0.0	***6
48.00	7.50	0.00	0.001	0.0	0.0	***5
48.00	6.50	2.18	999.000	0.0	0.0	***6
48.00	5.50	1.18	999.000	0.0	0.0	***6
48.00	4.50	0.18	999.000	0.0	0.0	***6
49.00	13.50	9.18	999.000	0.0	0.0	***6
49.00	12.50	0.00	0.001	0.0	0.0	***5
49.00	11.50	7.18	999.000	0.0	0.0	***6
49.00	10.50	6.18	999.000	0.0	0.0	***6
49.00	9.50	5.18	999.000	0.0	0.0	***6
49.00	8.50	4.18	999.000	0.0	0.0	***6
49.00	7.50	3.18	999.000	0.0	0.0	***6
49.00	6.50	2.18	999.000	0.0	0.0	***6
49.00	5.50	1.18	999.000	0.0	0.0	***6
49.00	4.50	0.18	999.000	0.0	0.0	***6

Table of B.A.

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

Center X(m),Y(m)

Y(m)	X(m)	30.00	31.00	32.00	33.00	34.00	35.00
13.50	Fs	2.132	2.132	2.132	2.377	2.548	2.548
	R(m)	17.50	17.50	17.50	16.50	14.50	14.50
12.50	Fs	2.131	2.131	2.376	2.376	2.548	2.548
	R(m)	16.50	16.50	15.50	15.50	13.50	13.50
11.50	Fs	2.130	2.130	2.130	2.130	2.376	2.548
	R(m)	15.50	15.50	15.50	15.50	14.50	12.50
10.50	Fs	2.128	2.128	2.128	2.128	2.375	2.375
	R(m)	14.50	14.50	14.50	14.50	13.50	13.50
9.50	Fs	2.127	2.127	2.127	2.127	2.127	2.374
	R(m)	13.50	13.50	13.50	13.50	13.50	12.50
8.50	Fs	2.125	2.125	2.125	2.125	2.125	2.125
	R(m)	12.50	12.50	12.50	12.50	12.50	12.50
7.50	Fs	2.122	2.122	2.122	2.122	2.122	2.122
	R(m)	11.50	11.50	11.50	11.50	11.50	11.50
6.50	Fs	2.119	2.119	2.119	2.119	2.119	2.119
	R(m)	10.50	10.50	10.50	10.50	10.50	10.50
5.50	Fs	2.116	2.116	2.116	2.116	2.116	2.116
	R(m)	9.50	9.50	9.50	9.50	9.50	9.50
4.50	Fs	2.112	2.112	2.112	2.112	2.112	2.112
	R(m)	8.50	8.50	8.50	8.50	8.50	8.50

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

Center X(m),Y(m)

Y(m)	X(m)	36.00	37.00	38.00	39.00	40.00	41.00
13.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
12.50	Fs	2.548	999.000	999.000	999.000	999.000	999.000
	R(m)	13.50	0.00	0.00	0.00	0.00	0.00
11.50	Fs	2.548	999.000	999.000	999.000	999.000	999.000
	R(m)	12.50	0.00	0.00	0.00	0.00	0.00
10.50	Fs	2.548	2.548	999.000	999.000	999.000	999.000
	R(m)	11.50	11.50	0.00	0.00	0.00	0.00
9.50	Fs	2.548	2.548	999.000	999.000	999.000	999.000
	R(m)	10.50	10.50	0.00	0.00	0.00	0.00
8.50	Fs	2.373	2.548	2.548	999.000	999.000	999.000
	R(m)	11.50	10.50	9.50	0.00	0.00	0.00
7.50	Fs	2.372	999.000	999.000	2.548	999.000	999.000
	R(m)	10.50	0.00	0.00	8.50	0.00	0.00
6.50	Fs	2.119	2.370	2.548	2.548	999.000	999.000
	R(m)	10.50	9.50	7.50	7.50	0.00	0.00
5.50	Fs	2.116	2.116	2.369	2.548	2.548	999.000
	R(m)	9.50	9.50	8.50	7.50	6.50	0.00
4.50	Fs	2.112	2.112	2.366	2.548	1.886	999.000
	R(m)	8.50	8.50	7.50	5.50	9.50	0.00

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

Center X(m),Y(m)

Y(m)	X(m)	42.00	43.00	44.00	45.00	46.00	47.00
13.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
12.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
11.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
10.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
9.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
8.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
7.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
6.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
5.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
4.50	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00

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

Center X(m),Y(m)

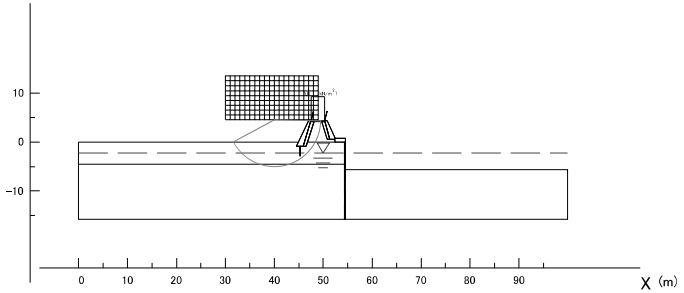
Y(m)	X(m)	48.00	49.00
13.50	Fs	999.000	999.000
	R(m)	0.00	0.00
12.50	Fs	999.000	999.000
	R(m)	0.00	0.00
11.50	Fs	999.000	999.000
	R(m)	0.00	0.00
10.50	Fs	999.000	999.000
	R(m)	0.00	0.00
9.50	Fs	999.000	999.000
	R(m)	0.00	0.00
8.50	Fs	999.000	999.000
	R(m)	0.00	0.00
7.50	Fs	999.000	999.000
	R(m)	0.00	0.00
6.50	Fs	999.000	999.000
	R(m)	0.00	0.00
5.50	Fs	999.000	999.000
	R(m)	0.00	0.00
4.50	Fs	999.000	999.000
	R(m)	0.00	0.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	1.886
Failure circle X(m)	=	40.00
Y(m)	=	4.50
R(m)	=	9.500
Resisting moment(kNm)	=	8366.5
Sliding moment(kNm)	=	4435.0
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



WARNING ***5 There are no arc contacting with base line.
count = 21

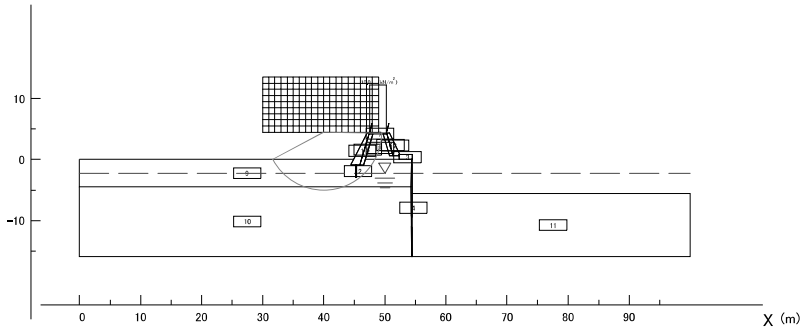
WARNING ***6 An arc does not cut the ground,
or An arc cuts the side of a model. count =179

Test of Embankment Stability

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

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	3.690	≧ 1.0 (OK)
Center of arc	X	=	40.00	(m)
	Y	=	4.50	(m)
Radius	R	=	9.500	(m)
Resisting moment	M_R	=	8593.7	(kNm)
Sliding moment	M_D	=	2329.1	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	24.00	24.00	0.00	1000.00	0.00	0.000	0.000
2	24.00	24.00	0.00	1000.00	0.00	0.000	0.000
3	24.00	24.00	0.00	1000.00	0.00	0.000	0.000
4	77.00	77.00	0.00	1000.00	0.00	0.000	0.000
5	20.00	19.00	35.00	0.00	0.00	0.000	0.000
6	20.00	19.00	35.00	0.00	0.00	0.000	0.000
7	24.00	24.00	30.00	1.00	0.00	0.000	0.000
8	19.00	18.00	30.00	1.00	0.00	0.000	0.000
9	18.50	17.50	27.00	0.00	0.00	0.000	0.000
10	19.00	18.00	0.00	100.00	0.00	0.000	0.000
11	19.00	18.00	0.00	100.00	0.00	0.000	0.000
12	77.00	77.00	0.00	1000.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)

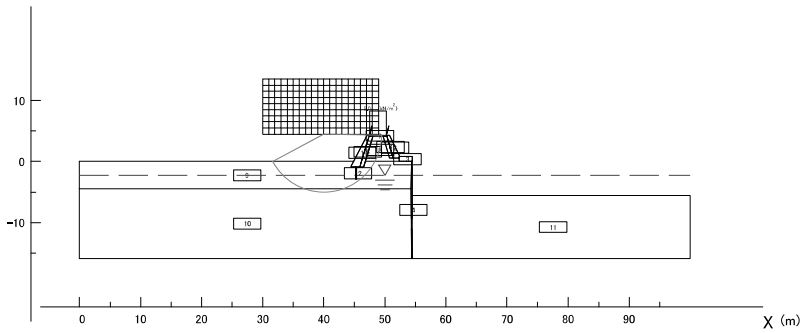
Safety Factor (Ordinary Condition)

Test of Embankment Stability

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

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	1.886	≧ 1.0 (OK)
Center of arc	X	=	40.00	(m)
	Y	=	4.50	(m)
Radius	R	=	9.500	(m)
Resisting moment	M_R	=	8366.5	(kNm)
Sliding moment	M_D	=	4435.0	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
2	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
3	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
4	77.00	77.00	0.00	1000.00	0.00	0.200	0.000
5	20.00	19.00	35.00	0.00	0.00	0.200	0.000
6	20.00	19.00	35.00	0.00	0.00	0.200	0.000
7	24.00	24.00	30.00	1.00	0.00	0.200	0.000
8	19.00	18.00	30.00	1.00	0.00	0.200	0.000
9	18.50	17.50	27.00	0.00	0.00	0.200	0.000
10	19.00	18.00	0.00	100.00	0.00	0.200	0.000
11	19.00	18.00	0.00	100.00	0.00	0.200	0.000
12	77.00	77.00	0.00	1000.00	0.00	0.200	0.000

Water unit weight = 10.00 (kN/m³)

Safety Factor (Seismic Condition)

1.2.1 SLOPE STABILITY　ANALYSIS

1.2.1.1　Normal and Seismic Conditions

(5)　R6+060

Circular Slip Surface

R+6060

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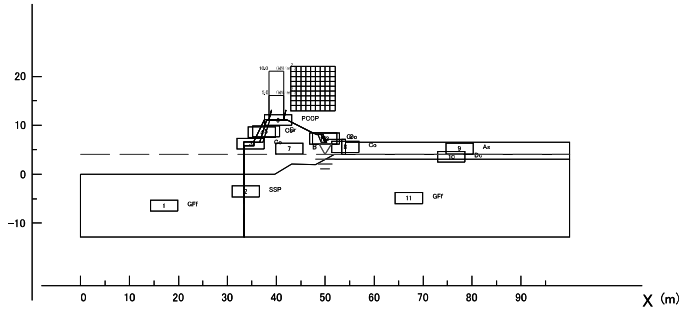
1. Input data list

// Design section //



// Design level of reliability design method //

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

// Combination of action //

// Setting of action //

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

// Partial coefficient concerning analytical technique γ_α //

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

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

No.	Action 1			Action 2											
	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$	γw	γc	$\gamma \tan\phi$			
1	1.00	1.00	1.00	1.00	1.00	1.00									
2	1.00	1.00	1.00	1.00	1.00	1.00									
3	1.00	1.00	1.00	1.00	1.00	1.00									
4	1.00	1.00	1.00	1.00	1.00	1.00									
5	1.00	1.00	1.00	1.00	1.00	1.00									
6	1.00	1.00	1.00	1.00	1.00	1.00									
7	1.00	1.00	1.00	1.00	1.00	1.00									
8	1.00	1.00	1.00	1.00	1.00	1.00									
9	1.00	1.00	1.00	1.00	1.00	1.00									
10	1.00	1.00	1.00	1.00	1.00	1.00									
11	1.00	1.00	1.00	1.00	1.00	1.00									
12	1.00	1.00	1.00	1.00	1.00	1.00									
13	1.00	1.00	1.00	1.00	1.00	1.00									

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

$$W_d' = \gamma_w W_k'$$

$$C_d = \gamma_c C_k$$

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

- M : Resistance moment
- γ_w : Partial coefficient concerning weight
- W_d' : Effective weight of slice of amount for each unit length splinter (value for design) (kN/m)
- W_k' : Effective weight of slice of amount for each unit length splinter (characteristic value)(kN/m)
- q_d : Perpendicular action because of the upper part of amount of slice (kN/m)
- γ_c : Partial coefficient concerning Cohesion
- C_d : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (value for design) (kN/m²)
- C_k : Cohesion of looking multiplication in drain condition in case of the sandy soil ground in case of viscous land board more non-drain shearing (characteristic value) (kN/m²)
- l : Length in base of amount of Slice (m)
- $\gamma_{\tan\phi}$: Partial coefficient concerning shearing resistance angle
- ϕ_d : 0 in case of viscous land board. Shearing resistance angle in drain condition in case of the sandy soil ground etc.(value for design)(°)
- ϕ_k : 0 in case of viscous land board. Shearing resistance angle in drain condition in case of the sandy soil ground etc.(characteristic value)(°)

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

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

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

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

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

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

- $M_{r,vl}$: Resistance moment of distribution load (Think as well as the ground)
- $M_{d,vl}$: Sliding moment of distribution load (Think as well as the ground)
- K : Resistance power coefficient
- r : Radius of slipping circular arc
- F : Distribution load i
- FR : Slipping line orthogonalization direction load value of load i
- FO : Slipping line direction load value of load i
- θ : Angle that slice bottom (slide surface) does to the horizontal
- $\gamma_{vl,i}$: Partial coefficient of distribution load i (Think as well as the ground).
- K_{hp} : The horizontal seismic intensity
- $\gamma_{vlEQ,i}$: Partial coefficient of inertia force of distribution load i (Think as well as the ground).
- ϕ : Internal friction angle of soil

// Partial coefficient to residual water level //

Action number	rRWL
1	1.00
2	1.00

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

- γ_{RWL} : Partial coefficient concerning residual water level
- RWL_d : Difference between residual water level and water level line (value for design) (m)
- RWL_k : Difference between residual water level and water level line (input value) (m)

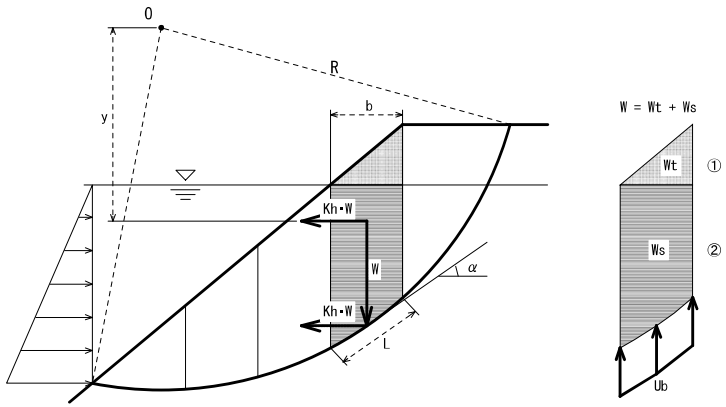
(DATA 01.)　// ANALYSIS //

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

Expression

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

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



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

(DATA 02.)　// CONTROL //

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

(DATA 04.) // SEISMIC LOAD //

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


(DATA 06.) // NODAL POINT //

No.	Coordinate		Y-coordinate
	x (m)	y (m)	before settlement (m)
1	0.00	0.00	0.00
2	33.34	0.00	0.00
3	33.34	5.85	0.00
4	33.34	6.65	0.00
5	33.49	5.85	0.00
6	35.34	6.65	0.00
7	35.49	6.50	0.00
8	37.59	11.15	0.00
9	38.04	11.15	0.00
10	37.98	10.95	0.00
11	38.61	10.95	0.00
12	42.04	11.15	0.00
13	42.04	10.95	0.00
14	35.49	5.85	0.00
15	36.65	6.50	0.00
16	37.27	6.50	0.00
17	50.00	7.17	0.00
18	53.36	7.17	0.00
19	54.15	7.17	0.00
20	100.00	6.50	0.00
21	100.00	4.03	0.00
22	54.15	4.03	0.00
23	53.36	4.03	0.00
24	51.88	4.03	0.00
25	50.04	3.08	0.00
26	47.97	2.01	0.00
27	43.17	2.04	0.00
28	39.74	0.00	0.00
29	33.49	0.00	0.00
30	100.00	3.08	0.00
31	100.00	-12.83	0.00
32	33.49	-12.83	0.00
33	33.34	-12.83	0.00
34	0.00	-12.83	0.00
35	54.15	6.50	0.00
36	48.20	8.07	0.00
37	48.49	8.07	0.00
38	49.16	8.07	0.00
39	49.55	8.07	0.00
40	50.25	6.67	0.00
41	50.25	6.52	0.00
42	49.93	6.52	0.00

(DATA 06.) // NODAL POINT //

No.	Coordinate		Y-coordinate
	x (m)	y (m)	before settlement (m)
43	49.17	6.52	0.00

(DATA 07.) // WATER LEVEL //

Unit weight of water (kN/m³) = 10.00

Action No.	Water level line number
1	1
2	1

Water level line number: 1

No.	Coordinate	
	X (m)	Y (m)
1	0.00	4.03
2	100.00	4.03

Water level line number: 2

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

(DATA 08.) // LAYER //

No.	material property No.	The name of the strata
1	8	GFf
2	2	SSP

No.	material property No.	The name of the strata
3	1	Co
4	1	Co
5	3	Gr
6	4	PCCP
7	5	B
8	1	Co
9	6	As
10	7	Dc
11	8	GFf
12	1	Co
13	3	Gr

No.	Num of Node	Node numbers composing a layer											Slip existence
1	4	1	34	33	2								Slip
2	6	2	33	32	29	5	3						Not Slip
3	6	3	5	14	7	6	4						Not Slip
4	6	6	7	15	10	9	8						Not Slip
5	4	10	15	16	11								Slip
6	5	9	10	11	13	12							Slip
7	23	5	29	28	27	26	25	24	23	18	17	40	Slip
		41	42	43	37	36	12	13	11	16	15	7	
		14											
8	4	18	23	22	19								Not Slip
9	4	35	22	21	20								Slip
10	6	21	22	23	24	25	30						Slip
11	8	25	26	27	28	29	32	31	30				Slip
12	6	38	42	41	40	17	39						Not Slip
13	4	37	43	42	38								Slip

(DATA 09.1) // MATERIAL PROPERTIES //

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

(DATA 09.1)　// MATERIAL PROPERTIES //

No.	Nature of soil division	Saturated weight (kN/m³)	Wet weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
7	Dc	19.00	18.00	50.00	0.00	0.00	0.00	0.000	0.0
8	GFf	18.00	17.00	******	0.00	30.00	0.00	0.000	0.0

(DATA 09.2)　// Characteristic of soil //

No.	Action Number									
	Act 1	Act 2								
1	8	8								
2	2	2								
3	1	1								
4	1	1								
5	3	3								
6	4	4								
7	5	5								
8	1	1								
9	6	6								
10	7	7								
11	8	8								
12	1	1								
13	3	3								

(DATA 11.)　// GRID POINT //

No.	Slip direction	Double cutting	GX (m)	GY (m)	X-point	Y-point	X-pitch (m)	Y-pitch (m)	Dx/Dy	NEXCO Radius
1	Downstream	Rigtlump	43.00	22.00	10	10	1.00	1.00	0.000	0.000

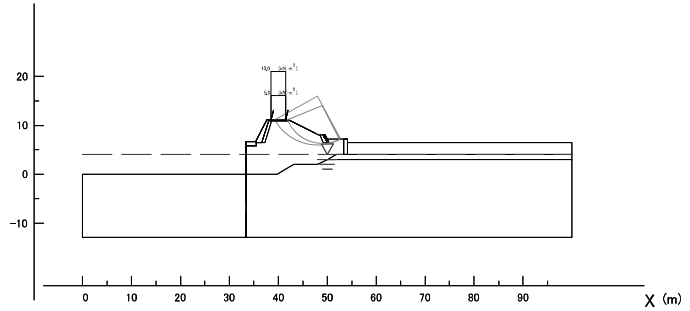
2. Check list

// Check of circular arc //

Action No.	Action name	Bearing force Action ratio	Judgment
1	normal	1.682	OK
2	seismic	1.033	OK

Action No.	Bearing force Action ratio	Partial coefficient r_a	Center of slipping circular arc X (m)	Center of slipping circular arc Y (m)	Radius of circular arc(m)	Resistance Moment (kNm)	Sliding Moment (kNm)
1	1.682	1.00	48.00	16.00	10.003	2867.1	1705.1
2	1.033	1.00	49.00	14.00	7.662	1123.6	1087.5

// Check Result chart //



3. Action01 (normal)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	8	18.00	17.00	8.00	1000.0	0 0.0	030.0	0 0.0	0 0.0	0 0.
0	2	2 77.0	0 77.0	0 67.0	01000.	00 0.	00 0.	00 0.	00 0.	00 0
0.0	3	1 24.	00 24.	00 14.	001000	0.00	0.00	0.00	0.00	0.00
0.0	4	1 24	0.00 2	0.00 1	0.0010	0.00	0.00	0.00	0.00	0.00
0.0	5	3 2	0.00 1	9.00 1	0.00	0.00	0.003	5.00	0.00	0.00
0.0	6	4 2	4.00 2	4.00 1	4.00	1.00	0.003	0.00	0.00	0.00
0.0	7	5 1	9.00 1	8.00	9.00	1.00	0.003	0.00	0.00	0.00
0.0	8	1 2	4.00 2	4.00 1	4.0010	00.00	0.00	0.00	0.00	0.00
0.	0 9	6	18.50	17.50	8.50	0.00	0.00	27.00	0.00	0.00
0.	0 10	7	19.00	18.00	9.00	50.00	0.00	0.00	0.00	0.00
0.	0 11	8	18.00	17.00	8.001	000.00	0.0	030.00	0.00	0.00
0	0.0 1	1	24.00	24.00	14.00	1000.0	0 0.	00 0.0	0 0.00	0.0
0	0.0 1	3	3 20.0	0 19.0	0 10.0	0 0.0	0 0.	0035.0	0 0.00	0.0
0	0.0									

// Distribution load that considers partial coefficient //

Load No.	Left			Right			Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)			
1	38.50	11.15	10.0	41.50	11.15	10.0	0.000	0.000	0.000

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

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	4.03	
2	100.00	4.03	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
43.00	22.00	0.00	0.001	0.0	0.0	***5
43.00	21.00	0.00	0.001	0.0	0.0	***5
43.00	20.00	0.00	0.001	0.0	0.0	***5
43.00	19.00	0.00	0.001	0.0	0.0	***5
43.00	18.00	0.00	0.001	0.0	0.0	***5
43.00	17.00	0.00	0.001	0.0	0.0	***5
43.00	16.00	0.00	0.001	0.0	0.0	***5
43.00	15.00	0.00	0.001	0.0	0.0	***5
43.00	14.00	0.00	0.001	0.0	0.0	***5
43.00	13.00	0.00	0.001	0.0	0.0	***5
44.00	22.00	0.00	0.001	0.0	0.0	***5
44.00	21.00	0.00	0.001	0.0	0.0	***5
44.00	20.00	0.00	0.001	0.0	0.0	***5
44.00	19.00	0.00	0.001	0.0	0.0	***5
44.00	18.00	0.00	0.001	0.0	0.0	***5
44.00	17.00	0.00	0.001	0.0	0.0	***5
44.00	16.00	0.00	0.001	0.0	0.0	***5
44.00	15.00	0.00	0.001	0.0	0.0	***5
44.00	14.00	0.00	0.001	0.0	0.0	***5
44.00	13.00	0.00	0.001	0.0	0.0	***5
45.00	22.00	0.00	0.001	0.0	0.0	***5
45.00	21.00	0.00	0.001	0.0	0.0	***5
45.00	20.00	0.00	0.001	0.0	0.0	***5
45.00	19.00	0.00	0.001	0.0	0.0	***5
45.00	18.00	0.00	0.001	0.0	0.0	***5
45.00	17.00	0.00	0.001	0.0	0.0	***5
45.00	16.00	0.00	0.001	0.0	0.0	***5
45.00	15.00	0.00	0.001	0.0	0.0	***5
45.00	14.00	0.00	0.001	0.0	0.0	***5
45.00	13.00	0.00	0.001	0.0	0.0	***5
46.00	22.00	0.00	0.001	0.0	0.0	***5
46.00	21.00	0.00	0.001	0.0	0.0	***5
46.00	20.00	0.00	0.001	0.0	0.0	***5
46.00	19.00	0.00	0.001	0.0	0.0	***5
46.00	18.00	0.00	0.001	0.0	0.0	***5
46.00	17.00	0.00	0.001	0.0	0.0	***5
46.00	16.00	0.00	0.001	0.0	0.0	***5
46.00	15.00	0.00	0.001	0.0	0.0	***5
46.00	14.00	0.00	0.001	0.0	0.0	***5
46.00	13.00	0.00	0.001	0.0	0.0	***5

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
47.00	22.00	0.00	0.001	0.0	0.0	***5
47.00	21.00	0.00	0.001	0.0	0.0	***5
47.00	20.00	0.00	0.001	0.0	0.0	***5
47.00	19.00	0.00	0.001	0.0	0.0	***5
47.00	18.00	0.00	0.001	0.0	0.0	***5
47.00	17.00	0.00	0.001	0.0	0.0	***5
47.00	16.00	0.00	0.001	0.0	0.0	***5
47.00	15.00	0.00	0.001	0.0	0.0	***5
47.00	14.00	8.77	1.872	3414.7	1824.3	
47.00	13.00	7.87	1.891	2921.9	1545.3	
48.00	22.00	0.00	0.001	0.0	0.0	***5
48.00	21.00	0.00	0.001	0.0	0.0	***5
48.00	20.00	0.00	0.001	0.0	0.0	***5
48.00	19.00	0.00	0.001	0.0	0.0	***5
48.00	18.00	0.00	0.001	0.0	0.0	***5
48.00	17.00	10.90	1.684	3189.2	1893.5	
48.00	16.00	10.00	1.682	2867.1	1705.1	
48.00	15.00	9.11	1.689	2533.7	1500.2	
48.00	14.00	8.21	1.715	2193.0	1278.6	
48.00	13.00	7.32	1.778	1850.3	1040.6	
49.00	22.00	0.00	0.001	0.0	0.0	***5
49.00	21.00	0.00	0.001	0.0	0.0	***5
49.00	20.00	0.00	0.001	0.0	0.0	***5
49.00	19.00	0.00	0.001	0.0	0.0	***5
49.00	18.00	0.00	0.001	0.0	0.0	***5
49.00	17.00	0.00	0.001	0.0	0.0	***5
49.00	16.00	0.00	0.001	0.0	0.0	***5
49.00	15.00	0.00	0.001	0.0	0.0	***5
49.00	14.00	7.66	1.712	1204.9	703.8	
49.00	13.00	0.00	0.001	0.0	0.0	***5
50.00	22.00	0.00	0.001	0.0	0.0	***5
50.00	21.00	0.00	0.001	0.0	0.0	***5
50.00	20.00	0.00	0.001	0.0	0.0	***5
50.00	19.00	0.00	0.001	0.0	0.0	***5
50.00	18.00	0.00	0.001	0.0	0.0	***5
50.00	17.00	0.00	0.001	0.0	0.0	***5
50.00	16.00	0.00	0.001	0.0	0.0	***5
50.00	15.00	11.94	4.790	17854.0	3727.2	
		12.00	7.067	26789.7	3791.0	
50.00	14.00	10.95	5.047	15915.6	3153.7	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
50.00	14.00	11.00	7.278	23358.4	3209.6	
50.00	13.00	9.95	5.473	14123.8	2580.7	
		10.00	7.647	20096.7	2628.1	
51.00	22.00	0.00	0.001	0.0	0.0	***5
51.00	21.00	0.00	0.001	0.0	0.0	***5
51.00	20.00	0.00	0.001	0.0	0.0	***5
51.00	19.00	0.00	0.001	0.0	0.0	***5
51.00	18.00	0.00	0.001	0.0	0.0	***5
51.00	17.00	0.00	0.001	0.0	0.0	***5
51.00	16.00	13.00	10.386	41859.0	4030.3	
51.00	15.00	12.00	10.823	37326.2	3448.9	
51.00	14.00	11.00	11.493	32957.5	2867.5	
51.00	13.00	10.00	12.582	28762.5	2286.1	
52.00	22.00	0.00	0.001	0.0	0.0	***5
52.00	21.00	0.00	0.001	0.0	0.0	***5
52.00	20.00	0.00	0.001	0.0	0.0	***5
52.00	19.00	15.20	2.365	9789.5	4138.5	
52.00	18.00	14.23	2.396	8792.5	3670.2	
		15.00	12.269	58339.3	4755.0	
52.00	17.00	13.26	2.449	7848.2	3204.0	
		14.00	12.549	52375.3	4173.6	
52.00	16.00	12.30	2.540	6961.0	2740.8	
		13.00	12.984	46639.9	3592.2	
52.00	15.00	11.35	2.690	6136.7	2281.6	
		12.00	13.665	41143.2	3010.8	
52.00	14.00	11.00	14.779	35902.2	2429.3	
52.00	13.00	0.00	0.001	0.0	0.0	***5

Table of B.A.

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

Center X(m),Y(m)

Y(m)	X(m)	43.00	44.00	45.00	46.00	47.00	48.00
22.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
21.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
20.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
19.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
18.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
17.00	Fs	999.000	999.000	999.000	999.000	999.000	1.684
	R(m)	0.00	0.00	0.00	0.00	0.00	10.90
16.00	Fs	999.000	999.000	999.000	999.000	999.000	1.682
	R(m)	0.00	0.00	0.00	0.00	0.00	10.00
15.00	Fs	999.000	999.000	999.000	999.000	999.000	1.689
	R(m)	0.00	0.00	0.00	0.00	0.00	9.11
14.00	Fs	999.000	999.000	999.000	999.000	1.872	1.715
	R(m)	0.00	0.00	0.00	0.00	8.77	8.21
13.00	Fs	999.000	999.000	999.000	999.000	1.891	1.778
	R(m)	0.00	0.00	0.00	0.00	7.87	7.32

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

Center X(m),Y(m)

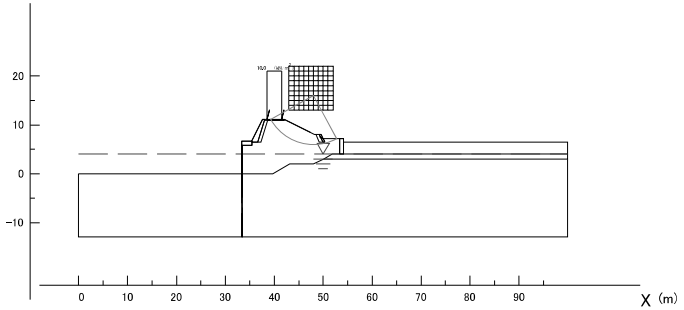
Y(m)	X(m)	49.00	50.00	51.00	52.00
22.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00
21.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00
20.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00
19.00	Fs	999.000	999.000	999.000	2.365
	R(m)	0.00	0.00	0.00	15.20
18.00	Fs	999.000	999.000	999.000	2.396
	R(m)	0.00	0.00	0.00	14.23
17.00	Fs	999.000	999.000	999.000	2.449
	R(m)	0.00	0.00	0.00	13.26
16.00	Fs	999.000	999.000	10.386	2.540
	R(m)	0.00	0.00	13.00	12.30
15.00	Fs	999.000	4.790	10.823	2.690
	R(m)	0.00	11.94	12.00	11.35
14.00	Fs	1.712	5.047	11.493	14.779
	R(m)	7.66	10.95	11.00	11.00
13.00	Fs	999.000	5.473	12.582	999.000
	R(m)	0.00	9.95	10.00	0.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)	
Bearing force Action ratio =	1.682
Failure circle X(m) =	48.00
Y(m) =	16.00
R(m) =	10.003
Resisting moment(kNm) =	2867.1
Sliding moment(kNm) =	1705.1
Partial coefficient concerning analytical technique =	1.0

// Check Result chart //



WARNING ***5 There are no arc contacting with base line.
count = 79

4. Action02 (seismic)

Value list for design

// Characteristic of soil that considers partial coefficient //

Lay No.	Chara No.	Saturated weight (kN/m³)	Wet weight (kN/m³)	Underwaterunit weight (kN/m³)	Cohesion C (kN/m²)	Cohesion coefficient	friction angle φ (°)	Unit weight calculation pore water (kN/m³)	Alpha	TAU (kN/m²)
1	8	18.00	17.00	8.00	1000.0	0 0.0	030.0	0 0.0	0 0.0	0 0.
0	2	2 77.0	0 77.0	0 67.0	01000.	00 0.	00 0.	00 0.	00 0.	00 0
0.0	3	1 24.	00 24.	00 14.	001000	0.00	0.00	0.00	0.00	0.00
0.0	4	1 24	0.00 2	0.00 1	0.0010	0.00	0.00	0.00	0.00	0.00
0.0	5	3 2	0.00 1	9.00 1	0.00	0.00	0.003	5.00	0.00	0.00
0.0	6	4 2	4.00 2	4.00 1	4.00	1.00	0.003	0.00	0.00	0.00
0.0	7	5 1	9.00 1	8.00	9.00	1.00	0.003	0.00	0.00	0.00
0.0	8	1 2	4.00 2	4.00 1	4.0010	00.00	0.00	0.00	0.00	0.00
0.	0 9	6	18.50	17.50	8.50	0.00	0.00	27.00	0.00	0.00
0.	0 10	7	19.00	18.00	9.00	50.00	0.00	0.00	0.00	0.00
0.	0 11	8	18.00	17.00	8.001	000.00	0.0	030.00	0.00	0.00
0	0.0 1	1	24.00	24.00	14.00	1000.0	0 0.	00 0.0	0 0.00	0.0
0	0.0 1	3	3 20.0	0 19.0	0 10.0	0 0.0	0 0.	0035.0	0 0.00	0.0
0	0.0									

// Distribution load that considers partial coefficient //

Load No.	Left			Right			Resisting coefficient of load	H.seismic intensity Khp	P.seismic intensity Kvp
	X (m)	Y (m)	Load Value(kN)	X (m)	Y (m)	Load Value(kN)			
2	38.50	11.15	5.0	41.50	11.15	5.0	0.000	0.200	0.000

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

No.	Coordinate		Residual water level
	X (m)	Y (m)	
1	0.00	4.03	
2	100.00	4.03	

Bearing force Action ratio

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
43.00	22.00	0.00	0.001	0.0	0.0	***5
43.00	21.00	0.00	0.001	0.0	0.0	***5
43.00	20.00	0.00	0.001	0.0	0.0	***5
43.00	19.00	0.00	0.001	0.0	0.0	***5
43.00	18.00	0.00	0.001	0.0	0.0	***5
43.00	17.00	0.00	0.001	0.0	0.0	***5
43.00	16.00	0.00	0.001	0.0	0.0	***5
43.00	15.00	0.00	0.001	0.0	0.0	***5
43.00	14.00	0.00	0.001	0.0	0.0	***5
43.00	13.00	0.00	0.001	0.0	0.0	***5
44.00	22.00	0.00	0.001	0.0	0.0	***5
44.00	21.00	0.00	0.001	0.0	0.0	***5
44.00	20.00	0.00	0.001	0.0	0.0	***5
44.00	19.00	0.00	0.001	0.0	0.0	***5
44.00	18.00	0.00	0.001	0.0	0.0	***5
44.00	17.00	0.00	0.001	0.0	0.0	***5
44.00	16.00	0.00	0.001	0.0	0.0	***5
44.00	15.00	0.00	0.001	0.0	0.0	***5
44.00	14.00	0.00	0.001	0.0	0.0	***5
44.00	13.00	0.00	0.001	0.0	0.0	***5
45.00	22.00	0.00	0.001	0.0	0.0	***5
45.00	21.00	0.00	0.001	0.0	0.0	***5
45.00	20.00	0.00	0.001	0.0	0.0	***5
45.00	19.00	0.00	0.001	0.0	0.0	***5
45.00	18.00	0.00	0.001	0.0	0.0	***5
45.00	17.00	0.00	0.001	0.0	0.0	***5
45.00	16.00	0.00	0.001	0.0	0.0	***5
45.00	15.00	0.00	0.001	0.0	0.0	***5
45.00	14.00	0.00	0.001	0.0	0.0	***5
45.00	13.00	0.00	0.001	0.0	0.0	***5
46.00	22.00	0.00	0.001	0.0	0.0	***5
46.00	21.00	0.00	0.001	0.0	0.0	***5
46.00	20.00	0.00	0.001	0.0	0.0	***5
46.00	19.00	0.00	0.001	0.0	0.0	***5
46.00	18.00	0.00	0.001	0.0	0.0	***5
46.00	17.00	0.00	0.001	0.0	0.0	***5
46.00	16.00	0.00	0.001	0.0	0.0	***5
46.00	15.00	0.00	0.001	0.0	0.0	***5
46.00	14.00	0.00	0.001	0.0	0.0	***5
46.00	13.00	0.00	0.001	0.0	0.0	***5

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
47.00	22.00	0.00	0.001	0.0	0.0	***5
47.00	21.00	0.00	0.001	0.0	0.0	***5
47.00	20.00	0.00	0.001	0.0	0.0	***5
47.00	19.00	0.00	0.001	0.0	0.0	***5
47.00	18.00	0.00	0.001	0.0	0.0	***5
47.00	17.00	0.00	0.001	0.0	0.0	***5
47.00	16.00	0.00	0.001	0.0	0.0	***5
47.00	15.00	0.00	0.001	0.0	0.0	***5
47.00	14.00	8.77	1.128	3226.3	2860.0	
47.00	13.00	7.87	1.130	2759.8	2442.3	
48.00	22.00	0.00	0.001	0.0	0.0	***5
48.00	21.00	0.00	0.001	0.0	0.0	***5
48.00	20.00	0.00	0.001	0.0	0.0	***5
48.00	19.00	0.00	0.001	0.0	0.0	***5
48.00	18.00	0.00	0.001	0.0	0.0	***5
48.00	17.00	10.90	1.057	2994.9	2832.9	
48.00	16.00	10.00	1.051	2690.1	2558.8	
48.00	15.00	9.11	1.049	2375.4	2265.1	
48.00	14.00	8.21	1.052	2055.2	1953.4	
48.00	13.00	7.32	1.067	1734.7	1625.3	
49.00	22.00	0.00	0.001	0.0	0.0	***5
49.00	21.00	0.00	0.001	0.0	0.0	***5
49.00	20.00	0.00	0.001	0.0	0.0	***5
49.00	19.00	0.00	0.001	0.0	0.0	***5
49.00	18.00	0.00	0.001	0.0	0.0	***5
49.00	17.00	0.00	0.001	0.0	0.0	***5
49.00	16.00	0.00	0.001	0.0	0.0	***5
49.00	15.00	0.00	0.001	0.0	0.0	***5
49.00	14.00	7.66	1.033	1123.6	1087.5	
49.00	13.00	0.00	0.001	0.0	0.0	***5
50.00	22.00	0.00	0.001	0.0	0.0	***5
50.00	21.00	0.00	0.001	0.0	0.0	***5
50.00	20.00	0.00	0.001	0.0	0.0	***5
50.00	19.00	0.00	0.001	0.0	0.0	***5
50.00	18.00	0.00	0.001	0.0	0.0	***5
50.00	17.00	0.00	0.001	0.0	0.0	***5
50.00	16.00	0.00	0.001	0.0	0.0	***5
50.00	15.00	11.94	2.677	17363.3	6485.6	
		12.00	3.977	26293.5	6611.8	
50.00	14.00	10.95	2.801	15488.3	5530.3	

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

Coordinate at center of circle		Radius	Bear force Action ratio	Resisting moment	Sliding moment	
X (m)	Y (m)	R (m)		(kNm)	(kNm)	
50.00	14.00	11.00	4.066	22926.2	5639.1	
50.00	13.00	9.95	2.990	13759.9	4601.9	
		10.00	4.204	19728.6	4692.7	
51.00	22.00	0.00	0.001	0.0	0.0	***5
51.00	21.00	0.00	0.001	0.0	0.0	***5
51.00	20.00	0.00	0.001	0.0	0.0	***5
51.00	19.00	0.00	0.001	0.0	0.0	***5
51.00	18.00	0.00	0.001	0.0	0.0	***5
51.00	17.00	0.00	0.001	0.0	0.0	***5
51.00	16.00	13.00	5.817	41335.2	7105.9	
51.00	15.00	12.00	6.017	36866.4	6127.4	
51.00	14.00	11.00	6.293	32561.7	5174.1	
51.00	13.00	10.00	6.693	28430.8	4247.9	
52.00	22.00	0.00	0.001	0.0	0.0	***5
52.00	21.00	0.00	0.001	0.0	0.0	***5
52.00	20.00	0.00	0.001	0.0	0.0	***5
52.00	19.00	15.20	1.307	9311.9	7122.8	
52.00	18.00	14.23	1.316	8360.9	6353.0	
		15.00	6.788	57737.9	8505.8	
52.00	17.00	13.26	1.332	7462.3	5603.7	
		14.00	6.912	51838.2	7499.9	
52.00	16.00	12.30	1.357	6620.4	4877.2	
		13.00	7.084	46167.1	6516.9	
52.00	15.00	11.35	1.399	5840.9	4176.5	
		12.00	7.329	40734.6	5558.2	
52.00	14.00	11.00	7.687	35558.1	4625.5	
52.00	13.00	0.00	0.001	0.0	0.0	***5

Table of B.A.

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

Center X(m),Y(m)

Y(m)	X(m)	43.00	44.00	45.00	46.00	47.00	48.00
22.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
21.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
20.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
19.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
18.00	Fs	999.000	999.000	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00	0.00	0.00
17.00	Fs	999.000	999.000	999.000	999.000	999.000	1.057
	R(m)	0.00	0.00	0.00	0.00	0.00	10.90
16.00	Fs	999.000	999.000	999.000	999.000	999.000	1.051
	R(m)	0.00	0.00	0.00	0.00	0.00	10.00
15.00	Fs	999.000	999.000	999.000	999.000	999.000	1.049
	R(m)	0.00	0.00	0.00	0.00	0.00	9.11
14.00	Fs	999.000	999.000	999.000	999.000	1.128	1.052
	R(m)	0.00	0.00	0.00	0.00	8.77	8.21
13.00	Fs	999.000	999.000	999.000	999.000	1.130	1.067
	R(m)	0.00	0.00	0.00	0.00	7.87	7.32

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

Center X(m),Y(m)

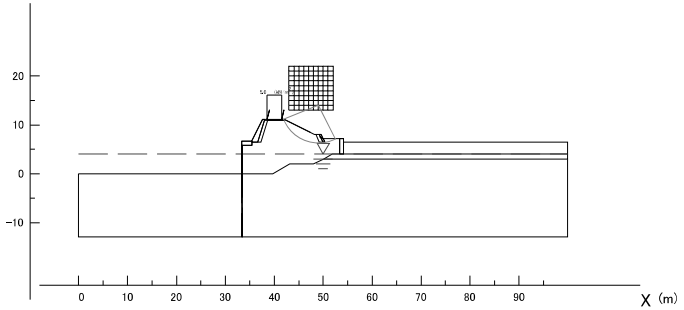
Y(m)	X(m)	49.00	50.00	51.00	52.00
22.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00
21.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00
20.00	Fs	999.000	999.000	999.000	999.000
	R(m)	0.00	0.00	0.00	0.00
19.00	Fs	999.000	999.000	999.000	1.307
	R(m)	0.00	0.00	0.00	15.20
18.00	Fs	999.000	999.000	999.000	1.316
	R(m)	0.00	0.00	0.00	14.23
17.00	Fs	999.000	999.000	999.000	1.332
	R(m)	0.00	0.00	0.00	13.26
16.00	Fs	999.000	999.000	5.817	1.357
	R(m)	0.00	0.00	13.00	12.30
15.00	Fs	999.000	2.677	6.017	1.399
	R(m)	0.00	11.94	12.00	11.35
14.00	Fs	1.033	2.801	6.293	7.687
	R(m)	7.66	10.95	11.00	11.00
13.00	Fs	999.000	2.990	6.693	999.000
	R(m)	0.00	9.95	10.00	0.00

Bearing force Action ratio

Bearing force Action ratio (Group number = 1)

(Loop = 0)		
Bearing force Action ratio	=	1.033
Failure circle X(m)	=	49.00
Y(m)	=	14.00
R(m)	=	7.662
Resisting moment(kNm)	=	1123.6
Sliding moment(kNm)	=	1087.5
Partial coefficient concerning analytical technique	=	1.0

// Check Result chart //



WARNING ***5 There are no arc contacting with base line.

count = 79

Test of Embankment Stability

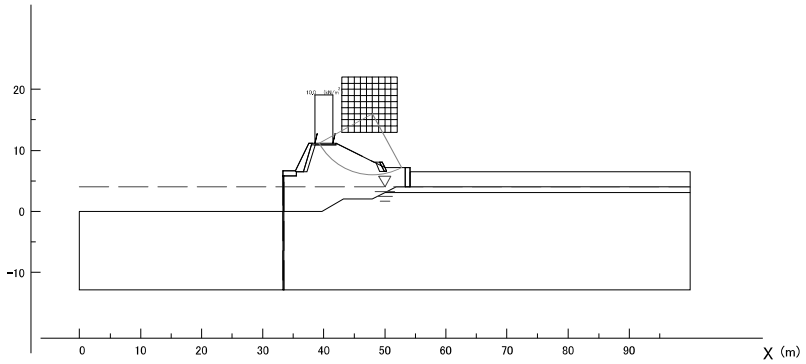
Action number = 1

Action name : normal

Examination at earthquake : It doesn't do.

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	1.682	≧ 1.0 (OK)
Center of arc	X	=	48.00	(m)
	Y	=	16.00	(m)
Radius	R	=	10.003	(m)
Resisting moment	M_R	=	2867.1	(kNm)
Sliding moment	M_D	=	1705.1	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	17.00	30.00	1000.00	0.00	0.200	0.000
2	77.00	77.00	0.00	1000.00	0.00	0.200	0.000
3	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
4	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
5	20.00	19.00	35.00	0.00	0.00	0.200	0.000
6	24.00	24.00	30.00	1.00	0.00	0.200	0.000
7	19.00	18.00	30.00	1.00	0.00	0.200	0.000
8	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
9	18.50	17.50	27.00	0.00	0.00	0.200	0.000
10	19.00	18.00	0.00	59.00	0.00	0.200	0.000
11	18.00	17.00	30.00	1000.00	0.00	0.200	0.000
12	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
13	20.00	19.00	35.00	0.00	0.00	0.200	0.000

Water unit weight = 10.00 (kN/m³)

Safety Factor (Ordinary Condition)

Test of Embankment Stability

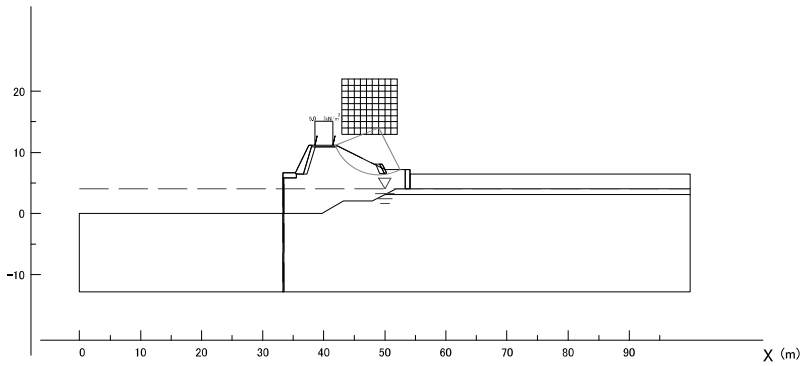
Action number = 2

Action name : seismic

Examination at earthquake : It does.

Scale : 1/ 792

Required Bearing force Action ratio	F_S	=	1.000	
Bearing force Action ratio		=	1.033	≧ 1.0 (OK)
Center of arc	X	=	49.00	(m)
	Y	=	14.00	(m)
Radius	R	=	7.662	(m)
Resisting moment	M_R	=	1123.6	(kNm)
Sliding moment	M_D	=	1087.5	(kNm)
Partial coefficient concerning	$\gamma\alpha$	=	1.00	



【Nature of soil condition table(Input value)】

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	17.00	30.00	1000.00	0.00	0.200	0.000
2	77.00	77.00	0.00	1000.00	0.00	0.200	0.000
3	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
4	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
5	20.00	19.00	35.00	0.00	0.00	0.200	0.000
6	24.00	24.00	30.00	1.00	0.00	0.200	0.000
7	19.00	18.00	30.00	1.00	0.00	0.200	0.000
8	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
9	18.50	17.50	27.00	0.00	0.00	0.200	0.000
10	19.00	18.00	0.00	59.00	0.00	0.200	0.000
11	18.00	17.00	30.00	1000.00	0.00	0.200	0.000
12	24.00	24.00	0.00	1000.00	0.00	0.200	0.000
13	20.00	19.00	35.00	0.00	0.00	0.200	0.000

Water unit weight = 10.00 (kN/m³)

Safety Factor (Seismic Condition)