Phụ lục 7-1

Kết quả tính toán xử lý nền đất yếu cho khu vực bến công-ten-nơ và khu vực đường sau cảng

Appendix 7-1

1) Required Embankment Height Calculation Result

2) Settlement-Time Curves with PVD for Reclamation Area
   (Block 1 to 16)

3) Economical Comparison Tables by PVD Spacing
   for Terminal Area (Block 1 to 12)

4) Slope Stability Analysis Result during Filling at Reclamation Area
   (Required Average Slope Gradient between Seabed and First Fill (CD+5.0m))

1) Required Embankment Height Calculation Result

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	30.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.00	2	6.50	22.75	80.00	0.60	0.12	1.45	137.40	0.174	0.480	0.654
	3b	2.00	54.50	104.50	0.25	0.05	0.80	137.40	0.016	0.073	0.089
	4	5.00	86.00	186.00	0.35	0.04	0.85	137.40	0.036	0.075	0.111
	5(U)	5.50	129.13	204.13	0.60	0.08	1.20	137.40	0.040	0.174	0.214
	5(L)	5.50	170.38	245.38	0.60	0.08	1.20	137.40	0.032	0.148	0.179
Ground Level											
-1.50	Total	24.50							0.297	0.950	1.247
									Final Ground Level (m)		4.753

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.50	2	6.50	22.75	80.00	0.60	0.12	1.45	146.40	0.174	0.518	0.691
	3b	2.00	54.50	104.50	0.25	0.05	0.80	146.40	0.016	0.079	0.095
	4	5.00	86.00	186.00	0.35	0.04	0.85	146.40	0.036	0.091	0.128
	5(U)	5.50	129.13	204.13	0.60	0.08	1.20	146.40	0.040	0.195	0.235
	5(L)	5.50	170.38	245.38	0.60	0.08	1.20	146.40	0.032	0.166	0.198
Ground Level											
-1.50	Total	24.50							0.297	1.050	1.347
									Final Ground Level (m)		5.153

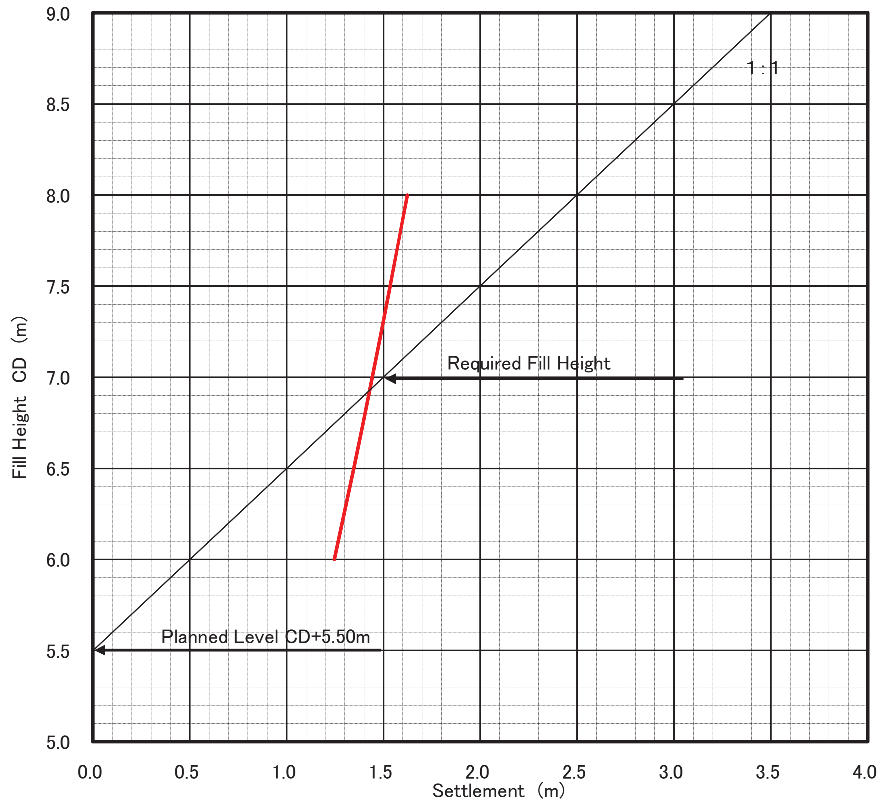
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.00	2	6.50	22.75	80.00	0.60	0.12	1.45	155.40	0.174	0.553	0.727
	3b	2.00	54.50	104.50	0.25	0.05	0.80	155.40	0.016	0.084	0.100
	4	5.00	86.00	186.00	0.35	0.04	0.85	155.40	0.036	0.107	0.143
	5(U)	5.50	129.13	204.13	0.60	0.08	1.20	155.40	0.040	0.216	0.256
	5(L)	5.50	170.38	245.38	0.60	0.08	1.20	155.40	0.032	0.185	0.216
Ground Level											
-1.50	Total	24.50							0.297	1.146	1.443
									Final Ground Level (m)		5.557

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.50	2	6.50	22.75	80.00	0.60	0.12	1.45	164.40	0.174	0.588	0.761
	3b	2.00	54.50	104.50	0.25	0.05	0.80	164.40	0.016	0.089	0.105
	4	5.00	86.00	186.00	0.35	0.04	0.85	164.40	0.036	0.122	0.158
	5(U)	5.50	129.13	204.13	0.60	0.08	1.20	164.40	0.040	0.237	0.276
	5(L)	5.50	170.38	245.38	0.60	0.08	1.20	164.40	0.032	0.202	0.234
Ground Level											
-1.50	Total	24.50							0.297	1.238	1.535
									Final Ground Level (m)		5.965

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
8.00	2	6.50	22.75	80.00	0.60	0.12	1.45	173.40	0.174	0.620	0.794
	3b	2.00	54.50	104.50	0.25	0.05	0.80	173.40	0.016	0.094	0.110
	4	5.00	86.00	186.00	0.35	0.04	0.85	173.40	0.036	0.137	0.173
	5(U)	5.50	129.13	204.13	0.60	0.08	1.20	173.40	0.040	0.256	0.296
	5(L)	5.50	170.38	245.38	0.60	0.08	1.20	173.40	0.032	0.220	0.251
Ground Level											
-1.50	Total	24.50							0.297	1.327	1.624
									Final Ground Level (m)		6.376

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.00	2	6.50	22.75	80.00	0.60	0.12	1.45	155.40	0.174	0.553	0.727
	3b	2.00	54.50	104.50	0.25	0.05	0.80	155.40	0.016	0.084	0.100
	4	5.00	86.00	186.00	0.35	0.04	0.85	155.40	0.036	0.107	0.143
	5(U)	5.50	129.13	204.13	0.60	0.08	1.20	155.40	0.040	0.216	0.256
	5(L)	5.50	170.38	245.38	0.60	0.08	1.20	155.40	0.032	0.185	0.216
Ground Level											
-1.50	Total	24.50							0.297	1.146	1.443
									Final Ground Level (m)		5.557



Required Embankment Height Calculation Result for【+5.50m:Block-1(Container Terminal Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	30.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.00	1a	2.00									
	1b	2.00	24.00	80.00	0.30	0.07	1.05	117.40	0.036	0.072	0.108
	2	4.00	46.00	80.00	0.60	0.12	1.45	117.40	0.047	0.304	0.351
	3a	1.00									
	3b	3.50	84.75	134.75	0.25	0.05	0.80	117.40	0.020	0.086	0.105
	4	4.00	118.50	218.50	0.35	0.04	0.85	117.40	0.023	0.025	0.048
	5(U)	5.00	155.25	230.25	0.60	0.08	1.20	117.40	0.031	0.100	0.131
Ground Level	5(L)	5.00	192.75	267.75	0.60	0.08	1.20	117.40	0.026	0.087	0.113
0.50	Total	26.50							0.182	0.674	0.857
									Final Ground Level (m)		5.143

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.50	1a	2.00									
	1b	2.00	24.00	80.00	0.30	0.07	1.05	126.40	0.036	0.080	0.116
	2	4.00	46.00	80.00	0.60	0.12	1.45	126.40	0.047	0.327	0.374
	3a	1.00									
	3b	3.50	84.75	134.75	0.25	0.05	0.80	126.40	0.020	0.095	0.114
	4	4.00	118.50	218.50	0.35	0.04	0.85	126.40	0.023	0.037	0.060
	5(U)	5.00	155.25	230.25	0.60	0.08	1.20	126.40	0.031	0.119	0.150
Ground Level	5(L)	5.00	192.75	267.75	0.60	0.08	1.20	126.40	0.026	0.104	0.130
0.50	Total	26.50							0.182	0.763	0.945
									Final Ground Level (m)		5.555

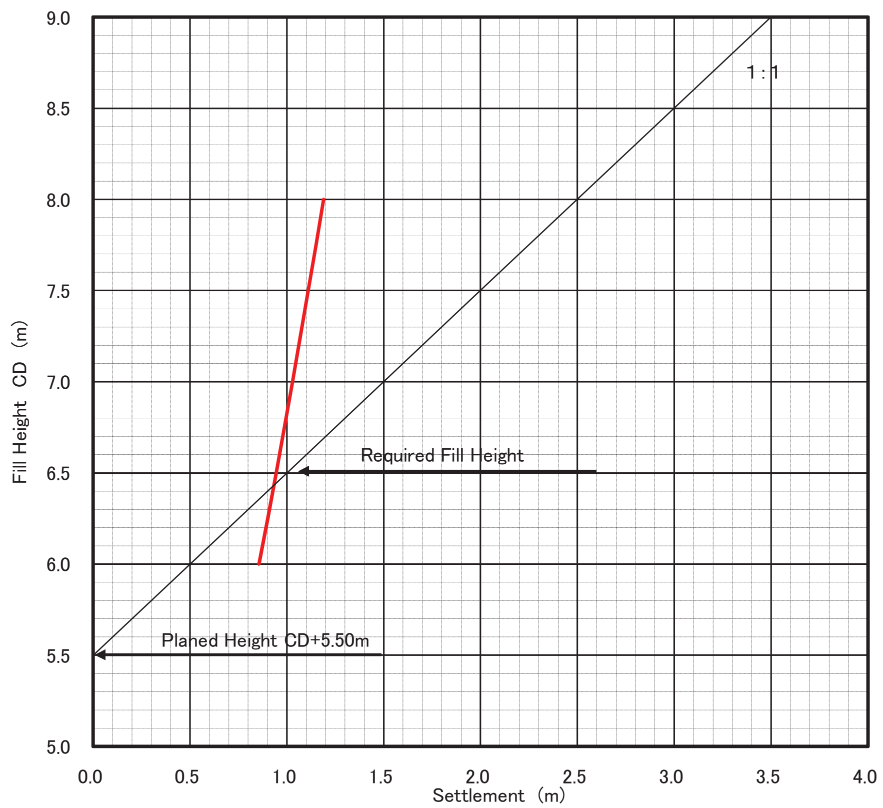
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.00	1a	2.00									
	1b	2.00	24.00	80.00	0.30	0.07	1.05	135.40	0.036	0.088	0.123
	2	4.00	46.00	80.00	0.60	0.12	1.45	135.40	0.047	0.348	0.395
	3a	1.00									
	3b	3.50	84.75	134.75	0.25	0.05	0.80	135.40	0.020	0.104	0.123
	4	4.00	118.50	218.50	0.35	0.04	0.85	135.40	0.023	0.049	0.072
	5(U)	5.00	155.25	230.25	0.60	0.08	1.20	135.40	0.031	0.138	0.169
Ground Level	5(L)	5.00	192.75	267.75	0.60	0.08	1.20	135.40	0.026	0.120	0.146
0.50	Total	26.50							0.182	0.847	1.030
									Final Ground Level (m)		5.970

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.50	1a	2.00									
	1b	2.00	24.00	80.00	0.30	0.07	1.05	144.40	0.036	0.095	0.130
	2	4.00	46.00	80.00	0.60	0.12	1.45	144.40	0.047	0.369	0.416
	3a	1.00									
	3b	3.50	84.75	134.75	0.25	0.05	0.80	144.40	0.020	0.112	0.132
	4	4.00	118.50	218.50	0.35	0.04	0.85	144.40	0.023	0.061	0.084
	5(U)	5.00	155.25	230.25	0.60	0.08	1.20	144.40	0.031	0.156	0.187
Ground Level	5(L)	5.00	192.75	267.75	0.60	0.08	1.20	144.40	0.026	0.136	0.162
0.50	Total	26.50							0.182	0.929	1.111
									Final Ground Level (m)		6.389

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
8.00	1a	2.00									
	1b	2.00	24.00	80.00	0.30	0.07	1.05	153.40	0.036	0.101	0.137
	2	4.00	46.00	80.00	0.60	0.12	1.45	153.40	0.047	0.389	0.436
	3a	1.00									
	3b	3.50	84.75	134.75	0.25	0.05	0.80	153.40	0.020	0.120	0.140
	4	4.00	118.50	218.50	0.35	0.04	0.85	153.40	0.023	0.072	0.095
	5(U)	5.00	155.25	230.25	0.60	0.08	1.20	153.40	0.031	0.174	0.205
Ground Level	5(L)	5.00	192.75	267.75	0.60	0.08	1.20	153.40	0.026	0.152	0.178
0.50	Total	26.50							0.182	1.007	1.190
									Final Ground Level (m)		6.810

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.50	1a	2.00									
	1b	2.00	24.00	80.00	0.30	0.07	1.05	126.40	0.036	0.080	0.116
	2	4.00	46.00	80.00	0.60	0.12	1.45	126.40	0.047	0.327	0.374
	3a	1.00									
	3b	3.50	84.75	134.75	0.25	0.05	0.80	126.40	0.020	0.095	0.114
	4	4.00	118.50	218.50	0.35	0.04	0.85	126.40	0.023	0.037	0.060
	5(U)	5.00	155.25	230.25	0.60	0.08	1.20	126.40	0.031	0.119	0.150
Ground Level	5(L)	5.00	192.75	267.75	0.60	0.08	1.20	126.40	0.026	0.104	0.130
0.50	Total	26.50							0.182	0.763	0.945
									Final Ground Level (m)		5.555



Required Embankment Height Calculation Result for【+5.50m：Block-2(Container Terminal Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	30.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1a	1.00									
	1b	2.50	18.00	80.00	0.30	0.07	1.05	122.40	0.055	0.089	0.145
	2	5.00	45.50	80.00	0.60	0.12	1.45	122.40	0.060	0.394	0.454
	3b	2.00	72.00	122.00	0.25	0.05	0.80	122.40	0.013	0.056	0.069
	3c	3.50									
	4	1.50	119.25	219.25	0.35	0.04	0.85	122.40	0.009	0.012	0.021
	5(U)	5.50	146.63	221.63	0.60	0.08	1.20	122.40	0.036	0.126	0.162
Ground Level	5(L)	6.00	189.75	264.75	0.60	0.08	1.20	122.40	0.032	0.117	0.149
0.00	Total	27.00							0.204	0.795	0.999
									Final Ground Level (m)		5.001

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1a	1.00									
	1b	2.50	18.00	80.00	0.30	0.07	1.05	131.40	0.055	0.099	0.155
	2	5.00	45.50	80.00	0.60	0.12	1.45	131.40	0.060	0.422	0.482
	3b	2.00	72.00	122.00	0.25	0.05	0.80	131.40	0.013	0.062	0.074
	3c	3.50									
	4	1.50	119.25	219.25	0.35	0.04	0.85	131.40	0.009	0.016	0.025
	5(U)	5.50	146.63	221.63	0.60	0.08	1.20	131.40	0.036	0.148	0.184
Ground Level	5(L)	6.00	189.75	264.75	0.60	0.08	1.20	131.40	0.032	0.137	0.169
0.00	Total	27.00							0.204	0.884	1.088
									Final Ground Level (m)		5.412

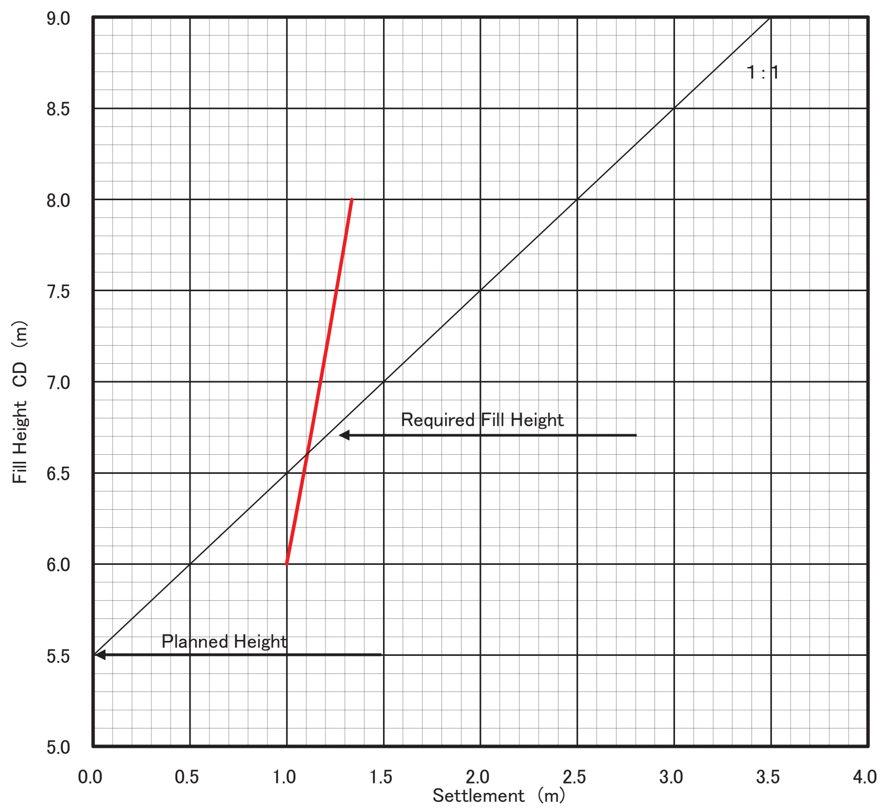
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1a	1.00									
	1b	2.50	18.00	80.00	0.30	0.07	1.05	140.40	0.055	0.109	0.164
	2	5.00	45.50	80.00	0.60	0.12	1.45	140.40	0.060	0.448	0.508
	3b	2.00	72.00	122.00	0.25	0.05	0.80	140.40	0.013	0.067	0.080
	3c	3.50									
	4	1.50	119.25	219.25	0.35	0.04	0.85	140.40	0.009	0.021	0.029
	5(U)	5.50	146.63	221.63	0.60	0.08	1.20	140.40	0.036	0.168	0.204
Ground Level	5(L)	6.00	189.75	264.75	0.60	0.08	1.20	140.40	0.032	0.157	0.188
0.00	Total	27.00							0.204	0.970	1.174
									Final Ground Level (m)		5.826

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1a	1.00									
	1b	2.50	18.00	80.00	0.30	0.07	1.05	149.40	0.055	0.117	0.173
	2	5.00	45.50	80.00	0.60	0.12	1.45	149.40	0.060	0.474	0.534
	3b	2.00	72.00	122.00	0.25	0.05	0.80	149.40	0.013	0.072	0.085
	3c	3.50									
	4	1.50	119.25	219.25	0.35	0.04	0.85	149.40	0.009	0.025	0.034
	5(U)	5.50	146.63	221.63	0.60	0.08	1.20	149.40	0.036	0.189	0.224
Ground Level	5(L)	6.00	189.75	264.75	0.60	0.08	1.20	149.40	0.032	0.176	0.208
0.00	Total	27.00							0.204	1.052	1.256
									Final Ground Level (m)		6.244

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1a	1.00									
	1b	2.50	18.00	80.00	0.30	0.07	1.05	158.40	0.055	0.126	0.181
	2	5.00	45.50	80.00	0.60	0.12	1.45	158.40	0.060	0.498	0.558
	3b	2.00	72.00	122.00	0.25	0.05	0.80	158.40	0.013	0.077	0.089
	3c	3.50									
	4	1.50	119.25	219.25	0.35	0.04	0.85	158.40	0.009	0.029	0.038
	5(U)	5.50	146.63	221.63	0.60	0.08	1.20	158.40	0.036	0.208	0.244
Ground Level	5(L)	6.00	189.75	264.75	0.60	0.08	1.20	158.40	0.032	0.195	0.226
0.00	Total	27.00							0.204	1.132	1.336
									Final Ground Level (m)		6.664

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.70	1a	1.00									
	1b	2.50	18.00	80.00	0.30	0.07	1.05	135.00	0.055	0.103	0.158
	2	5.00	45.50	80.00	0.60	0.12	1.45	135.00	0.060	0.433	0.493
	3b	2.00	72.00	122.00	0.25	0.05	0.80	135.00	0.013	0.064	0.077
	3c	3.50									
	4	1.50	119.25	219.25	0.35	0.04	0.85	135.00	0.009	0.018	0.027
	5(U)	5.50	146.63	221.63	0.60	0.08	1.20	135.00	0.036	0.156	0.192
Ground Level	5(L)	6.00	189.75	264.75	0.60	0.08	1.20	135.00	0.032	0.145	0.177
0.00	Total	27.00							0.204	0.919	1.123
									Final Ground Level (m)		5.577



Required Embankment Height Calculation Result for【+5.50m：Block-3(Container Terminal Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	30.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.00	1a	1.00									
	2	7.00	32.50	80.00	0.60	0.12	1.45	122.40	0.134	0.492	0.626
	3a	1.50									
	3b	3.00	84.00	134.00	0.25	0.05	0.80	122.40	0.017	0.078	0.095
	4	2.50	108.75	208.75	0.35	0.04	0.85	122.40	0.015	0.021	0.036
	5(U)	6.00	142.50	217.50	0.60	0.08	1.20	122.40	0.040	0.140	0.180
	5(L)	6.50	189.38	264.38	0.60	0.08	1.20	122.40	0.034	0.127	0.161
Ground Level											
0.00	Total	27.50							0.241	0.858	1.099
										Final Ground Level (m)	4.901

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.50	1a	1.00									
	2	7.00	32.50	80.00	0.60	0.12	1.45	131.40	0.134	0.534	0.668
	3a	1.50									
	3b	3.00	84.00	134.00	0.25	0.05	0.80	131.40	0.017	0.086	0.103
	4	2.50	108.75	208.75	0.35	0.04	0.85	131.40	0.015	0.029	0.044
	5(U)	6.00	142.50	217.50	0.60	0.08	1.20	131.40	0.040	0.164	0.204
	5(L)	6.50	189.38	264.38	0.60	0.08	1.20	131.40	0.034	0.149	0.183
Ground Level											
0.00	Total	27.50							0.241	0.961	1.202
										Final Ground Level (m)	5.298

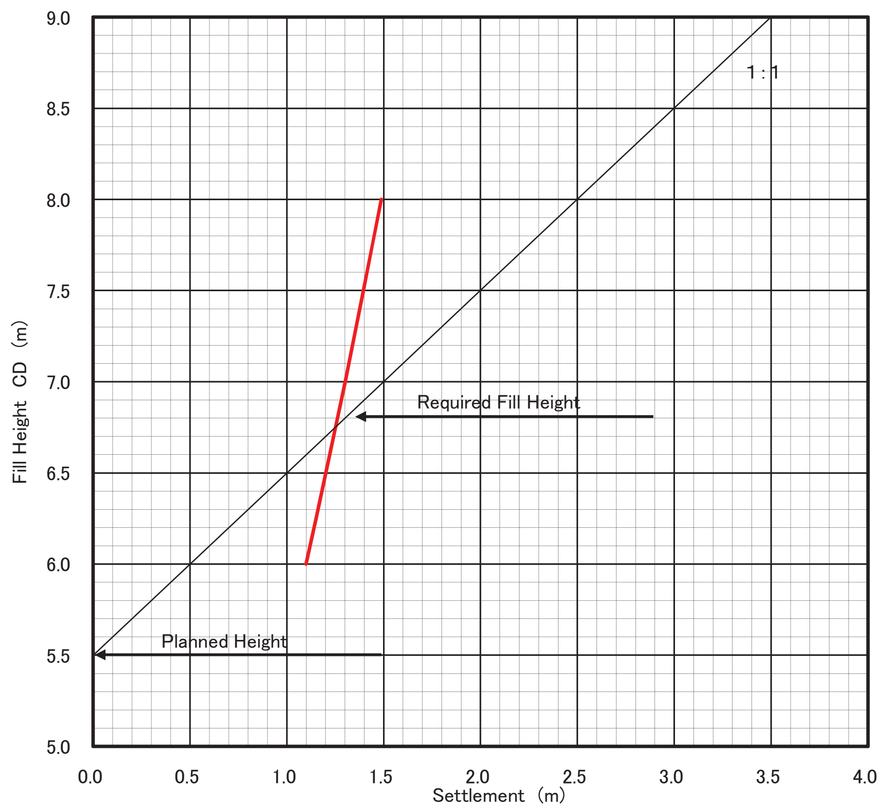
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.00	1a	1.00									
	2	7.00	32.50	80.00	0.60	0.12	1.45	140.40	0.134	0.574	0.708
	3a	1.50									
	3b	3.00	84.00	134.00	0.25	0.05	0.80	140.40	0.017	0.093	0.110
	4	2.50	108.75	208.75	0.35	0.04	0.85	140.40	0.015	0.036	0.052
	5(U)	6.00	142.50	217.50	0.60	0.08	1.20	140.40	0.040	0.187	0.227
	5(L)	6.50	189.38	264.38	0.60	0.08	1.20	140.40	0.034	0.170	0.204
Ground Level											
0.00	Total	27.50							0.241	1.060	1.301
										Final Ground Level (m)	5.699

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.50	1a	1.00									
	2	7.00	32.50	80.00	0.60	0.12	1.45	149.40	0.134	0.612	0.746
	3a	1.50									
	3b	3.00	84.00	134.00	0.25	0.05	0.80	149.40	0.017	0.100	0.117
	4	2.50	108.75	208.75	0.35	0.04	0.85	149.40	0.015	0.044	0.059
	5(U)	6.00	142.50	217.50	0.60	0.08	1.20	149.40	0.040	0.209	0.249
	5(L)	6.50	189.38	264.38	0.60	0.08	1.20	149.40	0.034	0.191	0.225
Ground Level											
0.00	Total	27.50							0.241	1.156	1.396
										Final Ground Level (m)	6.104

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
8.00	1a	1.00									
	2	7.00	32.50	80.00	0.60	0.12	1.45	158.40	0.134	0.648	0.782
	3a	1.50									
	3b	3.00	84.00	134.00	0.25	0.05	0.80	158.40	0.017	0.107	0.124
	4	2.50	108.75	208.75	0.35	0.04	0.85	158.40	0.015	0.051	0.066
	5(U)	6.00	142.50	217.50	0.60	0.08	1.20	158.40	0.040	0.231	0.271
	5(L)	6.50	189.38	264.38	0.60	0.08	1.20	158.40	0.034	0.211	0.245
Ground Level											
0.00	Total	27.50							0.241	1.247	1.488
										Final Ground Level (m)	6.512

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.80	1a	1.00									
	2	7.00	32.50	80.00	0.60	0.12	1.45	136.80	0.134	0.558	0.692
	3a	1.50									
	3b	3.00	84.00	134.00	0.25	0.05	0.80	136.80	0.017	0.090	0.107
	4	2.50	108.75	208.75	0.35	0.04	0.85	136.80	0.015	0.033	0.049
	5(U)	6.00	142.50	217.50	0.60	0.08	1.20	136.80	0.040	0.178	0.218
	5(L)	6.50	189.38	264.38	0.60	0.08	1.20	136.80	0.034	0.162	0.196
Ground Level											
0.00	Total	27.50							0.241	1.021	1.262
										Final Ground Level (m)	5.538



Required Embankment Height Calculation Result for【+5.50m：Block-4(Container Terminal Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	30.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1b	1.50	6.00	80.00	0.30	0.07	1.05	137.40	0.058	0.056	0.113
	2	5.00	29.50	80.00	0.60	0.12	1.45	137.40	0.106	0.391	0.497
	3a	1.50									
	3b	4.50	80.75	130.75	0.25	0.05	0.80	137.40	0.026	0.139	0.165
	5(U)	6.00	123.50	198.50	0.60	0.08	1.20	137.40	0.045	0.194	0.239
	5(L)	6.00	168.50	243.50	0.60	0.08	1.20	137.40	0.035	0.162	0.197
Ground Level											
−1.50	Total	24.50							0.270	0.942	1.212
									Final Ground Level (m)		4.788

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1b	1.50	6.00	80.00	0.30	0.07	1.05	146.40	0.058	0.061	0.119
	2	5.00	29.50	80.00	0.60	0.12	1.45	146.40	0.106	0.419	0.525
	3a	1.50									
	3b	4.50	80.75	130.75	0.25	0.05	0.80	146.40	0.026	0.150	0.176
	5(U)	6.00	123.50	198.50	0.60	0.08	1.20	146.40	0.045	0.218	0.263
	5(L)	6.00	168.50	243.50	0.60	0.08	1.20	146.40	0.035	0.183	0.218
Ground Level											
−1.50	Total	24.50							0.270	1.031	1.301
									Final Ground Level (m)		5.199

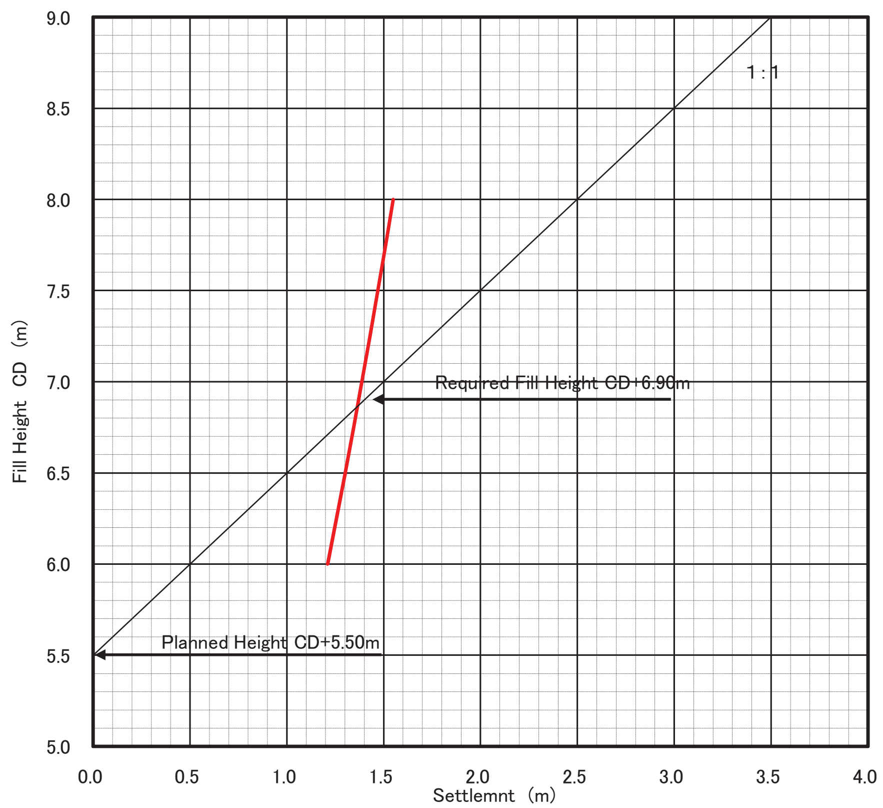
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1b	1.50	6.00	80.00	0.30	0.07	1.05	155.40	0.058	0.067	0.125
	2	5.00	29.50	80.00	0.60	0.12	1.45	155.40	0.106	0.446	0.552
	3a	1.50									
	3b	4.50	80.75	130.75	0.25	0.05	0.80	155.40	0.026	0.160	0.187
	5(U)	6.00	123.50	198.50	0.60	0.08	1.20	155.40	0.045	0.242	0.287
	5(L)	6.00	168.50	243.50	0.60	0.08	1.20	155.40	0.035	0.203	0.238
Ground Level											
−1.50	Total	24.50							0.270	1.117	1.387
									Final Ground Level (m)		5.613

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1b	1.50	6.00	80.00	0.30	0.07	1.05	164.40	0.058	0.072	0.130
	2	5.00	29.50	80.00	0.60	0.12	1.45	164.40	0.106	0.471	0.577
	3a	1.50									
	3b	4.50	80.75	130.75	0.25	0.05	0.80	164.40	0.026	0.171	0.197
	5(U)	6.00	123.50	198.50	0.60	0.08	1.20	164.40	0.045	0.264	0.309
	5(L)	6.00	168.50	243.50	0.60	0.08	1.20	164.40	0.035	0.222	0.257
Ground Level											
−1.50	Total	24.50							0.270	1.200	1.470
									Final Ground Level (m)		6.030

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1b	1.50	6.00	80.00	0.30	0.07	1.05	173.40	0.058	0.077	0.135
	2	5.00	29.50	80.00	0.60	0.12	1.45	173.40	0.106	0.495	0.601
	3a	1.50									
	3b	4.50	80.75	130.75	0.25	0.05	0.80	173.40	0.026	0.180	0.207
	5(U)	6.00	123.50	198.50	0.60	0.08	1.20	173.40	0.045	0.286	0.331
	5(L)	6.00	168.50	243.50	0.60	0.08	1.20	173.40	0.035	0.241	0.276
Ground Level											
−1.50	Total	24.50							0.270	1.280	1.549
									Final Ground Level (m)		6.451

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.90	1b	1.50	6.00	80.00	0.30	0.07	1.05	153.60	0.058	0.066	0.123
	2	5.00	29.50	80.00	0.60	0.12	1.45	153.60	0.106	0.440	0.546
	3a	1.50									
	3b	4.50	80.75	130.75	0.25	0.05	0.80	153.60	0.026	0.158	0.185
	5(U)	6.00	123.50	198.50	0.60	0.08	1.20	153.60	0.045	0.237	0.282
	5(L)	6.00	168.50	243.50	0.60	0.08	1.20	153.60	0.035	0.199	0.234
Ground Level											
−1.50	Total	24.50							0.270	1.100	1.370
									Final Ground Level (m)		5.530



Required Embankment Height Calculation Result for【+5.50m:Block-5(Container Terminal Area)】

Water Level =	1.95	m
Fill γt =	18.0	kN/m^3
γ' =	10.0	kN/m^3
Load q =	30.0	kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1a	1.00									
	1b	1.50	14.00	80.00	0.30	0.07	1.05	127.40	0.039	0.054	0.093
	2	4.50	35.75	80.00	0.60	0.12	1.45	127.40	0.077	0.341	0.418
	3b	4.00	69.50	119.50	0.25	0.05	0.80	127.40	0.026	0.120	0.147
	3c	3.50									
	5(U)	5.00	137.75	212.75	0.60	0.08	1.20	127.40	0.034	0.130	0.165
	5(L)	5.50	177.13	252.13	0.60	0.08	1.20	127.40	0.031	0.123	0.154
Ground Level											
−0.50	Total	25.00							0.207	0.769	0.976
									Final Ground Level (m)		5.024

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1a	1.00									
	1b	1.50	14.00	80.00	0.30	0.07	1.05	136.40	0.039	0.060	0.099
	2	4.50	35.75	80.00	0.60	0.12	1.45	136.40	0.077	0.367	0.444
	3b	4.00	69.50	119.50	0.25	0.05	0.80	136.40	0.026	0.131	0.157
	3c	3.50									
	5(U)	5.00	137.75	212.75	0.60	0.08	1.20	136.40	0.034	0.150	0.184
	5(L)	5.50	177.13	252.13	0.60	0.08	1.20	136.40	0.031	0.142	0.173
Ground Level											
−0.50	Total	25.00							0.207	0.850	1.057
									Final Ground Level (m)		5.443

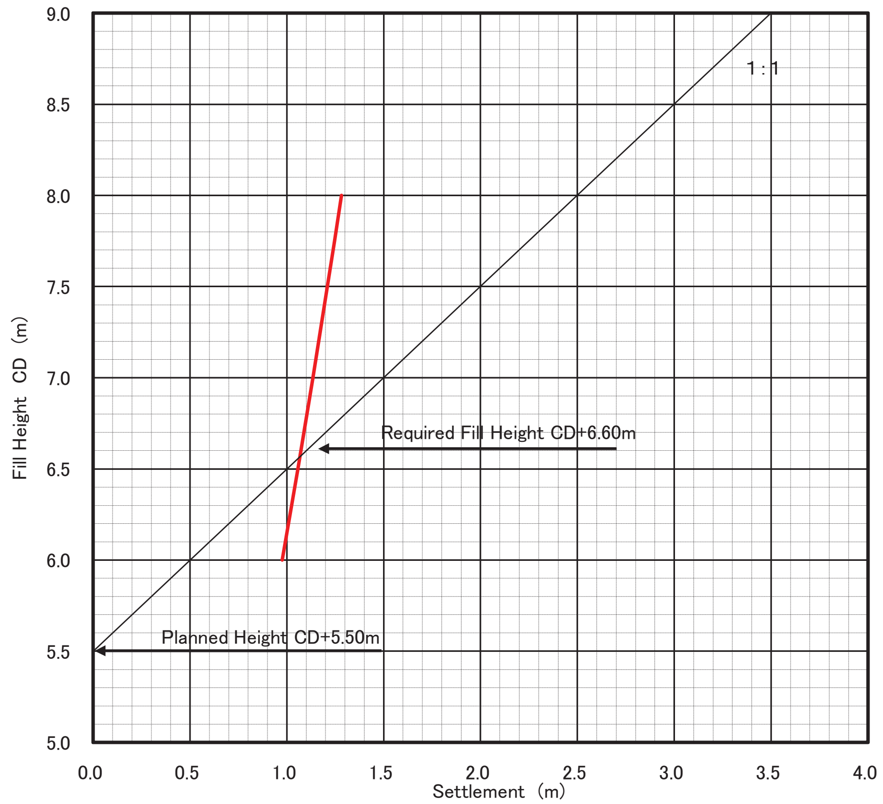
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1a	1.00									
	1b	1.50	14.00	80.00	0.30	0.07	1.05	145.40	0.039	0.066	0.104
	2	4.50	35.75	80.00	0.60	0.12	1.45	145.40	0.077	0.391	0.468
	3b	4.00	69.50	119.50	0.25	0.05	0.80	145.40	0.026	0.142	0.168
	3c	3.50									
	5(U)	5.00	137.75	212.75	0.60	0.08	1.20	145.40	0.034	0.169	0.204
	5(L)	5.50	177.13	252.13	0.60	0.08	1.20	145.40	0.031	0.160	0.191
Ground Level											
−0.50	Total	25.00							0.207	0.928	1.135
									Final Ground Level (m)		5.865

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1a	1.00									
	1b	1.50	14.00	80.00	0.30	0.07	1.05	154.40	0.039	0.071	0.110
	2	4.50	35.75	80.00	0.60	0.12	1.45	154.40	0.077	0.414	0.491
	3b	4.00	69.50	119.50	0.25	0.05	0.80	154.40	0.026	0.151	0.178
	3c	3.50									
	5(U)	5.00	137.75	212.75	0.60	0.08	1.20	154.40	0.034	0.188	0.222
	5(L)	5.50	177.13	252.13	0.60	0.08	1.20	154.40	0.031	0.178	0.209
Ground Level											
−0.50	Total	25.00							0.207	1.003	1.210
									Final Ground Level (m)		6.290

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1a	1.00									
	1b	1.50	14.00	80.00	0.30	0.07	1.05	163.40	0.039	0.076	0.115
	2	4.50	35.75	80.00	0.60	0.12	1.45	163.40	0.077	0.437	0.514
	3b	4.00	69.50	119.50	0.25	0.05	0.80	163.40	0.026	0.161	0.187
	3c	3.50									
	5(U)	5.00	137.75	212.75	0.60	0.08	1.20	163.40	0.034	0.206	0.240
	5(L)	5.50	177.13	252.13	0.60	0.08	1.20	163.40	0.031	0.196	0.226
Ground Level											
−0.50	Total	25.00							0.207	1.075	1.282
									Final Ground Level (m)		6.718

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.60	1a	1.00									
	1b	1.50	14.00	80.00	0.30	0.07	1.05	138.20	0.039	0.061	0.100
	2	4.50	35.75	80.00	0.60	0.12	1.45	138.20	0.077	0.372	0.449
	3b	4.00	69.50	119.50	0.25	0.05	0.80	138.20	0.026	0.133	0.160
	3c	3.50									
	5(U)	5.00	137.75	212.75	0.60	0.08	1.20	138.20	0.034	0.154	0.188
	5(L)	5.50	177.13	252.13	0.60	0.08	1.20	138.20	0.031	0.146	0.176
Ground Level											
−0.50	Total	25.00							0.207	0.866	1.073
									Final Ground Level (m)		5.527



Required Embankment Height Calculation Result for【+5.50m：Block-6(Container Terminal Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	30.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1a	2.50									
	2	6.50	42.75	80.00	0.60	0.12	1.45	112.40	0.087	0.458	0.545
	3c	5.50									
	4	2.00	124.00	224.00	0.35	0.04	0.85	112.40	0.011	0.009	0.020
	5(U)	4.50	149.88	224.88	0.60	0.08	1.20	112.40	0.029	0.082	0.111
	5(L)	5.00	185.50	260.50	0.60	0.08	1.20	112.40	0.027	0.079	0.106
Ground Level											
1.00	Total	26.00							0.153	0.628	0.782
									Final Ground Level (m)		5.218

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1a	2.50									
	2	6.50	42.75	80.00	0.60	0.12	1.45	121.40	0.087	0.497	0.584
	3c	5.50									
	4	2.00	124.00	224.00	0.35	0.04	0.85	121.40	0.011	0.015	0.026
	5(U)	4.50	149.88	224.88	0.60	0.08	1.20	121.40	0.029	0.100	0.129
	5(L)	5.00	185.50	260.50	0.60	0.08	1.20	121.40	0.027	0.097	0.124
Ground Level											
1.00	Total	26.00							0.153	0.709	0.862
									Final Ground Level (m)		5.638

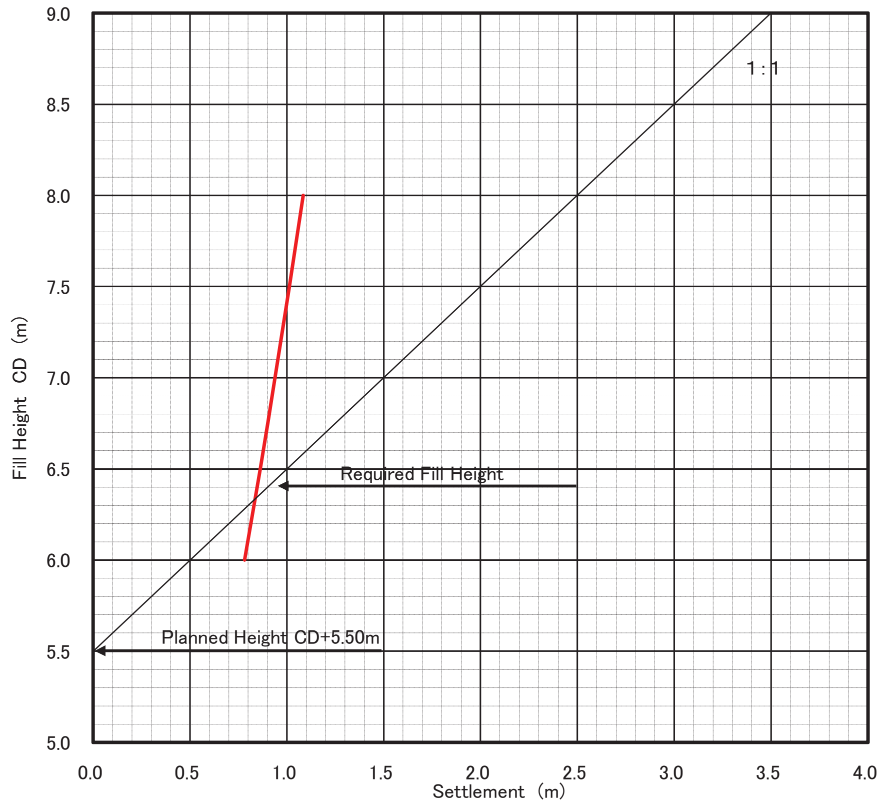
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1a	2.50									
	2	6.50	42.75	80.00	0.60	0.12	1.45	130.40	0.087	0.534	0.620
	3c	5.50									
	4	2.00	124.00	224.00	0.35	0.04	0.85	130.40	0.011	0.021	0.032
	5(U)	4.50	149.88	224.88	0.60	0.08	1.20	130.40	0.029	0.117	0.146
	5(L)	5.00	185.50	260.50	0.60	0.08	1.20	130.40	0.027	0.114	0.141
Ground Level											
1.00	Total	26.00							0.153	0.786	0.940
									Final Ground Level (m)		6.060

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1a	2.50									
	2	6.50	42.75	80.00	0.60	0.12	1.45	139.40	0.087	0.569	0.655
	3c	5.50									
	4	2.00	124.00	224.00	0.35	0.04	0.85	139.40	0.011	0.027	0.038
	5(U)	4.50	149.88	224.88	0.60	0.08	1.20	139.40	0.029	0.134	0.163
	5(L)	5.00	185.50	260.50	0.60	0.08	1.20	139.40	0.027	0.131	0.158
Ground Level											
1.00	Total	26.00							0.153	0.861	1.014
									Final Ground Level (m)		6.486

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1a	2.50									
	2	6.50	42.75	80.00	0.60	0.12	1.45	148.40	0.087	0.602	0.689
	3c	5.50									
	4	2.00	124.00	224.00	0.35	0.04	0.85	148.40	0.011	0.032	0.043
	5(U)	4.50	149.88	224.88	0.60	0.08	1.20	148.40	0.029	0.151	0.179
	5(L)	5.00	185.50	260.50	0.60	0.08	1.20	148.40	0.027	0.147	0.174
Ground Level											
1.00	Total	26.00							0.153	0.932	1.085
									Final Ground Level (m)		6.915

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.40	1a	2.50									
	2	6.50	42.75	80.00	0.60	0.12	1.45	119.60	0.087	0.489	0.576
	3c	5.50									
	4	2.00	124.00	224.00	0.35	0.04	0.85	119.60	0.011	0.014	0.025
	5(U)	4.50	149.88	224.88	0.60	0.08	1.20	119.60	0.029	0.096	0.125
	5(L)	5.00	185.50	260.50	0.60	0.08	1.20	119.60	0.027	0.094	0.120
Ground Level											
1.00	Total	26.00							0.153	0.693	0.846
									Final Ground Level (m)		5.554



Required Embankment Height Calculation Result for【+5.50m：Block-7(Container Terminal Area)】

Water Level =	1.95	m
Fill γt =	18.0	kN/m^3
γ' =	10.0	kN/m^3
Load q =	30.0	kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.00	1a	1.00									
	1b	2.00	16.00	80.00	0.30	0.07	1.05	117.40	0.048	0.065	0.113
	2	5.50	43.25	80.00	0.60	0.12	1.45	117.40	0.072	0.408	0.480
	3b	4.00	80.50	130.50	0.25	0.05	0.80	117.40	0.023	0.100	0.124
	4	3.00	112.00	212.00	0.35	0.04	0.85	117.40	0.018	0.019	0.037
	5(U)	5.50	146.13	221.13	0.60	0.08	1.20	117.40	0.036	0.114	0.150
	5(L)	5.50	187.38	262.38	0.60	0.08	1.20	117.40	0.029	0.098	0.127
Ground Level											
0.50	Total	26.50							0.226	0.805	1.031
									Final Ground Level (m)		4.969

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.50	1a	1.00									
	1b	2.00	16.00	80.00	0.30	0.07	1.05	126.40	0.048	0.073	0.121
	2	5.50	43.25	80.00	0.60	0.12	1.45	126.40	0.072	0.440	0.512
	3b	4.00	80.50	130.50	0.25	0.05	0.80	126.40	0.023	0.111	0.135
	4	3.00	112.00	212.00	0.35	0.04	0.85	126.40	0.018	0.029	0.047
	5(U)	5.50	146.13	221.13	0.60	0.08	1.20	126.40	0.036	0.136	0.172
	5(L)	5.50	187.38	262.38	0.60	0.08	1.20	126.40	0.029	0.117	0.146
Ground Level											
0.50	Total	26.50							0.226	0.906	1.132
									Final Ground Level (m)		5.368

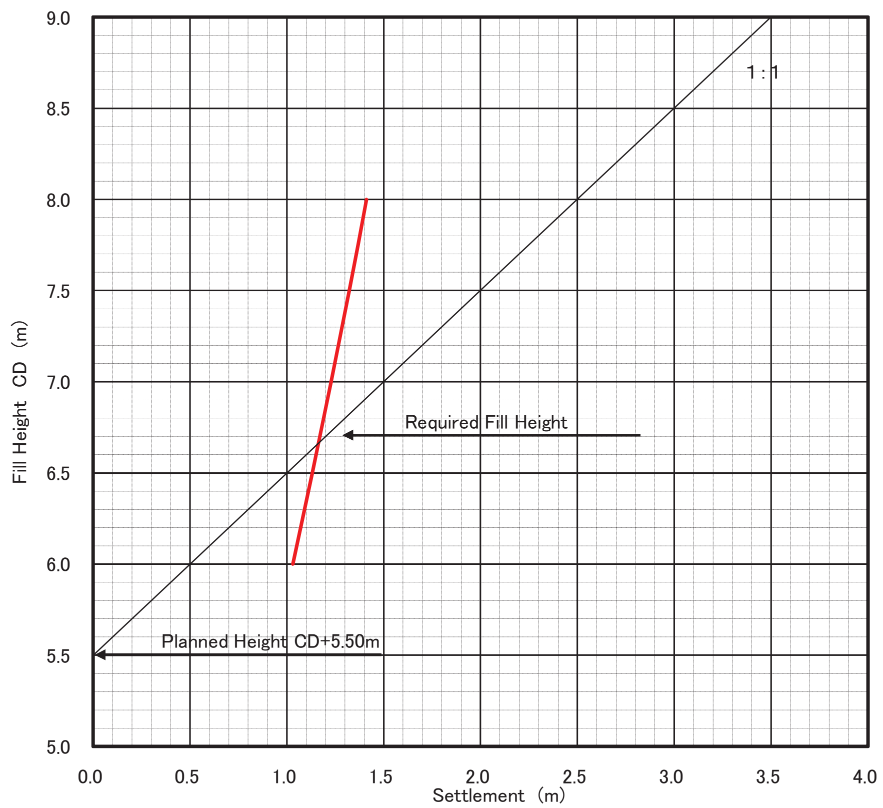
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.00	1a	1.00									
	1b	2.00	16.00	80.00	0.30	0.07	1.05	135.40	0.048	0.081	0.129
	2	5.50	43.25	80.00	0.60	0.12	1.45	135.40	0.072	0.470	0.542
	3b	4.00	80.50	130.50	0.25	0.05	0.80	135.40	0.023	0.121	0.145
	4	3.00	112.00	212.00	0.35	0.04	0.85	135.40	0.018	0.038	0.056
	5(U)	5.50	146.13	221.13	0.60	0.08	1.20	135.40	0.036	0.157	0.193
	5(L)	5.50	187.38	262.38	0.60	0.08	1.20	135.40	0.029	0.135	0.164
Ground Level											
0.50	Total	26.50							0.226	1.003	1.229
									Final Ground Level (m)		5.771

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.50	1a	1.00									
	1b	2.00	16.00	80.00	0.30	0.07	1.05	144.40	0.048	0.088	0.136
	2	5.50	43.25	80.00	0.60	0.12	1.45	144.40	0.072	0.499	0.571
	3b	4.00	80.50	130.50	0.25	0.05	0.80	144.40	0.023	0.131	0.155
	4	3.00	112.00	212.00	0.35	0.04	0.85	144.40	0.018	0.047	0.065
	5(U)	5.50	146.13	221.13	0.60	0.08	1.20	144.40	0.036	0.178	0.214
	5(L)	5.50	187.38	262.38	0.60	0.08	1.20	144.40	0.029	0.153	0.182
Ground Level											
0.50	Total	26.50							0.226	1.096	1.322
									Final Ground Level (m)		6.178

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
8.00	1a	1.00									
	1b	2.00	16.00	80.00	0.30	0.07	1.05	153.40	0.048	0.095	0.143
	2	5.50	43.25	80.00	0.60	0.12	1.45	153.40	0.072	0.526	0.598
	3b	4.00	80.50	130.50	0.25	0.05	0.80	153.40	0.023	0.141	0.164
	4	3.00	112.00	212.00	0.35	0.04	0.85	153.40	0.018	0.055	0.073
	5(U)	5.50	146.13	221.13	0.60	0.08	1.20	153.40	0.036	0.198	0.234
	5(L)	5.50	187.38	262.38	0.60	0.08	1.20	153.40	0.029	0.170	0.200
Ground Level											
0.50	Total	26.50							0.226	1.186	1.412
									Final Ground Level (m)		6.588

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.70	1a	1.00									
	1b	2.00	16.00	80.00	0.30	0.07	1.05	130.00	0.048	0.076	0.124
	2	5.50	43.25	80.00	0.60	0.12	1.45	130.00	0.072	0.452	0.524
	3b	4.00	80.50	130.50	0.25	0.05	0.80	130.00	0.023	0.115	0.139
	4	3.00	112.00	212.00	0.35	0.04	0.85	130.00	0.018	0.033	0.051
	5(U)	5.50	146.13	221.13	0.60	0.08	1.20	130.00	0.036	0.145	0.181
	5(L)	5.50	187.38	262.38	0.60	0.08	1.20	130.00	0.029	0.124	0.153
Ground Level											
0.50	Total	26.50							0.226	0.945	1.171
									Final Ground Level (m)		5.529



Required Embankment Height Calculation Result for【+5.50m：Block-8(Container Terminal Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	10.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1b	1.50	6.00	80.00	0.30	0.07	1.05	102.40	0.058	0.029	0.087
	2	5.00	29.50	80.00	0.60	0.12	1.45	102.40	0.106	0.266	0.372
	3b	5.00	69.50	119.50	0.25	0.05	0.80	102.40	0.033	0.110	0.142
	4	3.50	107.75	207.75	0.35	0.04	0.85	102.40	0.022	0.003	0.025
	5(U)	5.50	144.13	219.13	0.60	0.08	1.20	102.40	0.036	0.077	0.113
	5(L)	5.00	183.50	258.50	0.60	0.08	1.20	102.40	0.027	0.060	0.087
Ground Level											
0.00	Total	25.50							0.281	0.544	0.826
									Final Ground Level (m)		5.174

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1b	1.50	6.00	80.00	0.30	0.07	1.05	111.40	0.058	0.037	0.094
	2	5.00	29.50	80.00	0.60	0.12	1.45	111.40	0.106	0.301	0.407
	3b	5.00	69.50	119.50	0.25	0.05	0.80	111.40	0.033	0.125	0.158
	4	3.50	107.75	207.75	0.35	0.04	0.85	111.40	0.022	0.015	0.037
	5(U)	5.50	144.13	219.13	0.60	0.08	1.20	111.40	0.036	0.100	0.137
	5(L)	5.00	183.50	258.50	0.60	0.08	1.20	111.40	0.027	0.078	0.105
Ground Level											
0.00	Total	25.50							0.281	0.656	0.938
									Final Ground Level (m)		5.562

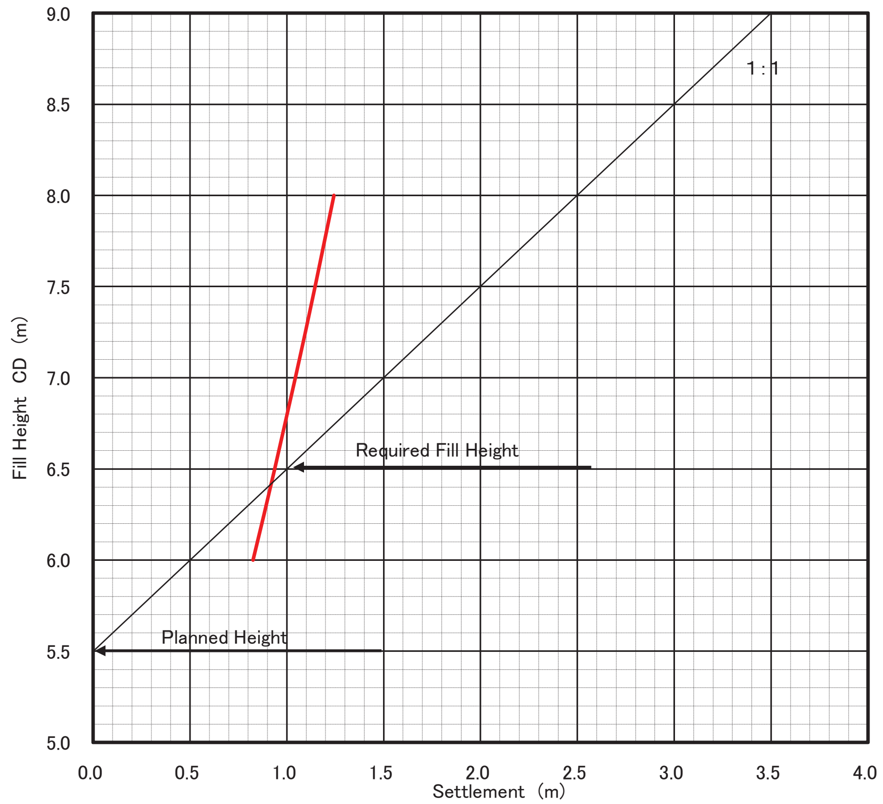
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1b	1.50	6.00	80.00	0.30	0.07	1.05	120.40	0.058	0.044	0.101
	2	5.00	29.50	80.00	0.60	0.12	1.45	120.40	0.106	0.334	0.440
	3b	5.00	69.50	119.50	0.25	0.05	0.80	120.40	0.033	0.140	0.172
	4	3.50	107.75	207.75	0.35	0.04	0.85	120.40	0.022	0.027	0.049
	5(U)	5.50	144.13	219.13	0.60	0.08	1.20	120.40	0.036	0.123	0.159
	5(L)	5.00	183.50	258.50	0.60	0.08	1.20	120.40	0.027	0.096	0.123
Ground Level											
0.00	Total	25.50							0.281	0.763	1.044
									Final Ground Level (m)		5.956

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1b	1.50	6.00	80.00	0.30	0.07	1.05	129.40	0.058	0.050	0.108
	2	5.00	29.50	80.00	0.60	0.12	1.45	129.40	0.106	0.365	0.471
	3b	5.00	69.50	119.50	0.25	0.05	0.80	129.40	0.033	0.154	0.186
	4	3.50	107.75	207.75	0.35	0.04	0.85	129.40	0.022	0.038	0.060
	5(U)	5.50	144.13	219.13	0.60	0.08	1.20	129.40	0.036	0.144	0.181
	5(L)	5.00	183.50	258.50	0.60	0.08	1.20	129.40	0.027	0.113	0.140
Ground Level											
0.00	Total	25.50							0.281	0.864	1.146
									Final Ground Level (m)		6.354

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1b	1.50	6.00	80.00	0.30	0.07	1.05	138.40	0.058	0.056	0.114
	2	5.00	29.50	80.00	0.60	0.12	1.45	138.40	0.106	0.394	0.500
	3b	5.00	69.50	119.50	0.25	0.05	0.80	138.40	0.033	0.167	0.200
	4	3.50	107.75	207.75	0.35	0.04	0.85	138.40	0.022	0.049	0.070
	5(U)	5.50	144.13	219.13	0.60	0.08	1.20	138.40	0.036	0.166	0.202
	5(L)	5.00	183.50	258.50	0.60	0.08	1.20	138.40	0.027	0.130	0.157
Ground Level											
0.00	Total	25.50							0.281	0.962	1.243
									Final Ground Level (m)		6.757

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1b	1.50	6.00	80.00	0.30	0.07	1.05	111.40	0.058	0.037	0.094
	2	5.00	29.50	80.00	0.60	0.12	1.45	111.40	0.106	0.301	0.407
	3b	5.00	69.50	119.50	0.25	0.05	0.80	111.40	0.033	0.125	0.158
	4	3.50	107.75	207.75	0.35	0.04	0.85	111.40	0.022	0.015	0.037
	5(U)	5.50	144.13	219.13	0.60	0.08	1.20	111.40	0.036	0.100	0.137
	5(L)	5.00	183.50	258.50	0.60	0.08	1.20	111.40	0.027	0.078	0.105
Ground Level											
0.00	Total	25.50							0.281	0.656	0.938
									Final Ground Level (m)		5.562



Required Embankment Height Calculation Result for【+5.50m：Block-9(Container Terminal Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	10.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1a	1.00									
	1b	1.00	12.00	80.00	0.30	0.07	1.05	112.40	0.028	0.028	0.056
	2	5.00	33.50	80.00	0.60	0.12	1.45	112.40	0.093	0.320	0.412
	3b	5.50	75.75	125.75	0.25	0.05	0.80	112.40	0.034	0.134	0.167
	4	1.50	107.25	207.25	0.35	0.04	0.85	112.40	0.009	0.007	0.016
	5(U)	5.50	134.63	209.63	0.60	0.08	1.20	112.40	0.038	0.107	0.145
	5(L)	5.50	175.88	250.88	0.60	0.08	1.20	112.40	0.031	0.091	0.121
Ground Level											
−1.00	Total	25.00							0.233	0.686	0.919
									Final Ground Level (m)		5.081

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1a	1.00									
	1b	1.00	12.00	80.00	0.30	0.07	1.05	121.40	0.028	0.032	0.061
	2	5.00	33.50	80.00	0.60	0.12	1.45	121.40	0.093	0.351	0.444
	3b	5.50	75.75	125.75	0.25	0.05	0.80	121.40	0.034	0.149	0.183
	4	1.50	107.25	207.25	0.35	0.04	0.85	121.40	0.009	0.012	0.021
	5(U)	5.50	134.63	209.63	0.60	0.08	1.20	121.40	0.038	0.130	0.169
	5(L)	5.50	175.88	250.88	0.60	0.08	1.20	121.40	0.031	0.111	0.141
Ground Level											
−1.00	Total	25.00							0.233	0.786	1.019
									Final Ground Level (m)		5.481

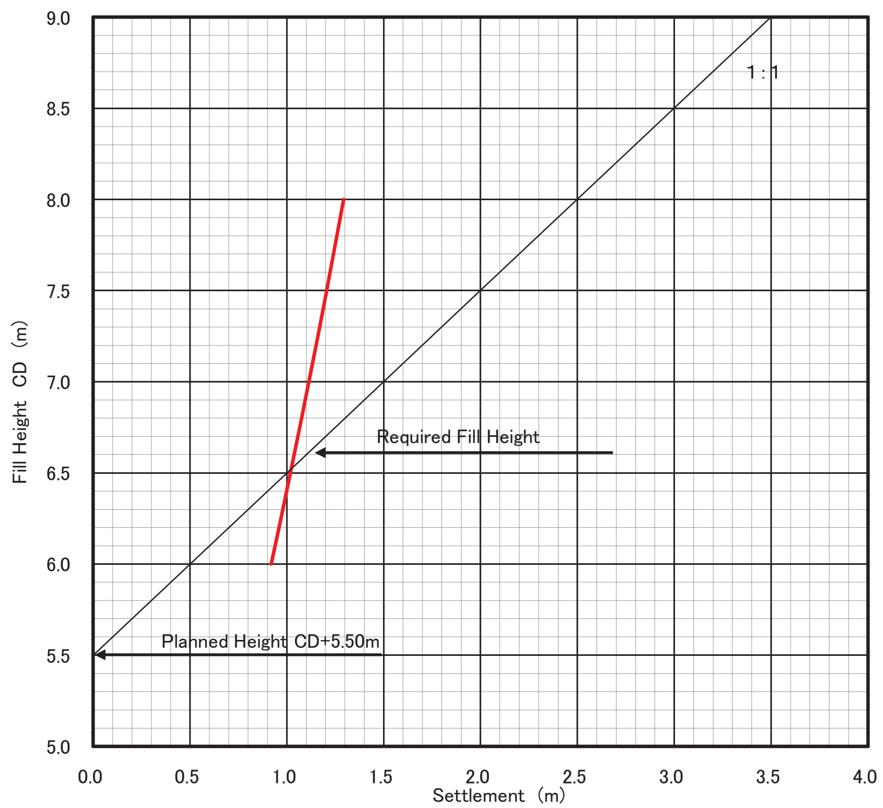
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1a	1.00									
	1b	1.00	12.00	80.00	0.30	0.07	1.05	130.40	0.028	0.037	0.065
	2	5.00	33.50	80.00	0.60	0.12	1.45	130.40	0.093	0.381	0.474
	3b	5.50	75.75	125.75	0.25	0.05	0.80	130.40	0.034	0.164	0.198
	4	1.50	107.25	207.25	0.35	0.04	0.85	130.40	0.009	0.017	0.026
	5(U)	5.50	134.63	209.63	0.60	0.08	1.20	130.40	0.038	0.153	0.191
	5(L)	5.50	175.88	250.88	0.60	0.08	1.20	130.40	0.031	0.130	0.161
Ground Level											
−1.00	Total	25.00							0.233	0.882	1.115
									Final Ground Level (m)		5.885

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1a	1.00									
	1b	1.00	12.00	80.00	0.30	0.07	1.05	139.40	0.028	0.041	0.069
	2	5.00	33.50	80.00	0.60	0.12	1.45	139.40	0.093	0.410	0.502
	3b	5.50	75.75	125.75	0.25	0.05	0.80	139.40	0.034	0.178	0.212
	4	1.50	107.25	207.25	0.35	0.04	0.85	139.40	0.009	0.021	0.031
	5(U)	5.50	134.63	209.63	0.60	0.08	1.20	139.40	0.038	0.175	0.213
	5(L)	5.50	175.88	250.88	0.60	0.08	1.20	139.40	0.031	0.149	0.180
Ground Level											
−1.00	Total	25.00							0.233	0.973	1.206
									Final Ground Level (m)		6.294

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1a	1.00									
	1b	1.00	12.00	80.00	0.30	0.07	1.05	148.40	0.028	0.044	0.072
	2	5.00	33.50	80.00	0.60	0.12	1.45	148.40	0.093	0.437	0.529
	3b	5.50	75.75	125.75	0.25	0.05	0.80	148.40	0.034	0.192	0.225
	4	1.50	107.25	207.25	0.35	0.04	0.85	148.40	0.009	0.026	0.035
	5(U)	5.50	134.63	209.63	0.60	0.08	1.20	148.40	0.038	0.196	0.234
	5(L)	5.50	175.88	250.88	0.60	0.08	1.20	148.40	0.031	0.167	0.198
Ground Level											
−1.00	Total	25.00							0.233	1.061	1.294
									Final Ground Level (m)		6.706

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.60	1a	1.00									
	1b	1.00	12.00	80.00	0.30	0.07	1.05	123.20	0.028	0.033	0.061
	2	5.00	33.50	80.00	0.60	0.12	1.45	123.20	0.093	0.358	0.450
	3b	5.50	75.75	125.75	0.25	0.05	0.80	123.20	0.034	0.152	0.186
	4	1.50	107.25	207.25	0.35	0.04	0.85	123.20	0.009	0.013	0.022
	5(U)	5.50	134.63	209.63	0.60	0.08	1.20	123.20	0.038	0.135	0.173
	5(L)	5.50	175.88	250.88	0.60	0.08	1.20	123.20	0.031	0.114	0.145
Ground Level											
−1.00	Total	25.00							0.233	0.805	1.038
									Final Ground Level (m)		5.562



Required Embankment Height Calculation Result for【+5.50m：Block−10(Container Terminal Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	10.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1a	3.50									
	2	5.50	47.25	80.00	0.60	0.12	1.45	87.40	0.062	0.305	0.366
	3b	3.50	82.25	132.25	0.25	0.05	0.80	87.40	0.020	0.053	0.073
	3c	5.00									
	5(U)	6.00	165.50	240.50	0.60	0.08	1.20	87.40	0.035	0.036	0.071
	5(L)	6.00	210.50	285.50	0.60	0.08	1.20	87.40	0.029	0.030	0.059
Ground Level 1.50	Total	29.50							0.146	0.423	0.569
									Final Ground Level (m)		5.431

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1a	3.50									
	2	5.50	47.25	80.00	0.60	0.12	1.45	96.40	0.062	0.342	0.404
	3b	3.50	82.25	132.25	0.25	0.05	0.80	96.40	0.020	0.063	0.084
	3c	5.00									
	5(U)	6.00	165.50	240.50	0.60	0.08	1.20	96.40	0.035	0.061	0.096
	5(L)	6.00	210.50	285.50	0.60	0.08	1.20	96.40	0.029	0.051	0.080
Ground Level 1.50	Total	29.50							0.146	0.518	0.664
									Final Ground Level (m)		5.836

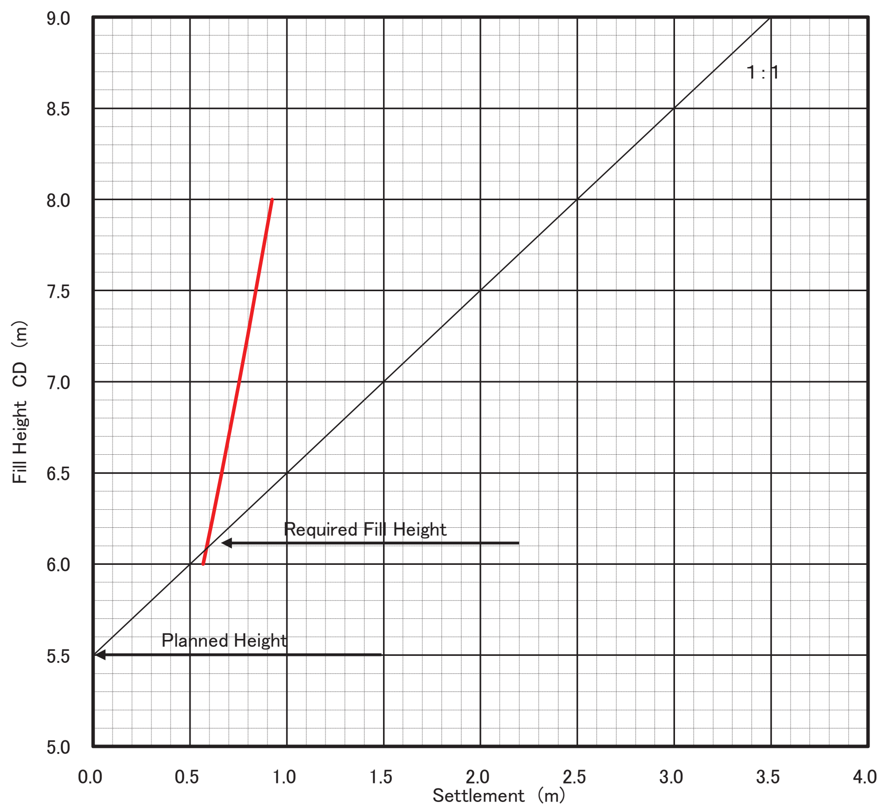
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1a	3.50									
	2	5.50	47.25	80.00	0.60	0.12	1.45	105.40	0.062	0.378	0.440
	3b	3.50	82.25	132.25	0.25	0.05	0.80	105.40	0.020	0.074	0.094
	3c	5.00									
	5(U)	6.00	165.50	240.50	0.60	0.08	1.20	105.40	0.035	0.085	0.120
	5(L)	6.00	210.50	285.50	0.60	0.08	1.20	105.40	0.029	0.072	0.101
Ground Level 1.50	Total	29.50							0.146	0.608	0.754
									Final Ground Level (m)		6.246

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1a	3.50									
	2	5.50	47.25	80.00	0.60	0.12	1.45	114.40	0.062	0.411	0.473
	3b	3.50	82.25	132.25	0.25	0.05	0.80	114.40	0.020	0.084	0.104
	3c	5.00									
	5(U)	6.00	165.50	240.50	0.60	0.08	1.20	114.40	0.035	0.108	0.143
	5(L)	6.00	210.50	285.50	0.60	0.08	1.20	114.40	0.029	0.092	0.121
Ground Level 1.50	Total	29.50							0.146	0.695	0.841
									Final Ground Level (m)		6.659

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1a	3.50									
	2	5.50	47.25	80.00	0.60	0.12	1.45	123.40	0.062	0.443	0.505
	3b	3.50	82.25	132.25	0.25	0.05	0.80	123.40	0.020	0.093	0.113
	3c	5.00									
	5(U)	6.00	165.50	240.50	0.60	0.08	1.20	123.40	0.035	0.130	0.166
	5(L)	6.00	210.50	285.50	0.60	0.08	1.20	123.40	0.029	0.111	0.140
Ground Level 1.50	Total	29.50							0.146	0.778	0.924
									Final Ground Level (m)		7.076

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.10	1a	3.50									
	2	5.50	47.25	80.00	0.60	0.12	1.45	89.20	0.062	0.312	0.374
	3b	3.50	82.25	132.25	0.25	0.05	0.80	89.20	0.020	0.055	0.075
	3c	5.00									
	5(U)	6.00	165.50	240.50	0.60	0.08	1.20	89.20	0.035	0.041	0.076
	5(L)	6.00	210.50	285.50	0.60	0.08	1.20	89.20	0.029	0.034	0.063
Ground Level 1.50	Total	29.50							0.146	0.442	0.588
									Final Ground Level (m)		5.512



Required Embankment Height Calculation Result for【+5.50m : Block-11(Container Terminal Area)】

Water Level =	1.95	m
Fill γt =	18.0	kN/m^3
γ' =	10.0	kN/m^3
Load q =	10.0	kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1a	2.50									
	2	6.00	41.00	80.00	0.60	0.12	1.45	97.40	0.085	0.350	0.435
	3b	5.00	84.50	134.50	0.25	0.05	0.80	97.40	0.028	0.091	0.119
	4	2.00	116.00	216.00	0.35	0.04	0.85	97.40	0.012	0.000	0.012
	5(U)	8.00	155.00	230.00	0.60	0.08	1.20	97.40	0.050	0.088	0.138
	5(L)	8.00	215.00	290.00	0.60	0.08	1.20	97.40	0.038	0.071	0.108
Ground Level											
0.50	Total	31.50							0.213	0.599	0.812
									Final Ground Level (m)		5.188

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1a	2.50									
	2	6.00	41.00	80.00	0.60	0.12	1.45	106.40	0.085	0.390	0.475
	3b	5.00	84.50	134.50	0.25	0.05	0.80	106.40	0.028	0.106	0.134
	4	2.00	116.00	216.00	0.35	0.04	0.85	106.40	0.012	0.005	0.016
	5(U)	8.00	155.00	230.00	0.60	0.08	1.20	106.40	0.050	0.121	0.171
	5(L)	8.00	215.00	290.00	0.60	0.08	1.20	106.40	0.038	0.097	0.135
Ground Level											
0.50	Total	31.50							0.213	0.719	0.932
									Final Ground Level (m)		5.568

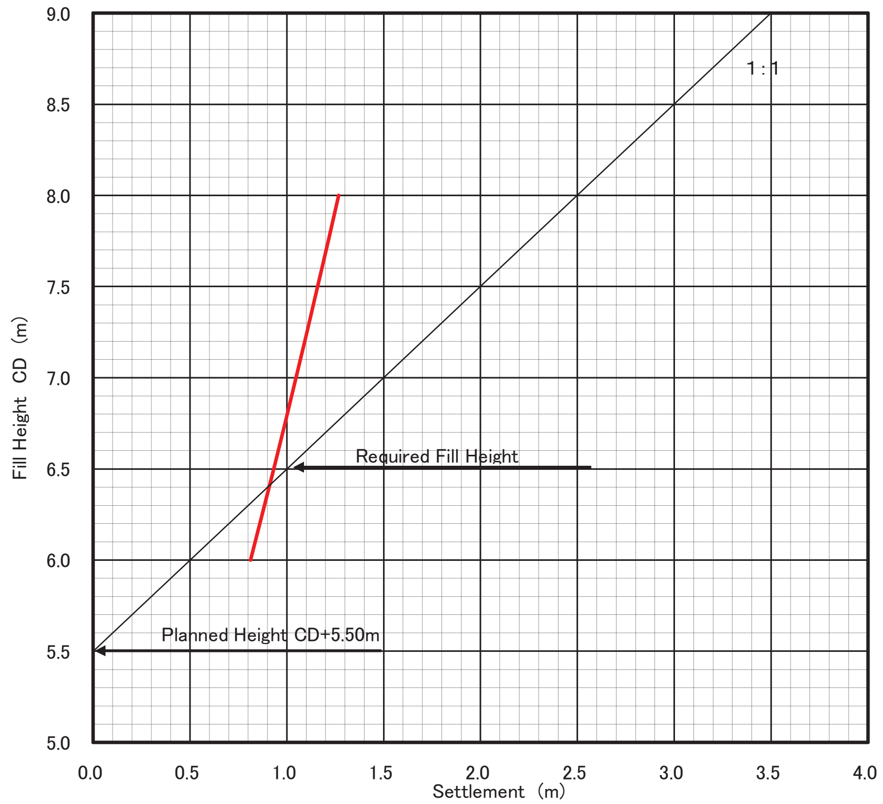
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1a	2.50									
	2	6.00	41.00	80.00	0.60	0.12	1.45	115.40	0.085	0.428	0.513
	3b	5.00	84.50	134.50	0.25	0.05	0.80	115.40	0.028	0.120	0.148
	4	2.00	116.00	216.00	0.35	0.04	0.85	115.40	0.012	0.011	0.023
	5(U)	8.00	155.00	230.00	0.60	0.08	1.20	115.40	0.050	0.153	0.203
	5(L)	8.00	215.00	290.00	0.60	0.08	1.20	115.40	0.038	0.124	0.161
Ground Level											
0.50	Total	31.50							0.213	0.836	1.048
									Final Ground Level (m)		5.952

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1a	2.50									
	2	6.00	41.00	80.00	0.60	0.12	1.45	124.40	0.085	0.464	0.549
	3b	5.00	84.50	134.50	0.25	0.05	0.80	124.40	0.028	0.133	0.161
	4	2.00	116.00	216.00	0.35	0.04	0.85	124.40	0.012	0.018	0.029
	5(U)	8.00	155.00	230.00	0.60	0.08	1.20	124.40	0.050	0.184	0.234
	5(L)	8.00	215.00	290.00	0.60	0.08	1.20	124.40	0.038	0.149	0.187
Ground Level											
0.50	Total	31.50							0.213	0.947	1.160
									Final Ground Level (m)		6.340

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1a	2.50									
	2	6.00	41.00	80.00	0.60	0.12	1.45	133.40	0.085	0.497	0.583
	3b	5.00	84.50	134.50	0.25	0.05	0.80	133.40	0.028	0.146	0.174
	4	2.00	116.00	216.00	0.35	0.04	0.85	133.40	0.012	0.024	0.035
	5(U)	8.00	155.00	230.00	0.60	0.08	1.20	133.40	0.050	0.214	0.264
	5(L)	8.00	215.00	290.00	0.60	0.08	1.20	133.40	0.038	0.174	0.212
Ground Level											
0.50	Total	31.50							0.213	1.055	1.267
									Final Ground Level (m)		6.733

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1a	2.50									
	2	6.00	41.00	80.00	0.60	0.12	1.45	106.40	0.085	0.390	0.475
	3b	5.00	84.50	134.50	0.25	0.05	0.80	106.40	0.028	0.106	0.134
	4	2.00	116.00	216.00	0.35	0.04	0.85	106.40	0.012	0.005	0.016
	5(U)	8.00	155.00	230.00	0.60	0.08	1.20	106.40	0.050	0.121	0.171
	5(L)	8.00	215.00	290.00	0.60	0.08	1.20	106.40	0.038	0.097	0.135
Ground Level											
0.50	Total	31.50							0.213	0.719	0.932
									Final Ground Level (m)		5.568



Required Embankment Height Calculation Result for【+5.50m：Block-12(Container Terminal Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	10.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1b	2.50	10.00	80.00	0.30	0.07	1.05	102.40	0.077	0.054	0.131
	2	3.50	32.25	80.00	0.60	0.12	1.45	102.40	0.068	0.194	0.261
	3a	1.50									
	3b	6.00	85.00	135.00	0.25	0.05	0.80	102.40	0.033	0.119	0.152
	3c	2.50									
	5(U)	5.00	153.25	228.25	0.60	0.08	1.20	102.40	0.031	0.067	0.099
	5(L)	4.50	188.88	263.88	0.60	0.08	1.20	102.40	0.024	0.053	0.076
Ground Level											
0.00	Total	25.50							0.233	0.486	0.720
									Final Ground Level (m)		5.280

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1b	2.50	10.00	80.00	0.30	0.07	1.05	111.40	0.077	0.066	0.143
	2	3.50	32.25	80.00	0.60	0.12	1.45	111.40	0.068	0.218	0.286
	3a	1.50									
	3b	6.00	85.00	135.00	0.25	0.05	0.80	111.40	0.033	0.136	0.169
	3c	2.50									
	5(U)	5.00	153.25	228.25	0.60	0.08	1.20	111.40	0.031	0.088	0.119
	5(L)	4.50	188.88	263.88	0.60	0.08	1.20	111.40	0.024	0.069	0.093
Ground Level											
0.00	Total	25.50							0.233	0.576	0.810
									Final Ground Level (m)		5.690

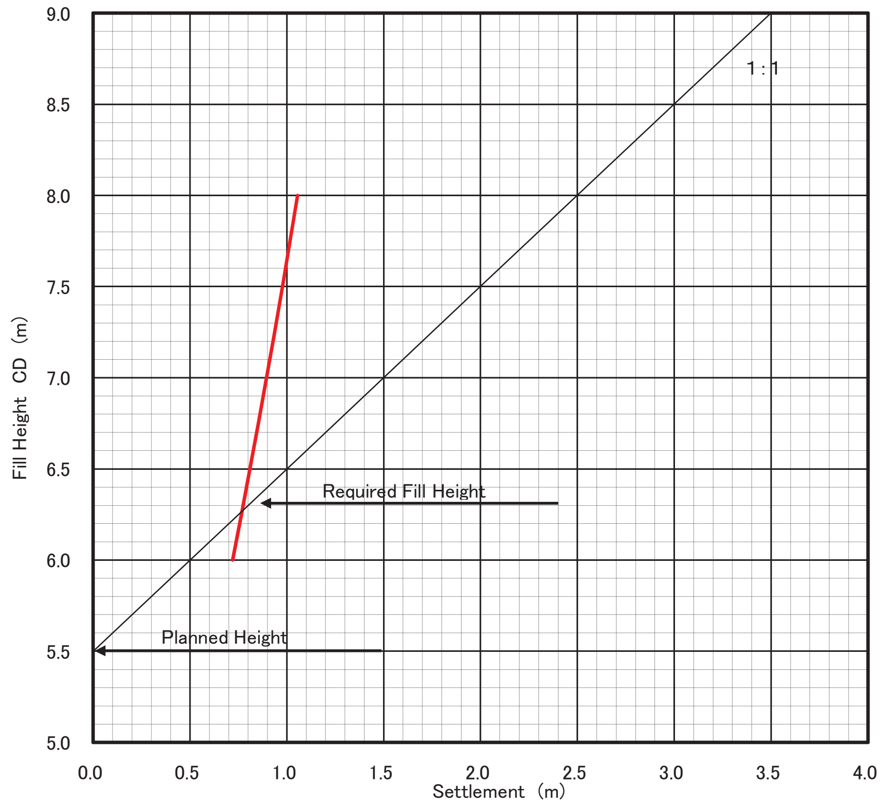
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1b	2.50	10.00	80.00	0.30	0.07	1.05	120.40	0.077	0.078	0.155
	2	3.50	32.25	80.00	0.60	0.12	1.45	120.40	0.068	0.241	0.308
	3a	1.50									
	3b	6.00	85.00	135.00	0.25	0.05	0.80	120.40	0.033	0.152	0.185
	3c	2.50									
	5(U)	5.00	153.25	228.25	0.60	0.08	1.20	120.40	0.031	0.107	0.139
	5(L)	4.50	188.88	263.88	0.60	0.08	1.20	120.40	0.024	0.085	0.108
Ground Level											
0.00	Total	25.50							0.233	0.662	0.896
									Final Ground Level (m)		6.104

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1b	2.50	10.00	80.00	0.30	0.07	1.05	129.40	0.077	0.088	0.165
	2	3.50	32.25	80.00	0.60	0.12	1.45	129.40	0.068	0.262	0.329
	3a	1.50									
	3b	6.00	85.00	135.00	0.25	0.05	0.80	129.40	0.033	0.167	0.201
	3c	2.50									
	5(U)	5.00	153.25	228.25	0.60	0.08	1.20	129.40	0.031	0.127	0.158
	5(L)	4.50	188.88	263.88	0.60	0.08	1.20	129.40	0.024	0.100	0.124
Ground Level											
0.00	Total	25.50							0.233	0.744	0.977
									Final Ground Level (m)		6.523

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1b	2.50	10.00	80.00	0.30	0.07	1.05	138.40	0.077	0.098	0.175
	2	3.50	32.25	80.00	0.60	0.12	1.45	138.40	0.068	0.282	0.350
	3a	1.50									
	3b	6.00	85.00	135.00	0.25	0.05	0.80	138.40	0.033	0.182	0.216
	3c	2.50									
	5(U)	5.00	153.25	228.25	0.60	0.08	1.20	138.40	0.031	0.145	0.177
	5(L)	4.50	188.88	263.88	0.60	0.08	1.20	138.40	0.024	0.115	0.139
Ground Level											
0.00	Total	25.50							0.233	0.822	1.056
									Final Ground Level (m)		6.944

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.30	1b	2.50	10.00	80.00	0.30	0.07	1.05	107.80	0.077	0.061	0.139
	2	3.50	32.25	80.00	0.60	0.12	1.45	107.80	0.068	0.208	0.276
	3a	1.50									
	3b	6.00	85.00	135.00	0.25	0.05	0.80	107.80	0.033	0.129	0.162
	3c	2.50									
	5(U)	5.00	153.25	228.25	0.60	0.08	1.20	107.80	0.031	0.080	0.111
	5(L)	4.50	188.88	263.88	0.60	0.08	1.20	107.80	0.024	0.062	0.086
Ground Level											
0.00	Total	25.50							0.233	0.541	0.774
									Final Ground Level (m)		5.526



Required Embankment Height Calculation Result for【+5.50m：Block-13(Access Road Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	10.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.00	1a	1.50									
	2	5.50	31.25	80.00	0.60	0.12	1.45	112.40	0.110	0.342	0.452
	3b	7.50	84.25	134.25	0.25	0.05	0.80	112.40	0.042	0.173	0.215
	3c	2.00									
	5(U)	4.50	152.88	227.88	0.60	0.08	1.20	112.40	0.028	0.081	0.109
	5(L)	5.00	188.50	263.50	0.60	0.08	1.20	112.40	0.026	0.079	0.105
Ground Level											
−1.00	Total	26.00							0.207	0.675	0.882
									Final Ground Level (m)		5.118

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.50	1a	1.50									
	2	5.50	31.25	80.00	0.60	0.12	1.45	121.40	0.110	0.378	0.488
	3b	7.50	84.25	134.25	0.25	0.05	0.80	121.40	0.042	0.193	0.235
	3c	2.00									
	5(U)	4.50	152.88	227.88	0.60	0.08	1.20	121.40	0.028	0.099	0.127
	5(L)	5.00	188.50	263.50	0.60	0.08	1.20	121.40	0.026	0.096	0.123
Ground Level											
−1.00	Total	26.00							0.207	0.766	0.973
									Final Ground Level (m)		5.527

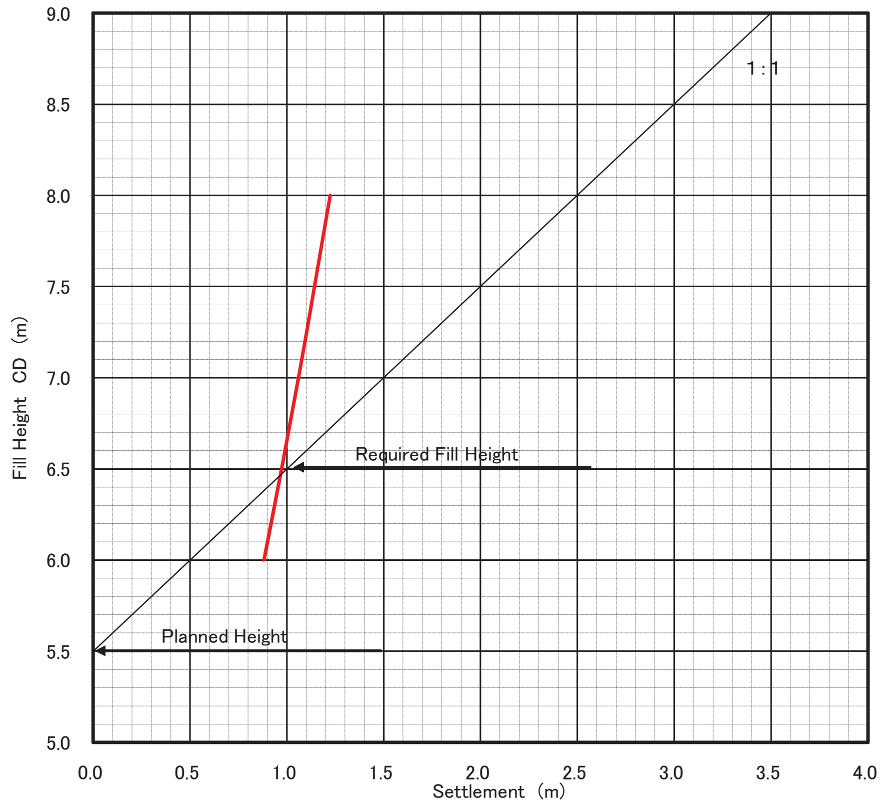
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.00	1a	1.50									
	2	5.50	31.25	80.00	0.60	0.12	1.45	130.40	0.110	0.411	0.521
	3b	7.50	84.25	134.25	0.25	0.05	0.80	130.40	0.042	0.212	0.254
	3c	2.00									
	5(U)	4.50	152.88	227.88	0.60	0.08	1.20	130.40	0.028	0.116	0.144
	5(L)	5.00	188.50	263.50	0.60	0.08	1.20	130.40	0.026	0.113	0.139
Ground Level											
−1.00	Total	26.00							0.207	0.853	1.060
									Final Ground Level (m)		5.940

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.50	1a	1.50									
	2	5.50	31.25	80.00	0.60	0.12	1.45	139.40	0.110	0.443	0.553
	3b	7.50	84.25	134.25	0.25	0.05	0.80	139.40	0.042	0.231	0.273
	3c	2.00									
	5(U)	4.50	152.88	227.88	0.60	0.08	1.20	139.40	0.028	0.133	0.161
	5(L)	5.00	188.50	263.50	0.60	0.08	1.20	139.40	0.026	0.129	0.156
Ground Level											
−1.00	Total	26.00							0.207	0.936	1.143
									Final Ground Level (m)		6.357

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
8.00	1a	1.50									
	2	5.50	31.25	80.00	0.60	0.12	1.45	148.40	0.110	0.473	0.583
	3b	7.50	84.25	134.25	0.25	0.05	0.80	148.40	0.042	0.249	0.291
	3c	2.00									
	5(U)	4.50	152.88	227.88	0.60	0.08	1.20	148.40	0.028	0.149	0.177
	5(L)	5.00	188.50	263.50	0.60	0.08	1.20	148.40	0.026	0.146	0.172
Ground Level											
−1.00	Total	26.00							0.207	1.016	1.223
									Final Ground Level (m)		6.777

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.50	1a	1.50									
	2	5.50	31.25	80.00	0.60	0.12	1.45	121.40	0.110	0.378	0.488
	3b	7.50	84.25	134.25	0.25	0.05	0.80	121.40	0.042	0.193	0.235
	3c	2.00									
	5(U)	4.50	152.88	227.88	0.60	0.08	1.20	121.40	0.028	0.099	0.127
	5(L)	5.00	188.50	263.50	0.60	0.08	1.20	121.40	0.026	0.096	0.123
Ground Level											
−1.00	Total	26.00							0.207	0.766	0.973
									Final Ground Level (m)		5.527



Required Embankment Height Calculation Result for【+5.50m：Block-14(Access Road Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	10.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.00	1a	2.00									
	2	7.00	40.50	80.00	0.60	0.12	1.45	97.40	0.101	0.405	0.507
	3c	2.50									
	4	3.50	103.25	203.25	0.35	0.04	0.85	97.40	0.022	0.000	0.022
	5(U)	7.50	147.13	222.13	0.60	0.08	1.20	97.40	0.049	0.085	0.134
	5(L)	7.00	201.50	276.50	0.60	0.08	1.20	97.40	0.035	0.065	0.100
Ground Level											
0.50	Total	29.50							0.207	0.555	0.763
									Final Ground Level (m)		5.237

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.50	1a	2.00									
	2	7.00	40.50	80.00	0.60	0.12	1.45	106.40	0.101	0.452	0.554
	3c	2.50									
	4	3.50	103.25	203.25	0.35	0.04	0.85	106.40	0.022	0.009	0.031
	5(U)	7.50	147.13	222.13	0.60	0.08	1.20	106.40	0.049	0.117	0.166
	5(L)	7.00	201.50	276.50	0.60	0.08	1.20	106.40	0.035	0.089	0.124
Ground Level											
0.50	Total	29.50							0.207	0.668	0.875
									Final Ground Level (m)		5.625

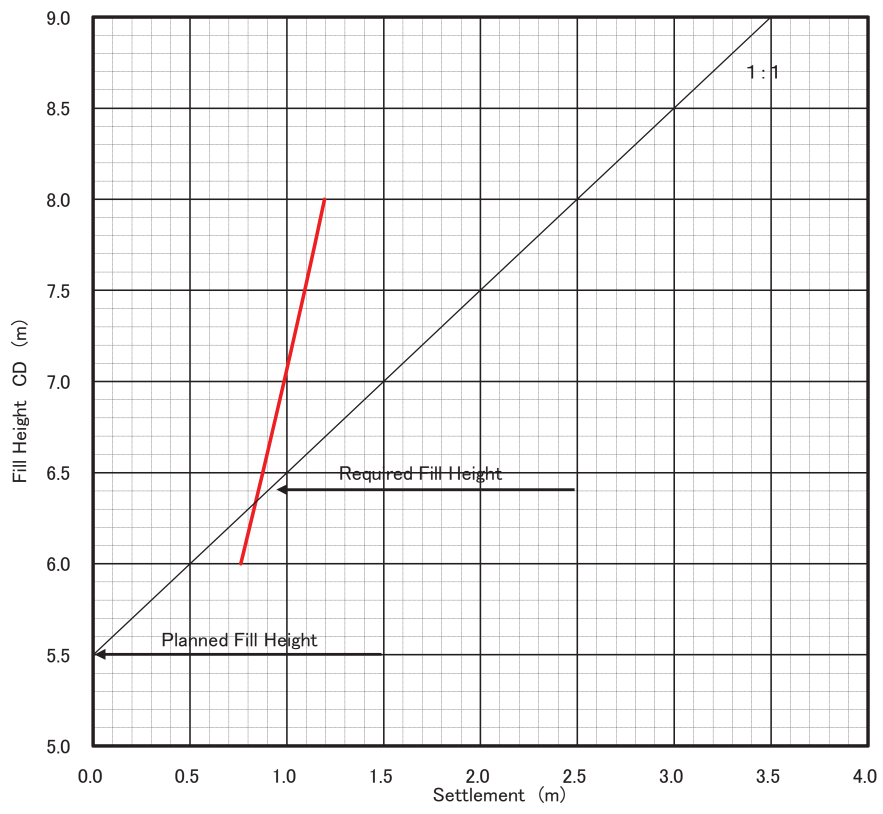
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.00	1a	2.00									
	2	7.00	40.50	80.00	0.60	0.12	1.45	115.40	0.101	0.497	0.598
	3c	2.50									
	4	3.50	103.25	203.25	0.35	0.04	0.85	115.40	0.022	0.021	0.043
	5(U)	7.50	147.13	222.13	0.60	0.08	1.20	115.40	0.049	0.148	0.197
	5(L)	7.00	201.50	276.50	0.60	0.08	1.20	115.40	0.035	0.113	0.148
Ground Level											
0.50	Total	29.50							0.207	0.779	0.987
									Final Ground Level (m)		6.013

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
7.50	1a	2.00									
	2	7.00	40.50	80.00	0.60	0.12	1.45	124.40	0.101	0.539	0.640
	3c	2.50									
	4	3.50	103.25	203.25	0.35	0.04	0.85	124.40	0.022	0.033	0.055
	5(U)	7.50	147.13	222.13	0.60	0.08	1.20	124.40	0.049	0.178	0.227
	5(L)	7.00	201.50	276.50	0.60	0.08	1.20	124.40	0.035	0.136	0.171
Ground Level											
0.50	Total	29.50							0.207	0.886	1.093
									Final Ground Level (m)		6.407

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
8.00	1a	2.00									
	2	7.00	40.50	80.00	0.60	0.12	1.45	133.40	0.101	0.578	0.679
	3c	2.50									
	4	3.50	103.25	203.25	0.35	0.04	0.85	133.40	0.022	0.044	0.066
	5(U)	7.50	147.13	222.13	0.60	0.08	1.20	133.40	0.049	0.207	0.256
	5(L)	7.00	201.50	276.50	0.60	0.08	1.20	133.40	0.035	0.159	0.194
Ground Level											
0.50	Total	29.50							0.207	0.988	1.195
									Final Ground Level (m)		6.805

Required Embankment Height

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	N.C. (m)	Sub Total (m)
6.40	1a	2.00									
	2	7.00	40.50	80.00	0.60	0.12	1.45	104.60	0.101	0.443	0.545
	3c	2.50									
	4	3.50	103.25	203.25	0.35	0.04	0.85	104.60	0.022	0.006	0.029
	5(U)	7.50	147.13	222.13	0.60	0.08	1.20	104.60	0.049	0.111	0.160
	5(L)	7.00	201.50	276.50	0.60	0.08	1.20	104.60	0.035	0.084	0.119
Ground Level											
0.50	Total	29.50							0.207	0.645	0.853
									Final Ground Level (m)		5.547



Required Embankment Height Calculation Result for【+5.50m：Block-14(Access Road Area)】

Water Level =	1.95 m
Fill γt =	18.0 kN/m^3
γ' =	10.0 kN/m^3
Load q =	10.0 kN/m^2

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.00	1a	2.00									
	1b	2.50	26.00	80.00	0.30	0.07	1.05	92.40	0.042	0.062	0.104
	2	4.00	50.00	80.00	0.60	0.12	1.45	92.40	0.040	0.245	0.285
	3b	4.00	82.00	132.00	0.25	0.05	0.80	92.40	0.023	0.067	0.090
	4	1.00	104.50	204.50	0.35	0.04	0.85	92.40	0.006	0.000	0.006
	5(U)	8.50	140.88	215.88	0.60	0.08	1.20	92.40	0.057	0.078	0.135
	5(L)	9.00	206.50	281.50	0.60	0.08	1.20	92.40	0.044	0.064	0.108
Ground Level											
1.00	Total	31.00							0.212	0.517	0.729
									Final Ground Level (m)		5.271

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.50	1a	2.00									
	1b	2.50	26.00	80.00	0.30	0.07	1.05	101.40	0.042	0.074	0.116
	2	4.00	50.00	80.00	0.60	0.12	1.45	101.40	0.040	0.271	0.311
	3b	4.00	82.00	132.00	0.25	0.05	0.80	101.40	0.023	0.079	0.102
	4	1.00	104.50	204.50	0.35	0.04	0.85	101.40	0.006	0.001	0.007
	5(U)	8.50	140.88	215.88	0.60	0.08	1.20	101.40	0.057	0.116	0.173
	5(L)	9.00	206.50	281.50	0.60	0.08	1.20	101.40	0.044	0.096	0.140
Ground Level											
1.00	Total	31.00							0.212	0.637	0.849
									Final Ground Level (m)		5.651

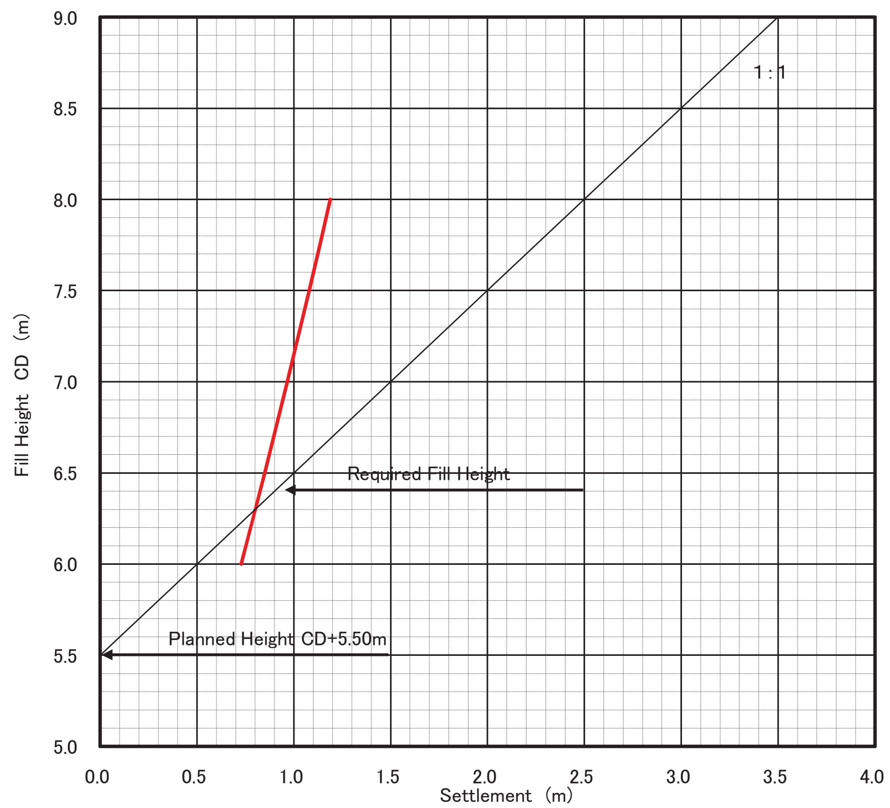
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.00	1a	2.00									
	1b	2.50	26.00	80.00	0.30	0.07	1.05	110.40	0.042	0.085	0.126
	2	4.00	50.00	80.00	0.60	0.12	1.45	110.40	0.040	0.296	0.336
	3b	4.00	82.00	132.00	0.25	0.05	0.80	110.40	0.023	0.091	0.114
	4	1.00	104.50	204.50	0.35	0.04	0.85	110.40	0.006	0.004	0.010
	5(U)	8.50	140.88	215.88	0.60	0.08	1.20	110.40	0.057	0.153	0.210
	5(L)	9.00	206.50	281.50	0.60	0.08	1.20	110.40	0.044	0.126	0.170
Ground Level											
1.00	Total	31.00							0.212	0.755	0.967
									Final Ground Level (m)		6.033

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
7.50	1a	2.00									
	1b	2.50	26.00	80.00	0.30	0.07	1.05	119.40	0.042	0.095	0.137
	2	4.00	50.00	80.00	0.60	0.12	1.45	119.40	0.040	0.319	0.359
	3b	4.00	82.00	132.00	0.25	0.05	0.80	119.40	0.023	0.102	0.125
	4	1.00	104.50	204.50	0.35	0.04	0.85	119.40	0.006	0.007	0.014
	5(U)	8.50	140.88	215.88	0.60	0.08	1.20	119.40	0.057	0.188	0.246
	5(L)	9.00	206.50	281.50	0.60	0.08	1.20	119.40	0.044	0.156	0.200
Ground Level											
1.00	Total	31.00							0.212	0.868	1.080
									Final Ground Level (m)		6.420

Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
8.00	1a	2.00									
	1b	2.50	26.00	80.00	0.30	0.07	1.05	128.40	0.042	0.104	0.146
	2	4.00	50.00	80.00	0.60	0.12	1.45	128.40	0.040	0.341	0.381
	3b	4.00	82.00	132.00	0.25	0.05	0.80	128.40	0.023	0.112	0.135
	4	1.00	104.50	204.50	0.35	0.04	0.85	128.40	0.006	0.011	0.017
	5(U)	8.50	140.88	215.88	0.60	0.08	1.20	128.40	0.057	0.223	0.280
	5(L)	9.00	206.50	281.50	0.60	0.08	1.20	128.40	0.044	0.185	0.229
Ground Level											
1.00	Total	31.00							0.212	0.977	1.189
									Final Ground Level (m)		6.811

Required Embankment Height

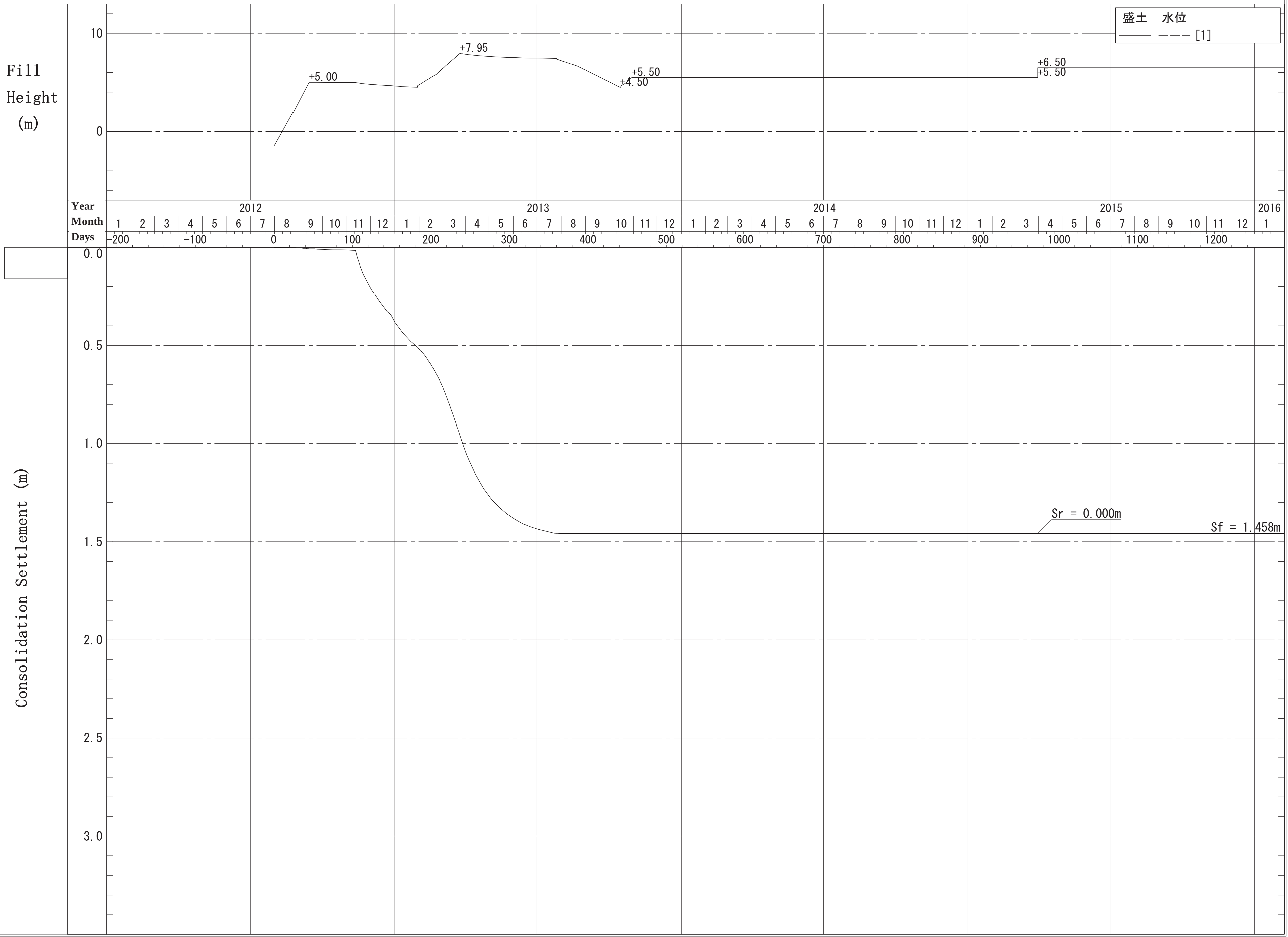
Fill Height (m)	Soil Layer	Thick. H (m)	Initial Stress Po (kN/m^2)	Preconso. Pressure Pc (kN/m^2)	Compression Index Cc (N.C.)	Recomp. Index Cr (O.C.)	Initial Void Ratio e0	Increased Stress ΔP (kN/m^2)	Prim. Conso. Settle. Sf O.C. (m)	Prim. Conso. Settle. Sf N.C. (m)	Sub Total (m)
6.40	1a	2.00									
	1b	2.50	26.00	80.00	0.30	0.07	1.05	99.60	0.042	0.072	0.113
	2	4.00	50.00	80.00	0.60	0.12	1.45	99.60	0.040	0.266	0.306
	3b	4.00	82.00	132.00	0.25	0.05	0.80	99.60	0.023	0.077	0.100
	4	1.00	104.50	204.50	0.35	0.04	0.85	99.60	0.006	0.000	0.006
	5(U)	8.50	140.88	215.88	0.60	0.08	1.20	99.60	0.057	0.109	0.166
	5(L)	9.00	206.50	281.50	0.60	0.08	1.20	99.60	0.044	0.089	0.133
Ground Level											
1.00	Total	31.00							0.212	0.613	0.825
									Final Ground Level (m)		5.575



Required Embankment Height Calculation Result for【+5.50m：Block-16(Access Road Area)】

2) Settlement-Time Curves with PVD for Reclamation Area (Block 1 to 16)

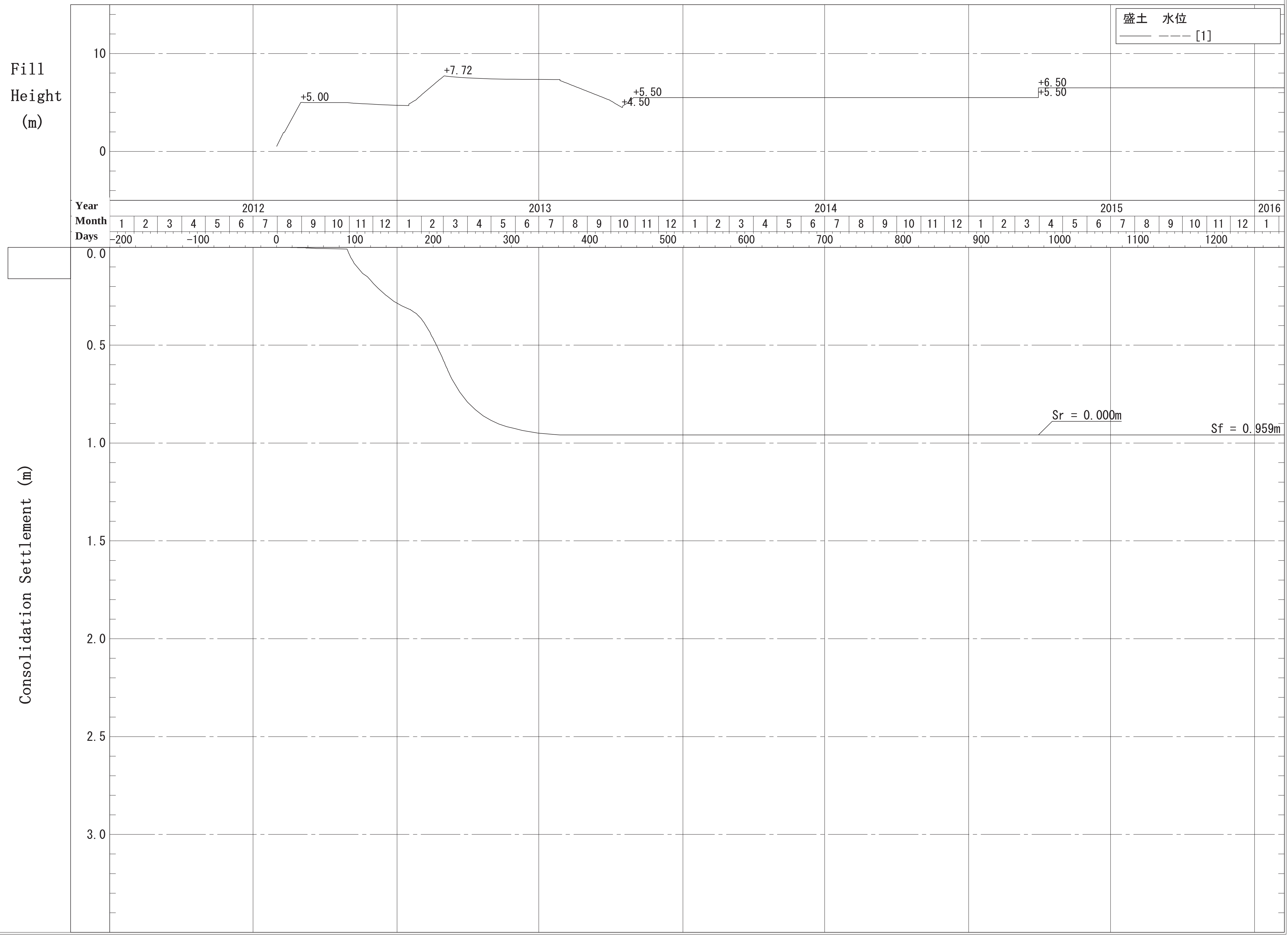
Settlement - Time Curve Block-1 (PVD d=1.1m, Preload dH=3.9m)



種 類	縮 尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

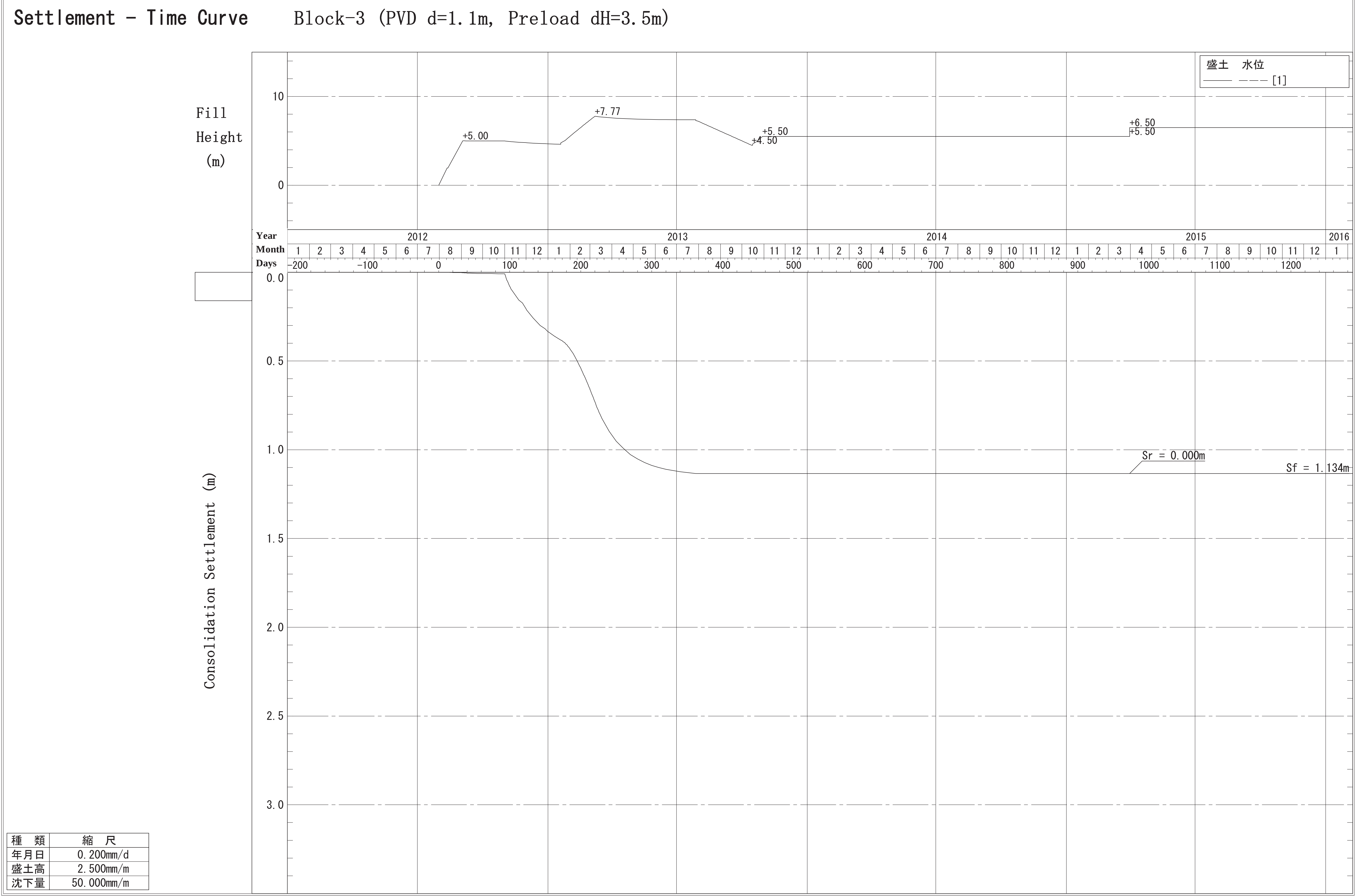
ファイル名 1:[1-ｄ□=1.1m-2段(h=3.9m).Ptw]

Settlement - Time Curve   Block-2 (PVD d=1.1m, Preload dH=3.3m)



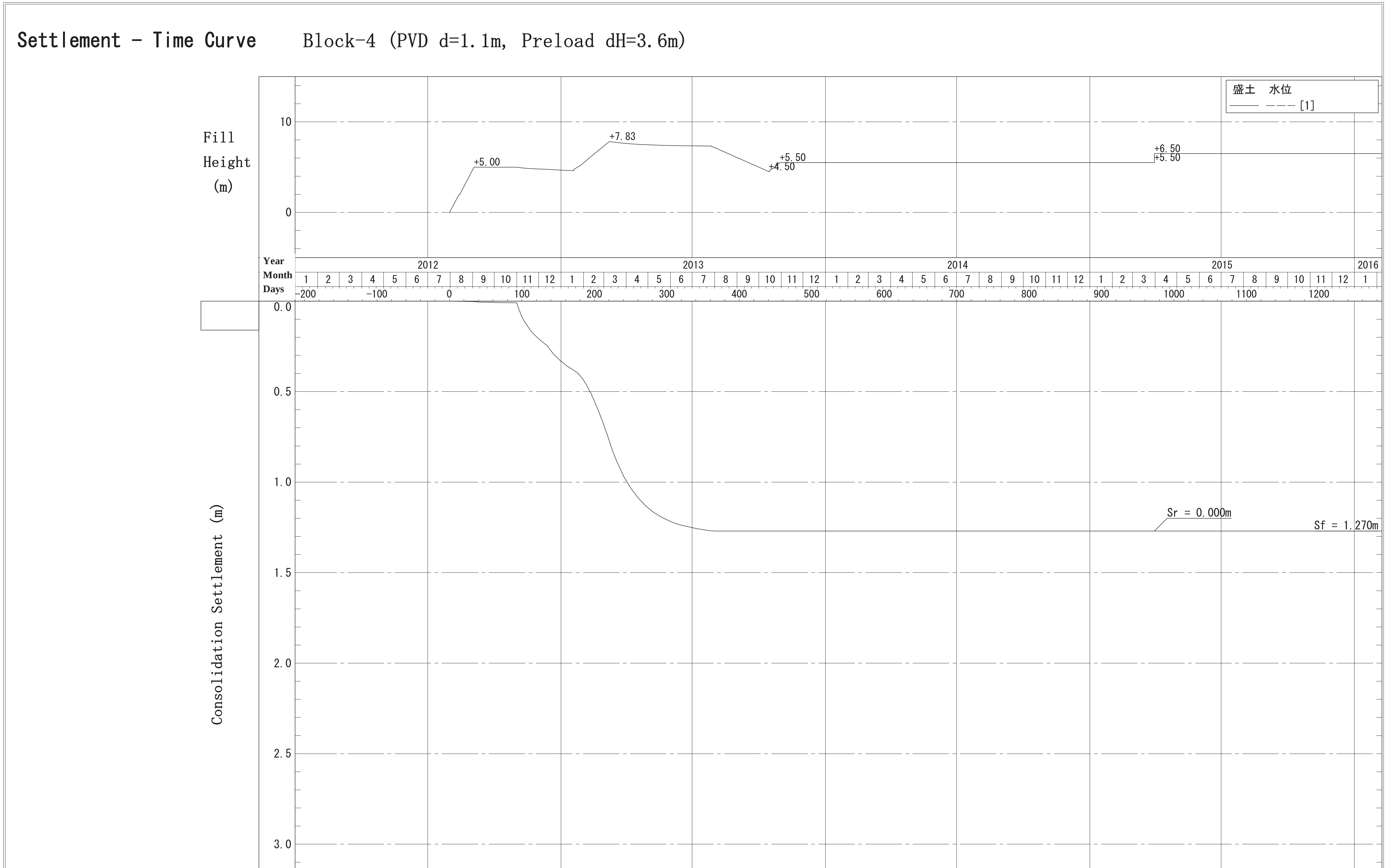
種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[2-d□=1.1m-2段(h=3.3m).Ptw]



種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

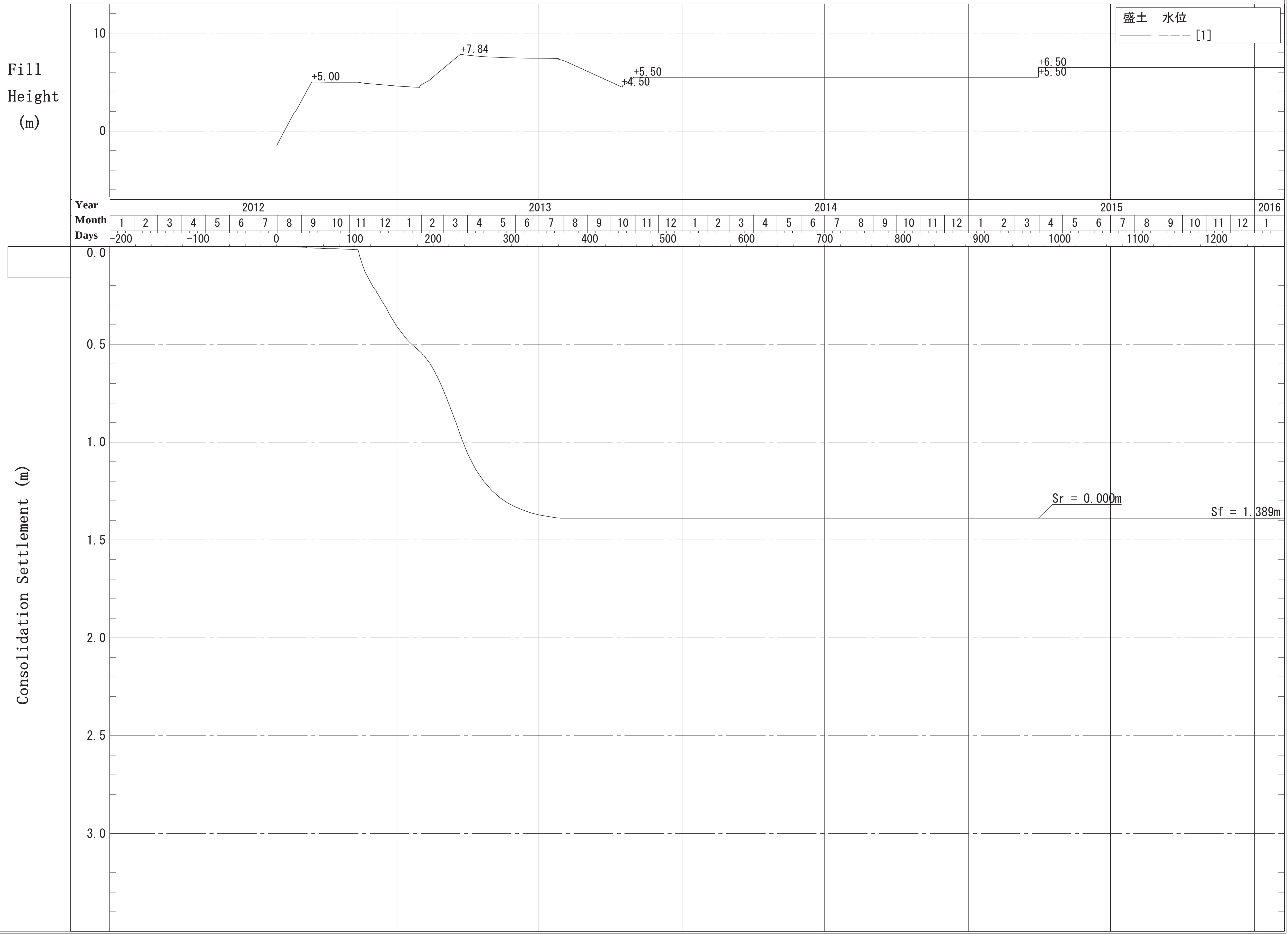
ファイル名 1:[3-ｄ□=1.1m-2段(h=3.5m).Ptw]



種 類	縮 尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[4-d□=1.1m-2段(h=3.6m).Ptw]

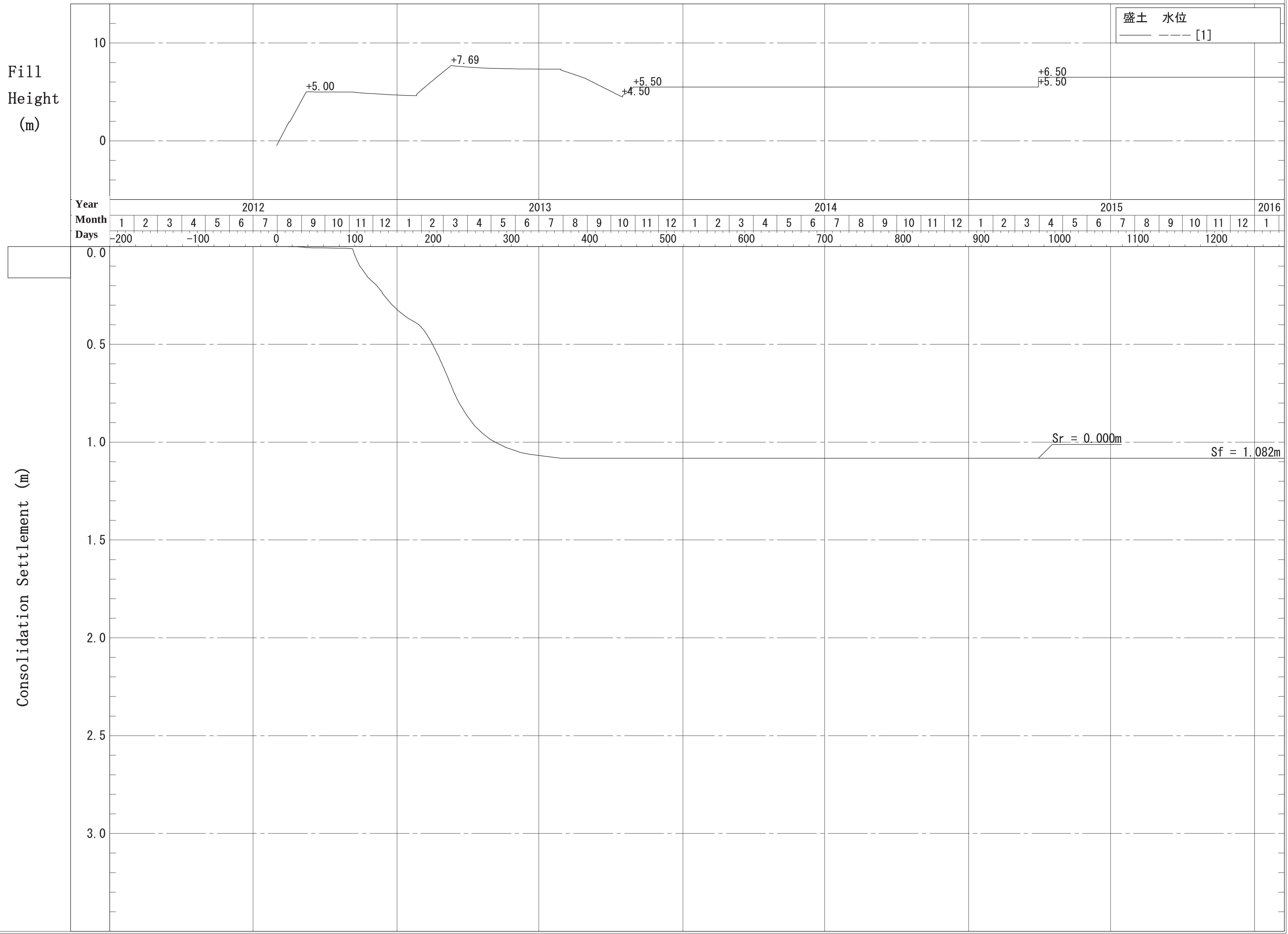
Settlement - Time Curve Block-5 (PVD d=1.1m, Preload dH=3.8m)



種 類	縮 尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[5-ｄ□=1.1m-2段(h=3.8m).Ptw]

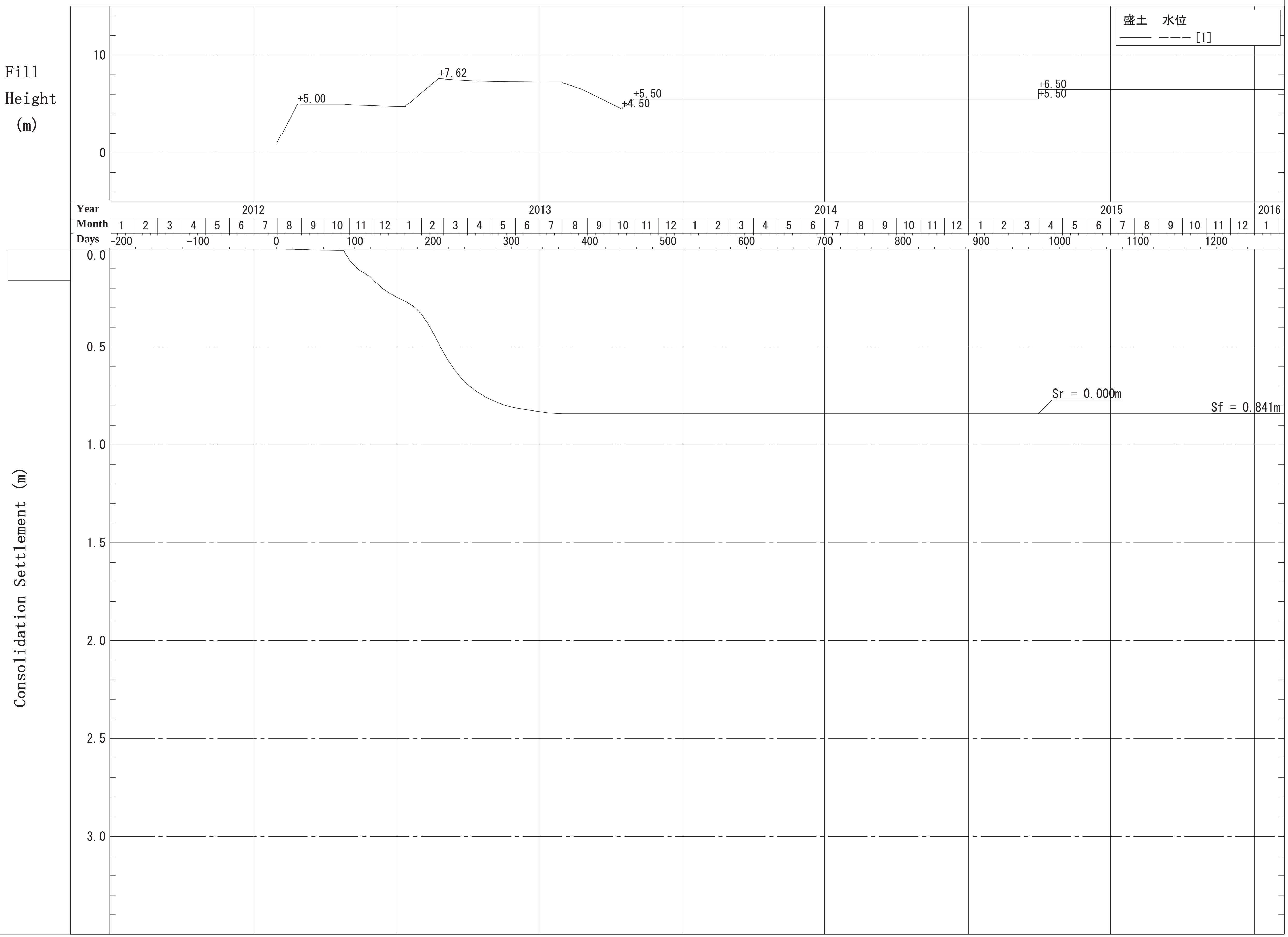
Settlement - Time Curve   Block-6 (PVD d=1.1m, Preload dH=3.4m)



種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[6-ｄ□=1.1m-2段(h=3.4m).Ptw]

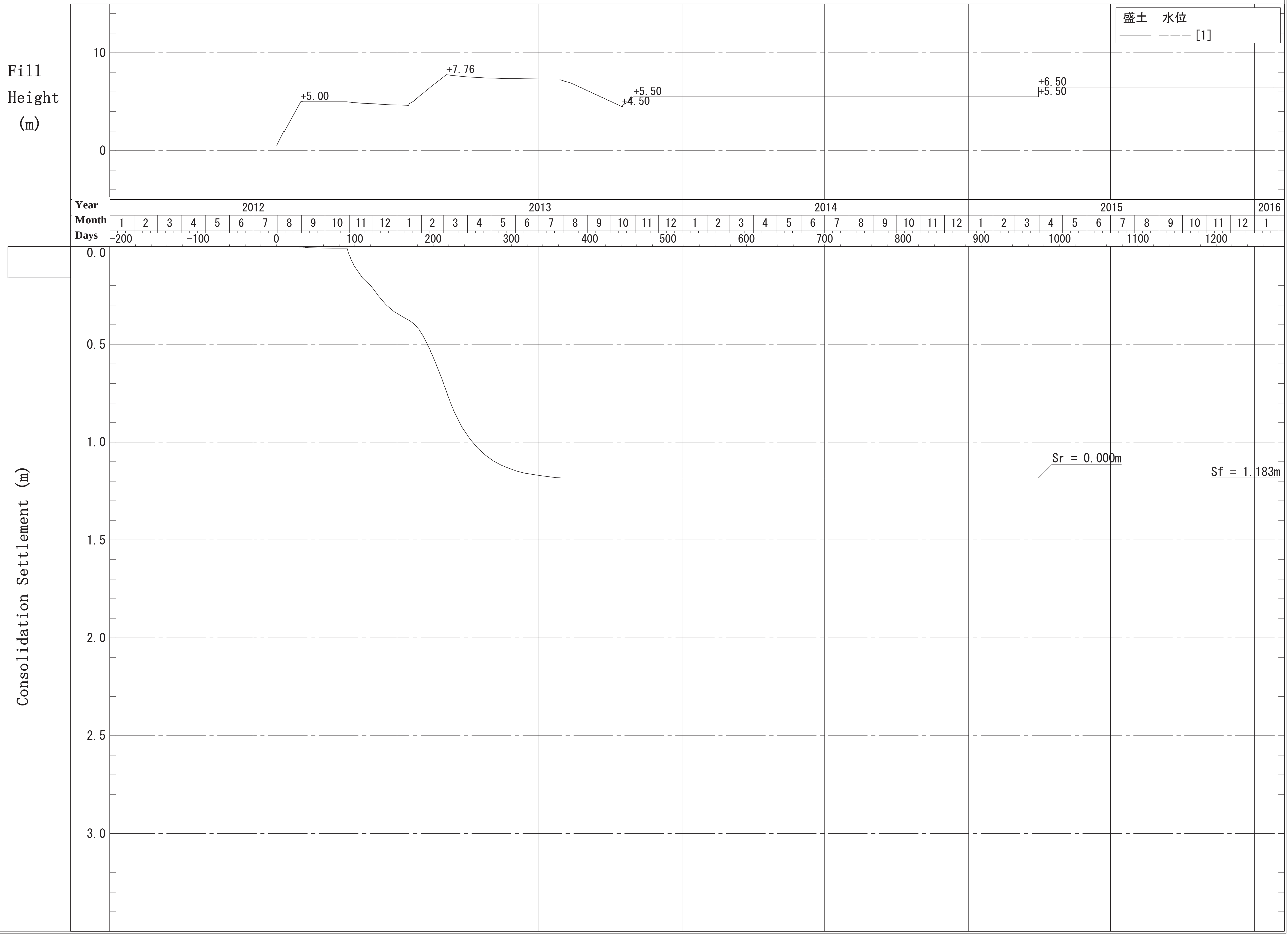
Settlement - Time Curve   Block-7 (PVD d=1.1m, Preload dH=3.1m)



種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[7-d□=1.1m-2段(h=3.1m).Ptw]

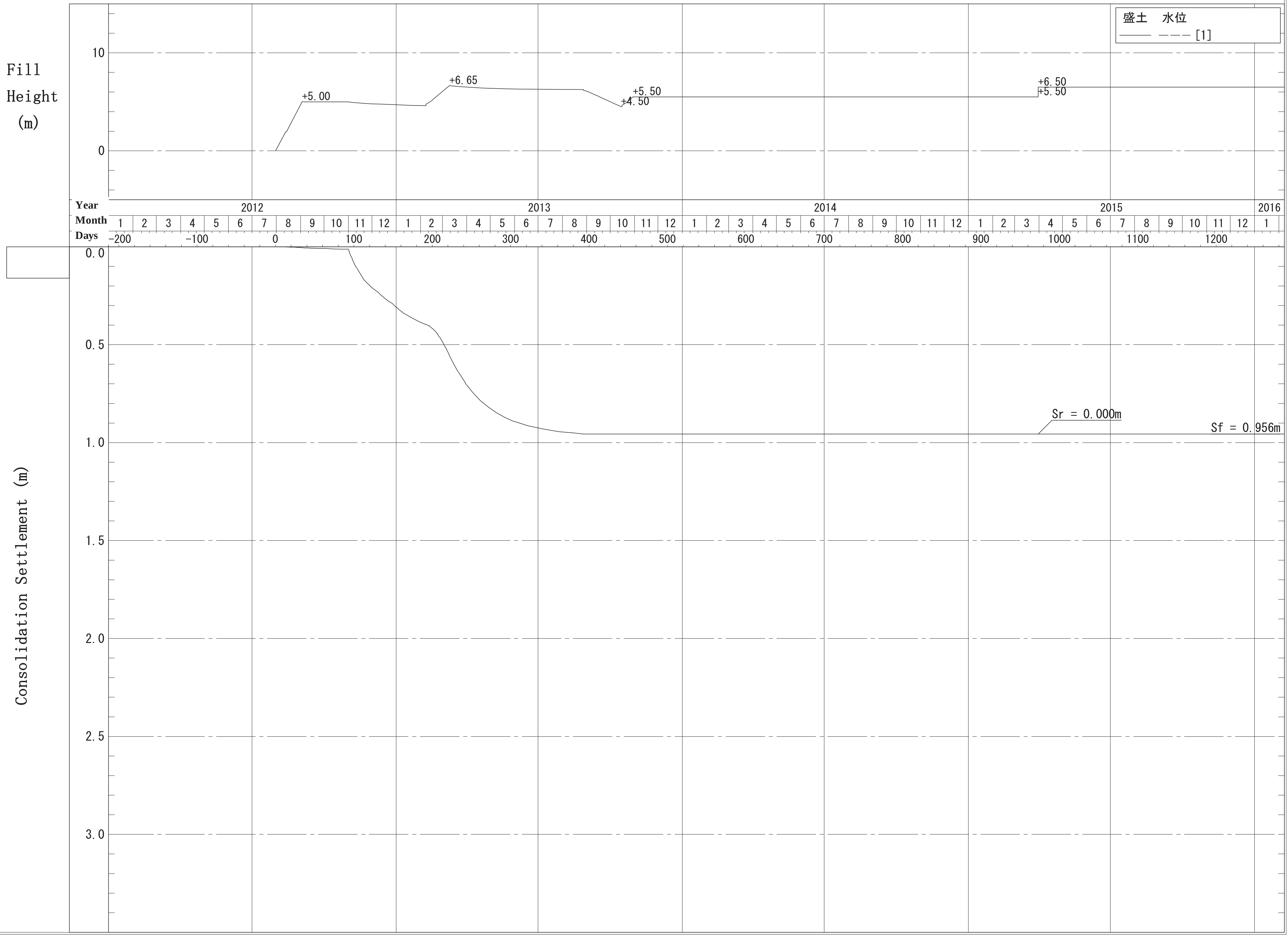
Settlement - Time Curve   Block-8 (PVD d=1.1m, Preload dH=3.5m)



種 類	縮 尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[8-d□=1.1m-2段(h=3.5m).Ptw]

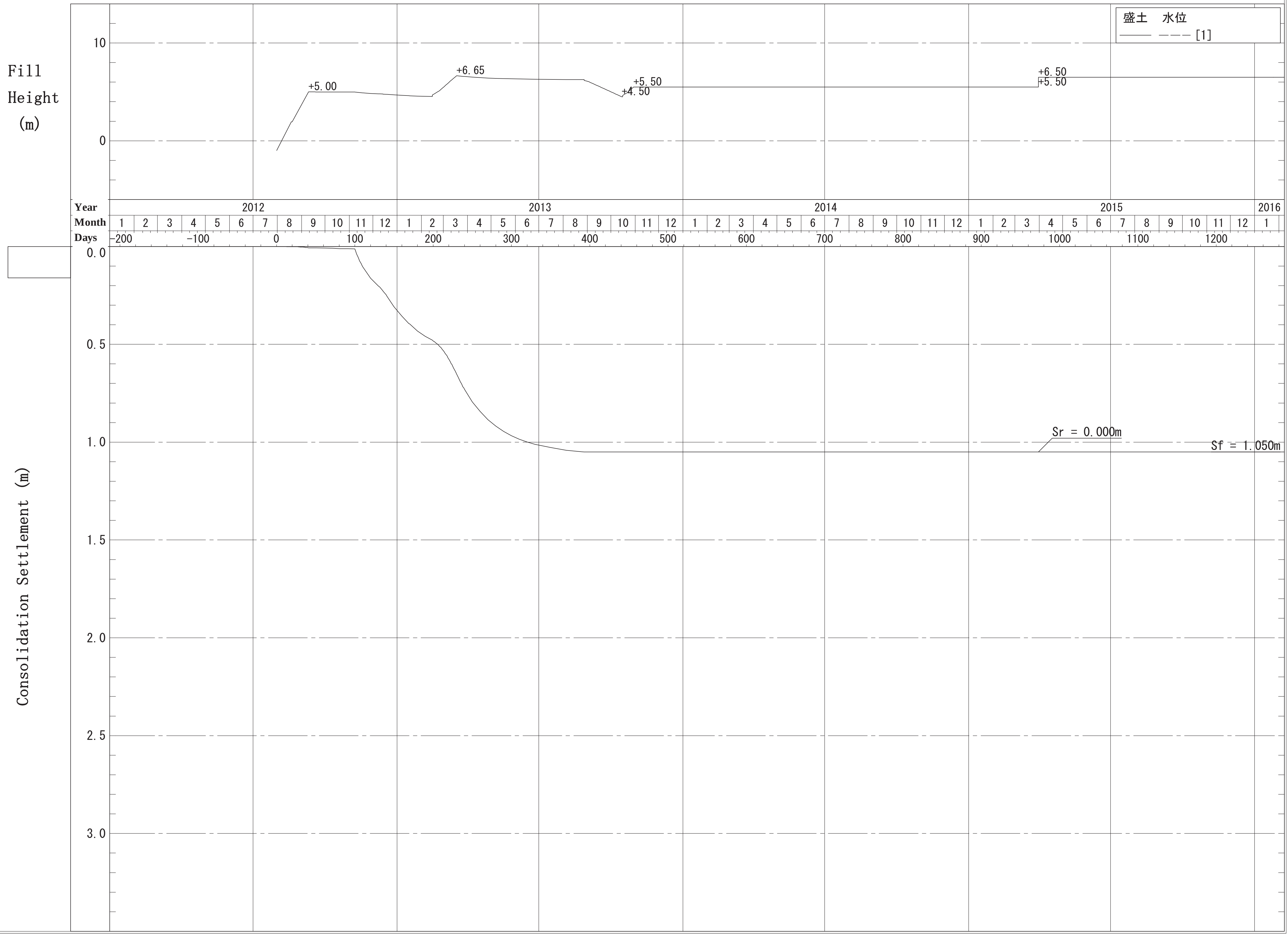
Settlement - Time Curve   Block-9 (PVD d=1.2m, Preload dH=2.2m)



種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

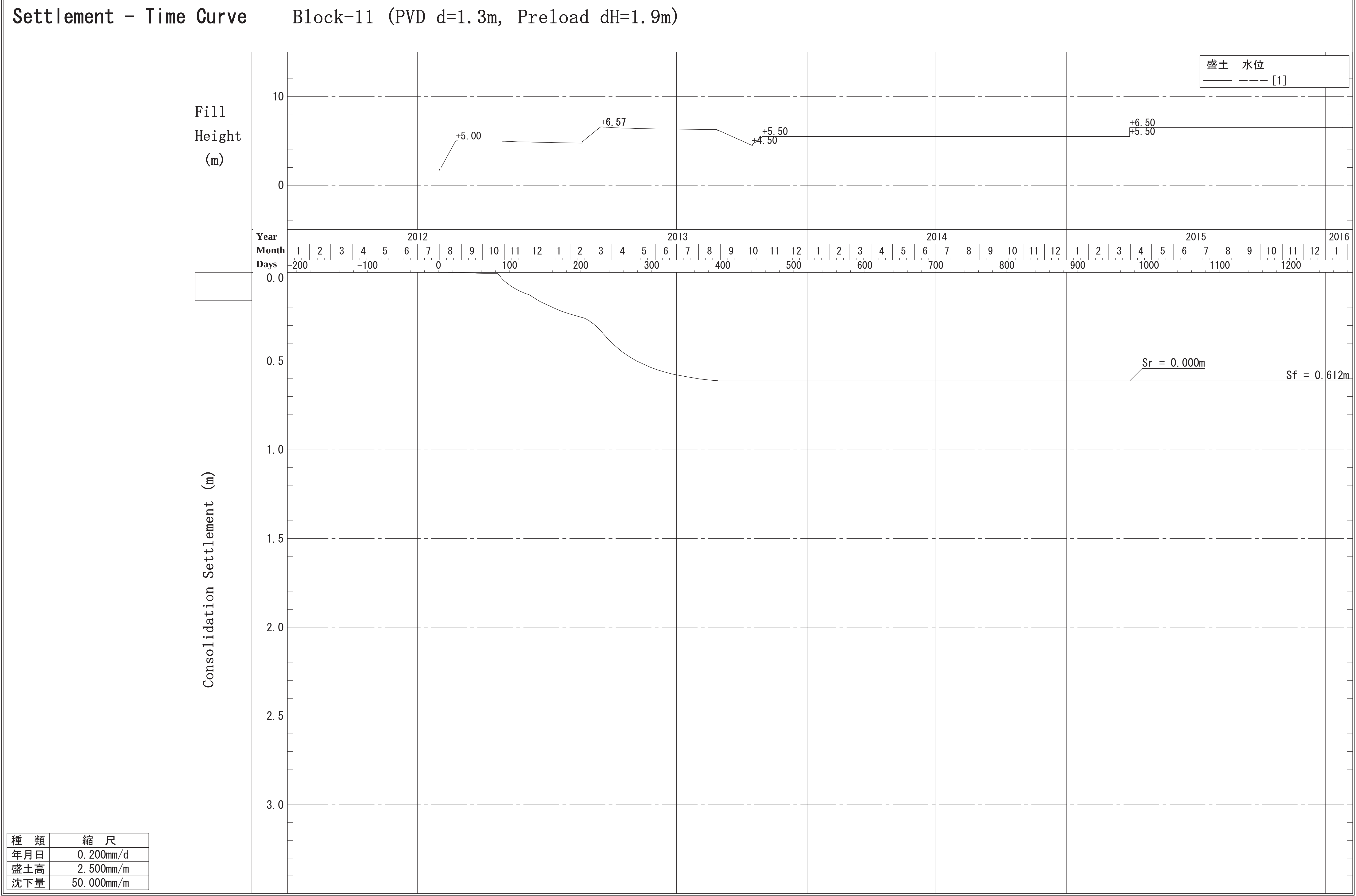
ファイル名 1:[9-ｄ□=1.2m-2段(h=2.2m).Ptw]

Settlement - Time Curve   Block-10 (PVD d=1.2m, Preload dH=2.3m)



種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

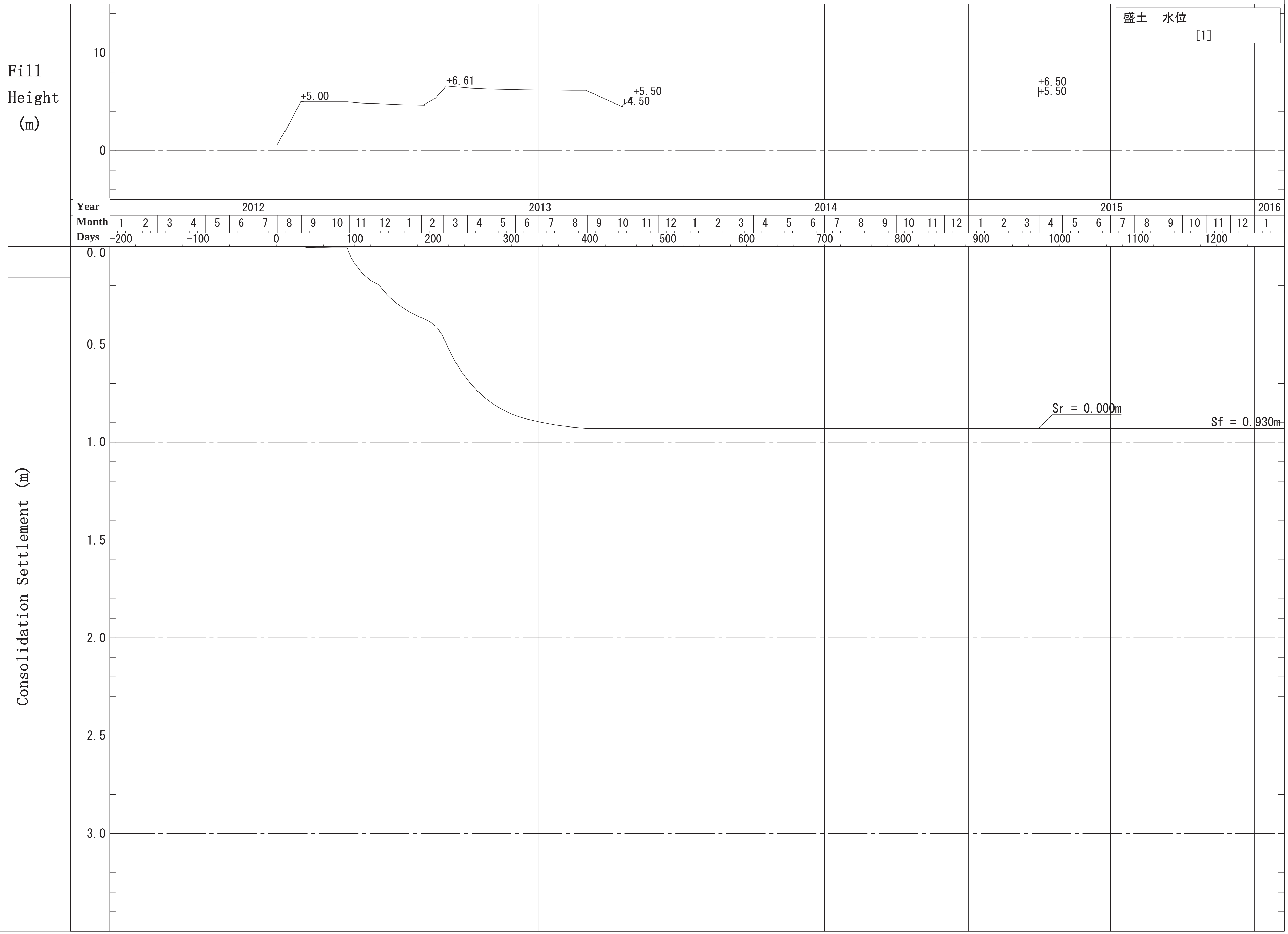
ファイル名 1:[10-d口=1.2m-2段(h=2.3m).Ptw]



種 類	縮 尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[11-d口=1.3m-2段(h=1.9m).Ptw]

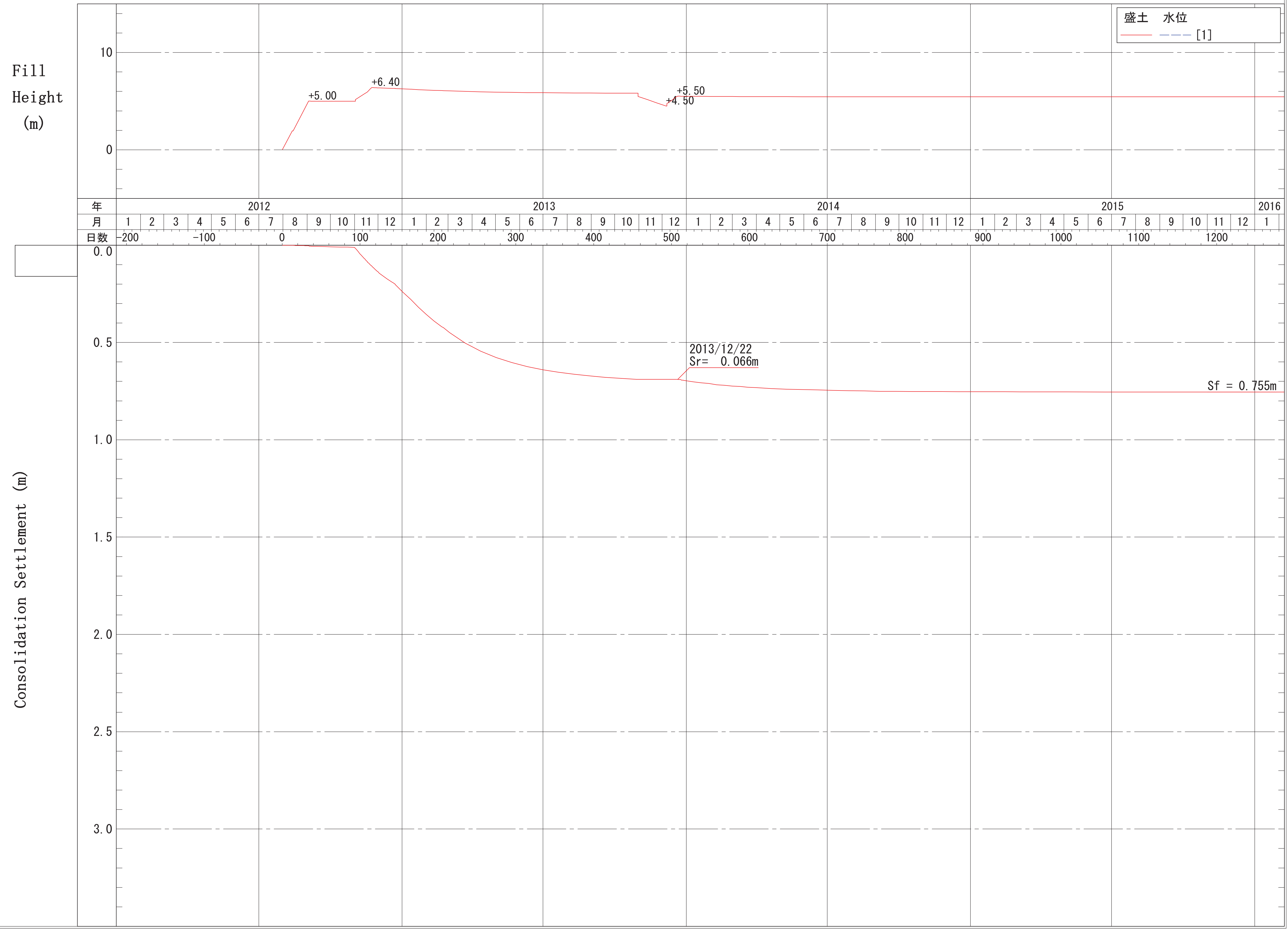
Settlement - Time Curve   Block-12 (PVD d=1.2m, Preload dH=2.1m)



種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[12-d口=1.2m-2段(h=2.1m).Ptw]

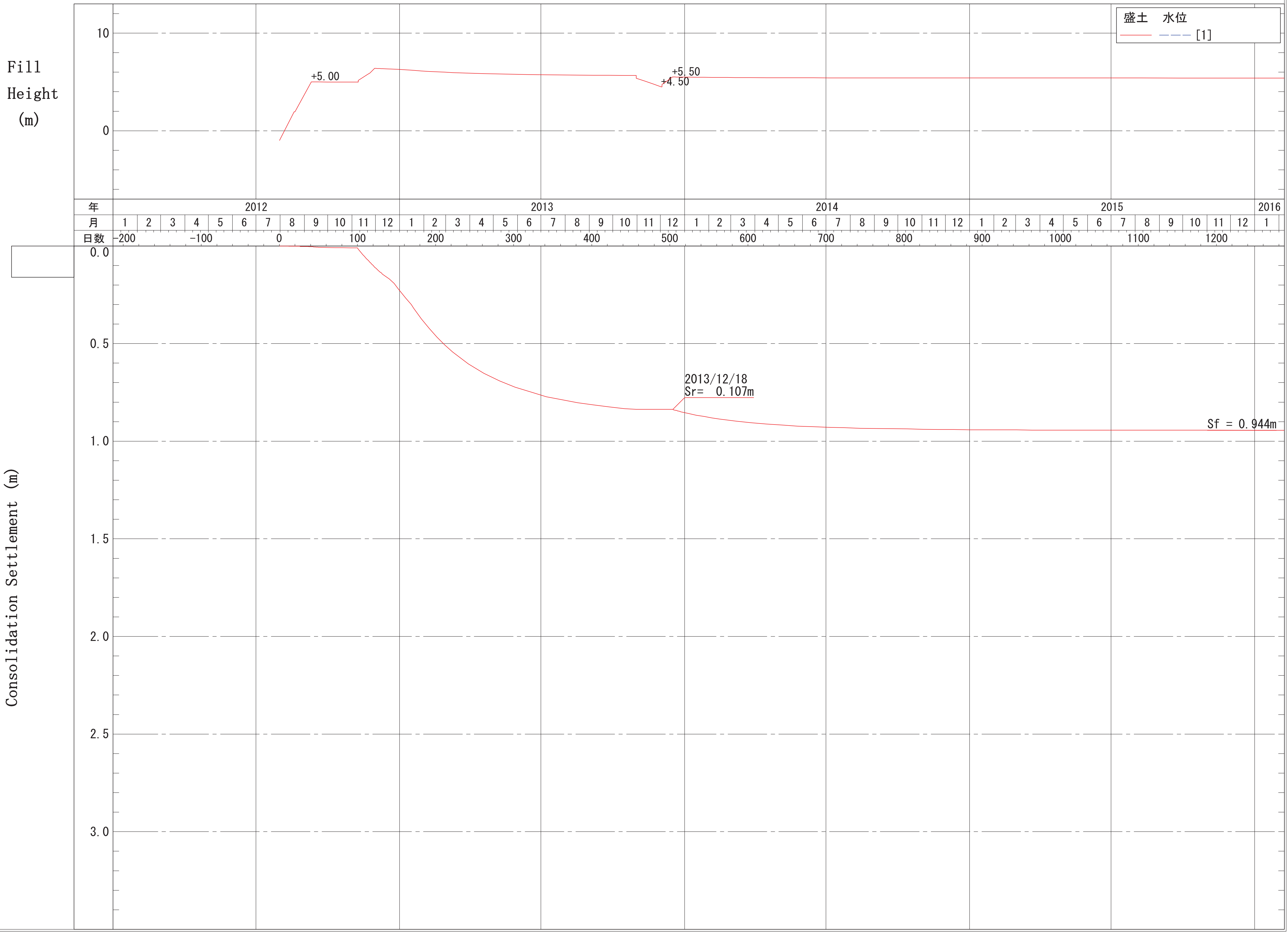
Settlement - Time Curve　　Block-13 (PVD d=1.6m, Preload dH=1.5m)



種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[13-d口=1.6m-2段(h=1.5m).Ptw]

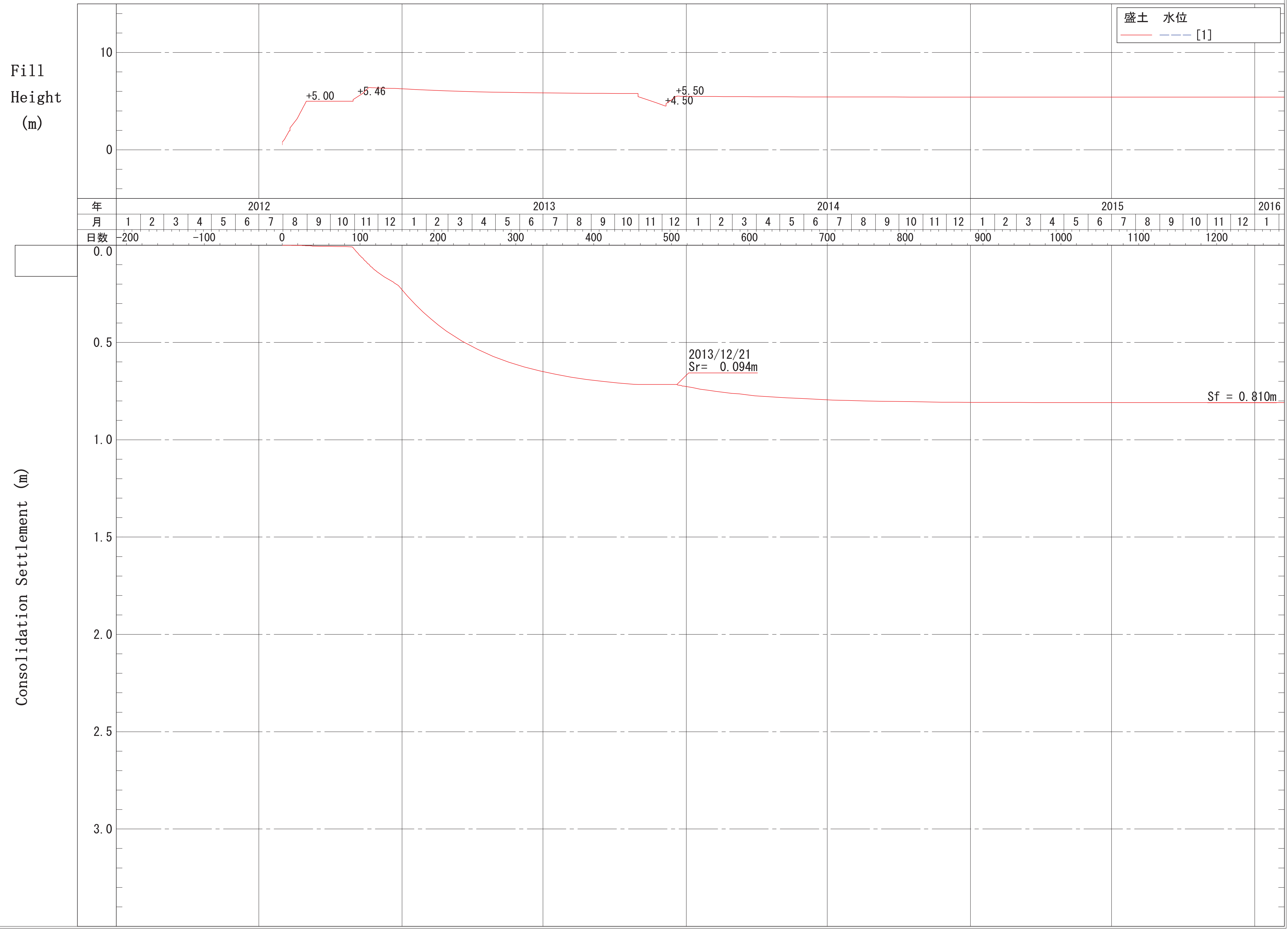
Settlement - Time Curve   Block-14 (PVD d=1.6m, Preload dH=1.5m)



種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[14-d ロ=1.6m-2段(h=1.5m).Ptw]

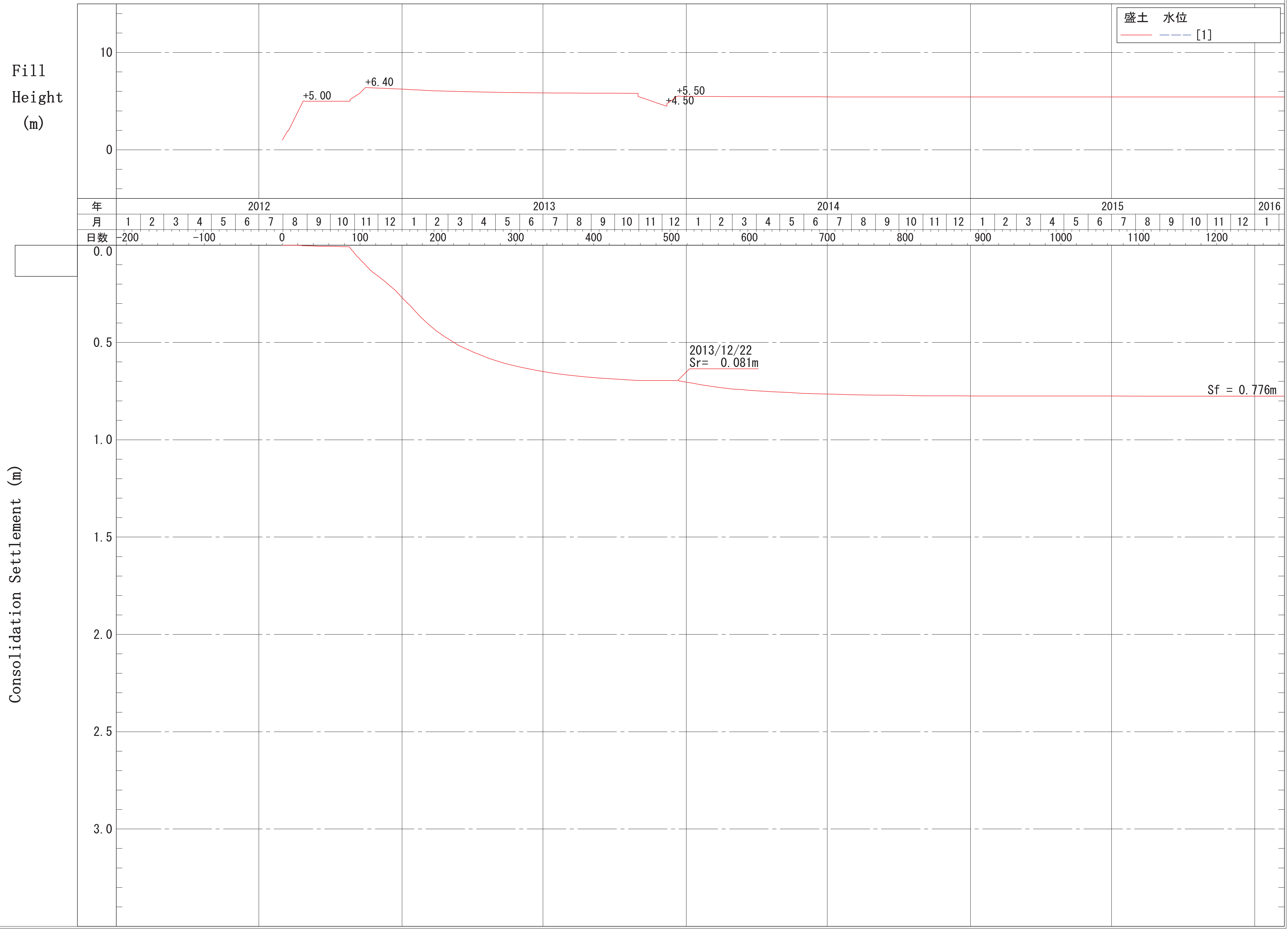
Settlement - Time Curve   Block-15 (PVD d=1.6m, Preload dH=1.5m)



種　類	縮　尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[15-ｄ口=1.6m-2段(h=1.5m).Ptw]

Settlement - Time Curve   Block-16 (PVD d=1.6m, Preload dH=1.5m)



種 類	縮 尺
年月日	0.200mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[16-d口=1.6m-2段(h=1.5m).Ptw]

3) Economical Comparison Tables by PVD Spacing for Terminal Area (Block 1 to 12)

Economical Comparison Tables with Several PVD Installation Intervals (1/4)

	Block No.	1			
	Sea Bed Level (CD; m)	-1.5			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-26.0			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	30.5	30.5	30.5	30.5
	1st Fill Thickness (m)	6.5	6.5	6.5	6.5
	Preloading Fill Thickness (m)	3.7	3.9	4.5	5.4
	Removal Thickness of Preload (m)	2.763	2.948	3.519	4.472
	Consolidation Degree U (%)	100.0	100.0	100.0	98.5
	Consolidation Settlement (m)	1.444	1.458	1.488	1.435
	Consolidation Periods (days)	261	256	242	213
Unit Price	Cost Total (V Dong; per m2)	2,199,647.9	2,197,070.3	2,296,539.4	2,475,413.5
171,756	Filling Sand	1,116,414.0	1,116,414.0	1,116,414.0	1,116,414.0
191,271	Preload	707,702.7	745,956.9	860,719.5	1,032,863.4
36,632	Removal of Preload	101,214.2	107,991.1	128,908.0	163,818.3
8,994	PVD	274,317.0	226,708.3	190,497.9	162,317.8
	Economical Comparison	2	1	3	4

	Block No.	2			
	Sea Bed Level (CD; m)	0.5			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-26.0			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	30.5	30.5	30.5	30.5
	1st Fill Thickness (m)	4.5	4.5	4.5	4.5
	Preloading Fill Thickness (m)	3.2	3.3	3.6	4.7
	Removal Thickness of Preload (m)	2.754	2.854	3.122	4.178
	Consolidation Degree U (%)	100.0	100.0	100.0	100.0
	Consolidation Settlement (m)	0.948	0.959	0.980	1.025
	Consolidation Periods (days)	275	272	265	235
Unit Price	Cost Total (V Dong; per m2)	1,760,170.7	1,735,352.3	1,766,340.6	1,987,241.9
171,756	Filling Sand (m3)	772,902.0	772,902.0	772,902.0	772,902.0
191,271	Preload (m3)	612,067.2	631,194.3	688,575.6	898,973.7
36,632	Removal of Preload (m3)	100,884.5	104,547.7	114,365.1	153,048.5
8,994	PVD (m)	274,317.0	226,708.3	190,497.9	162,317.8
	Evaluation	2	1	3	4

	Block No.	3			
	Sea Bed Level (CD; m)	0.0			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-27.0			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	31.5	31.5	31.5	31.5
	1st Fill Thickness (m)	5.0	5.0	5.0	5.0
	Preloading Fill Thickness (m)	3.4	3.5	3.8	5
	Removal Thickness of Preload (m)	2.777	2.871	3.156	4.321
	Consolidation Degree U (%)	100.0	100.0	100.0	99.7
	Consolidation Settlement (m)	1.127	1.134	1.148	1.181
	Consolidation Periods (days)	271	269	261	229
Unit Price	Cost Total (V Dong; per m2)	1,894,139.5	1,867,540.3	1,897,964.1	2,141,061.5
171,756	Filling Sand (m3)	858,780.0	858,780.0	858,780.0	858,780.0
191,271	Preload (m3)	650,321.4	669,448.5	726,829.8	956,355.0
36,632	Removal of Preload (m3)	101,727.1	105,170.5	115,610.6	158,286.9
8,994	PVD (m)	283,311.0	234,141.3	196,743.8	167,639.6
	Evaluation	2	1	3	4

Economical Comparison Tables with Several PVD Installation Intervals (2/4)

	Block No.	4			
	Sea Bed Level (CD; m)	0.0			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-27.5			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	32.0	32.0	32.0	32.0
	1st Fill Thickness (m)	5.0	5.0	5.0	5.0
	Preloading Fill Thickness (m)	3.5	3.6	4	5.3
	Removal Thickness of Preload (m)	2.739	2.833	3.27	4.483
	Consolidation Degree U (%)	100.0	100.0	100.0	99.6
	Consolidation Settlement (m)	1.265	1.27	1.297	1.319
	Consolidation Periods (days)	272	270	259	224
Unit Price	Cost Total (V Dong; per m2)	1,916,371.5	1,888,991.9	1,943,517.3	2,207,038.1
171,756	Filling Sand (m3)	858,780.0	858,780.0	858,780.0	858,780.0
191,271	Preload (m3)	669,448.5	688,575.6	765,084.0	1,013,736.3
36,632	Removal of Preload (m3)	100,335.0	103,778.5	119,786.6	164,221.3
8,994	PVD (m)	287,808.0	237,857.9	199,866.7	170,300.6
	Evaluation	2	1	3	4

	Block No.	5			
	Sea Bed Level (CD; m)	-1.5			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-26.0			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	30.5	30.5	30.5	30.5
	1st Fill Thickness (m)	6.5	6.5	6.5	6.5
	Preloading Fill Thickness (m)	3.6	3.8	4.4	5
	Removal Thickness of Preload (m)	2.735	2.917	3.485	4.131
	Consolidation Degree U (%)	100.0	100.0	100.0	98.6
	Consolidation Settlement (m)	1.373	1.389	1.422	1.375
	Consolidation Periods (days)	261	256	240	222
Unit Price	Cost Total (V Dong; per m2)	2,179,495.1	2,176,807.6	2,276,166.8	2,386,413.5
171,756	Filling Sand (m3)	1,116,414.0	1,116,414.0	1,116,414.0	1,116,414.0
191,271	Preload (m3)	688,575.6	726,829.8	841,592.4	956,355.0
36,632	Removal of Preload (m3)	100,188.5	106,855.5	127,662.5	151,326.8
8,994	PVD (m)	274,317.0	226,708.3	190,497.9	162,317.8
	Evaluation	2	1	3	4

	Block No.	6			
	Sea Bed Level (CD; m)	-0.5			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-25.5			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	30.0	30.0	30.0	30.0
	1st Fill Thickness (m)	5.5	5.5	5.5	5.5
	Preloading Fill Thickness (m)	3.3	3.4	3.8	4.9
	Removal Thickness of Preload (m)	2.728	2.823	3.196	4.281
	Consolidation Degree U (%)	100.0	100.0	100.0	99.5
	Consolidation Settlement (m)	1.076	1.082	1.108	1.124
	Consolidation Periods (days)	269	266	256	225
Unit Price	Cost Total (V Dong; per m2)	1,945,604.4	1,921,383.3	1,975,938.7	2,198,364.3
171,756	Filling Sand (m3)	944,658.0	944,658.0	944,658.0	944,658.0
191,271	Preload (m3)	631,194.3	650,321.4	726,829.8	937,227.9
36,632	Removal of Preload (m3)	99,932.1	103,412.1	117,075.9	156,821.6
8,994	PVD (m)	269,820.0	222,991.7	187,375.0	159,656.8
	Evaluation	2	1	3	4

Economical Comparison Tables with Several PVD Installation Intervals (3/4)

	Block No.	7			
	Sea Bed Level (CD; m)	1.0			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-25.0			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	29.5	29.5	29.5	29.5
	1st Fill Thickness (m)	4.0	4.0	4.0	4.0
	Preloading Fill Thickness (m)	3.1	3.1	3.4	4.1
	Removal Thickness of Preload (m)	2.753	2.761	3.044	3.726
	Consolidation Degree U (%)	100.0	100.0	100.0	100.0
	Consolidation Settlement (m)	0.849	0.841	0.858	0.877
	Consolidation Periods (days)	279	279	271	252
Unit Price	Cost Total (V Dong; per m2)	1,646,135.0	1,600,380.3	1,633,105.3	1,764,721.8
171,756	Filling Sand (m3)	687,024.0	687,024.0	687,024.0	687,024.0
191,271	Preload (m3)	592,940.1	592,940.1	650,321.4	784,211.1
36,632	Removal of Preload (m3)	100,847.9	101,141.0	111,507.8	136,490.8
8,994	PVD (m)	265,323.0	219,275.2	184,252.1	156,995.9
	Evaluation	3	1	2	4

	Block No.	8			
	Sea Bed Level (CD; m)	0.5			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-26.0			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	30.5	30.5	30.5	30.5
	1st Fill Thickness (m)	4.5	4.5	4.5	4.5
	Preloading Fill Thickness (m)	3.4	3.5	3.8	5
	Removal Thickness of Preload (m)	2.728	2.82	3.098	4.245
	Consolidation Degree U (%)	100.0	100.0	100.0	99.8
	Consolidation Settlement (m)	1.175	1.183	1.206	1.258
	Consolidation Periods (days)	276	272	265	233
Unit Price	Cost Total (V Dong; per m2)	1,797,472.5	1,772,361.0	1,803,715.7	2,047,077.6
171,756	Filling Sand (m3)	772,902.0	772,902.0	772,902.0	772,902.0
191,271	Preload (m3)	650,321.4	669,448.5	726,829.8	956,355.0
36,632	Removal of Preload (m3)	99,932.1	103,302.2	113,485.9	155,502.8
8,994	PVD (m)	274,317.0	226,708.3	190,497.9	162,317.8
	Evaluation	2	1	3	4

	Block No.	9			
	Sea Bed Level (CD; m)	0.0			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-25.5			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	30.0	30.0	30.0	30.0
	1st Fill Thickness (m)	5.0	5.0	5.0	5.0
	Preloading Fill Thickness (m)	2.1	2.1	2.2	2.4
	Removal Thickness of Preload (m)	1.66	1.662	1.75	1.934
	Consolidation Degree U (%)	100.0	100.0	100.0	100.0
	Consolidation Settlement (m)	0.945	0.943	0.956	0.971
Unit Price	Consolidation Periods (days)	271	286	300	295
Unit Price	Cost Total (V Dong; per m2)	1,591,078.2	1,544,323.2	1,531,057.2	1,548,333.5
171,756	Filling Sand (m3)	858,780.0	858,780.0	858,780.0	858,780.0
191,271	Preload (m3)	401,669.1	401,669.1	420,796.2	459,050.4
36,632	Removal of Preload (m3)	60,809.1	60,882.4	64,106.0	70,846.3
8,994	PVD (m)	269,820.0	222,991.7	187,375.0	159,656.8
	Evaluation	4	2	1	3

Economical Comparison Tables with Several PVD Installation Intervals (4/4)

	Block No.	10			
	Sea Bed Level (CD; m)	-1.0			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-26.0			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	30.5	30.5	30.5	30.5
	1st Fill Thickness (m)	6.0	6.0	6.0	6.0
	Preloading Fill Thickness (m)	2.2	2.2	2.3	2.6
	Removal Thickness of Preload (m)	1.659	1.663	1.755	2.032
	Consolidation Degree U (%)	100.0	100.0	100.0	100.0
	Consolidation Settlement (m)	1.046	1.043	1.050	1.075
	Consolidation Periods (days)	273	288	293	285
Unit Price	Cost Total (V Dong; per m2)	1,786,421.7	1,738,959.5	1,725,246.4	1,764,594.6
171,756	Filling Sand (m3)	1,030,536.0	1,030,536.0	1,030,536.0	1,030,536.0
191,271	Preload (m3)	420,796.2	420,796.2	439,923.3	497,304.6
36,632	Removal of Preload (m3)	60,772.5	60,919.0	64,289.2	74,436.2
8,994	PVD (m)	274,317.0	226,708.3	190,497.9	162,317.8
	Evaluation	4	2	1	3

	Block No.	11			
	Sea Bed Level (CD; m)	1.5			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-28.0			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	32.5	32.5	32.5	32.5
	1st Fill Thickness (m)	3.5	3.5	3.5	3.5
	Preloading Fill Thickness (m)	1.7	1.7	1.8	1.9
	Removal Thickness of Preload (m)	1.606	1.609	1.695	1.79
	Consolidation Degree U (%)	100.0	100.0	100.0	100.0
	Consolidation Settlement (m)	0.595	0.593	0.606	0.612
	Consolidation Periods (days)	266	281	302	0.309
Unit Price	Cost Total (V Dong; per m2)	1,277,442.7	1,226,822.0	1,210,514.6	1,203,093.7
171,756	Filling Sand (m3)	601,146.0	601,146.0	601,146.0	601,146.0
191,271	Preload (m3)	325,160.7	325,160.7	344,287.8	363,414.9
36,632	Removal of Preload (m3)	58,831.0	58,940.9	62,091.2	65,571.3
8,994	PVD (m)	292,305.0	241,574.4	202,989.6	172,961.5
	Evaluation	4	3	2	1

* Considering the continuity of soft soil treatment with surrounding areas, PVD installation interval 1.2m is selected.

	Block No.	12			
	Sea Bed Level (CD; m)	0.5			
	Top Level of First Fill (CD; m)	5.0			
	Top Level of PVD Installation (CD; m)	4.5			
	Bottom Level of Clay (CD; m)	-31.0			
	PVD Spacing (m)	1.0	1.1	1.2	1.3
	PVD Length (m)	35.5	35.5	35.5	35.5
	1st Fill Thickness (m)	4.5	4.5	4.5	4.5
	Preloading Fill Thickness (m)	2.1	2.1	2.1	2.4
	Removal Thickness of Preload (m)	1.662	1.666	1.674	1.936
	Consolidation Degree U (%)	100.0	100.0	100.0	100.0
	Consolidation Settlement (m)	0.941	0.937	0.930	0.968
	Consolidation Periods (days)	271	286	306	298
Unit Price	Cost Total (V Dong; per m2)	1,554,740.5	1,499,473.6	1,457,620.2	1,491,799.2
171,756	Filling Sand (m3)	772,902.0	772,902.0	772,902.0	772,902.0
191,271	Preload (m3)	401,669.1	401,669.1	401,669.1	459,050.4
36,632	Removal of Preload (m3)	60,882.4	61,028.9	61,322.0	70,919.6
8,994	PVD (m)	319,287.0	263,873.6	221,727.1	188,927.2
	Evaluation	4	3	1	2

4) Slope Stability Analysis Result during Filling at Reclamation Area

(Required Average Slope Gradient between Seabed and First Fill (CD+5.0m))

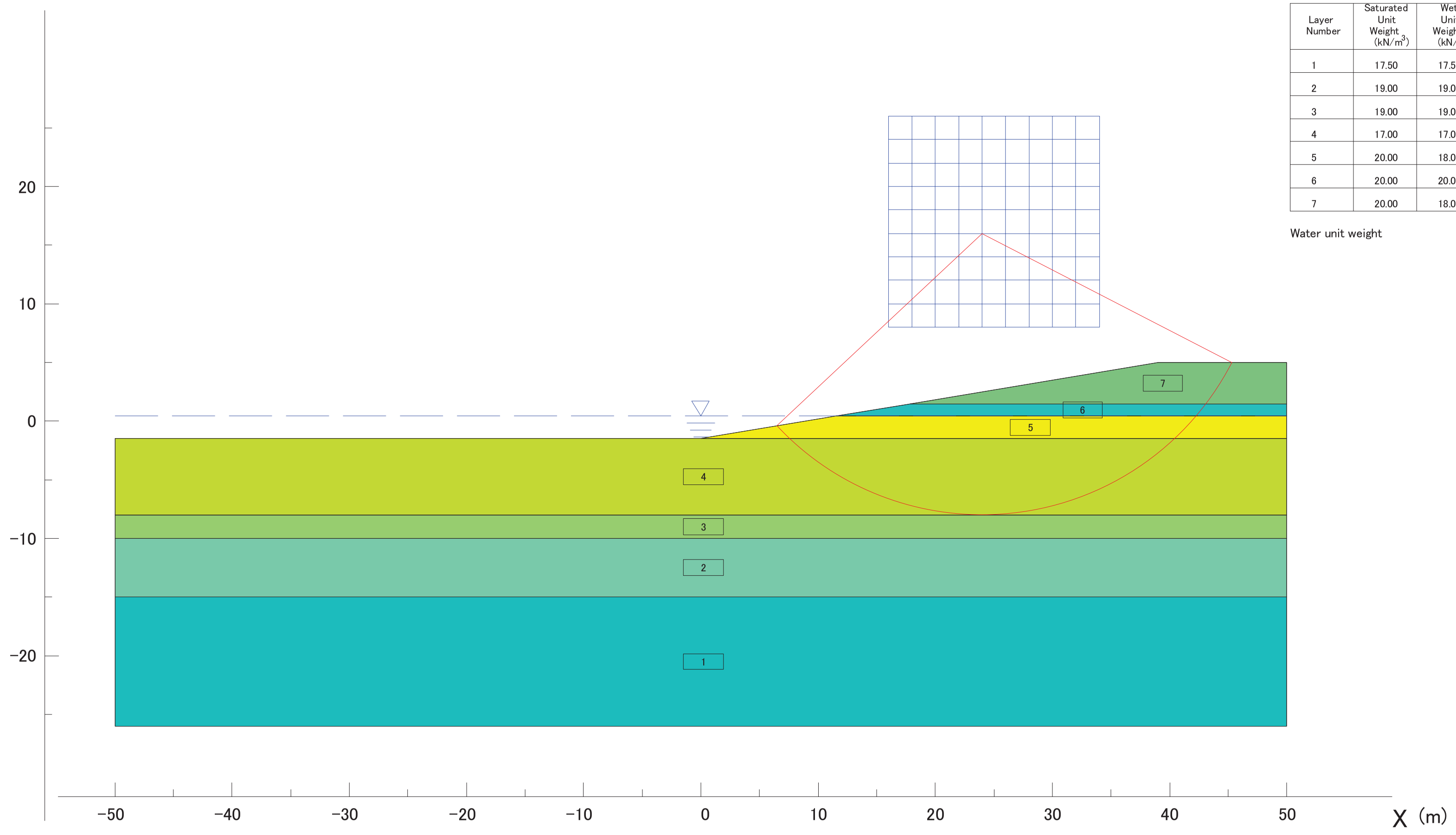
【Block−1】

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.104	
Center of arc	X	=	24.00	(m)
	Y	=	16.00	(m)
Radius	R	=	24.00	(m)
Resisting moment	M_R	=	15880.4	(kNm)
Sliding moment	M_D	=	14381.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	20.00	18.00	30.00	0.00	0.00	0.000	0.000
6	20.00	20.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

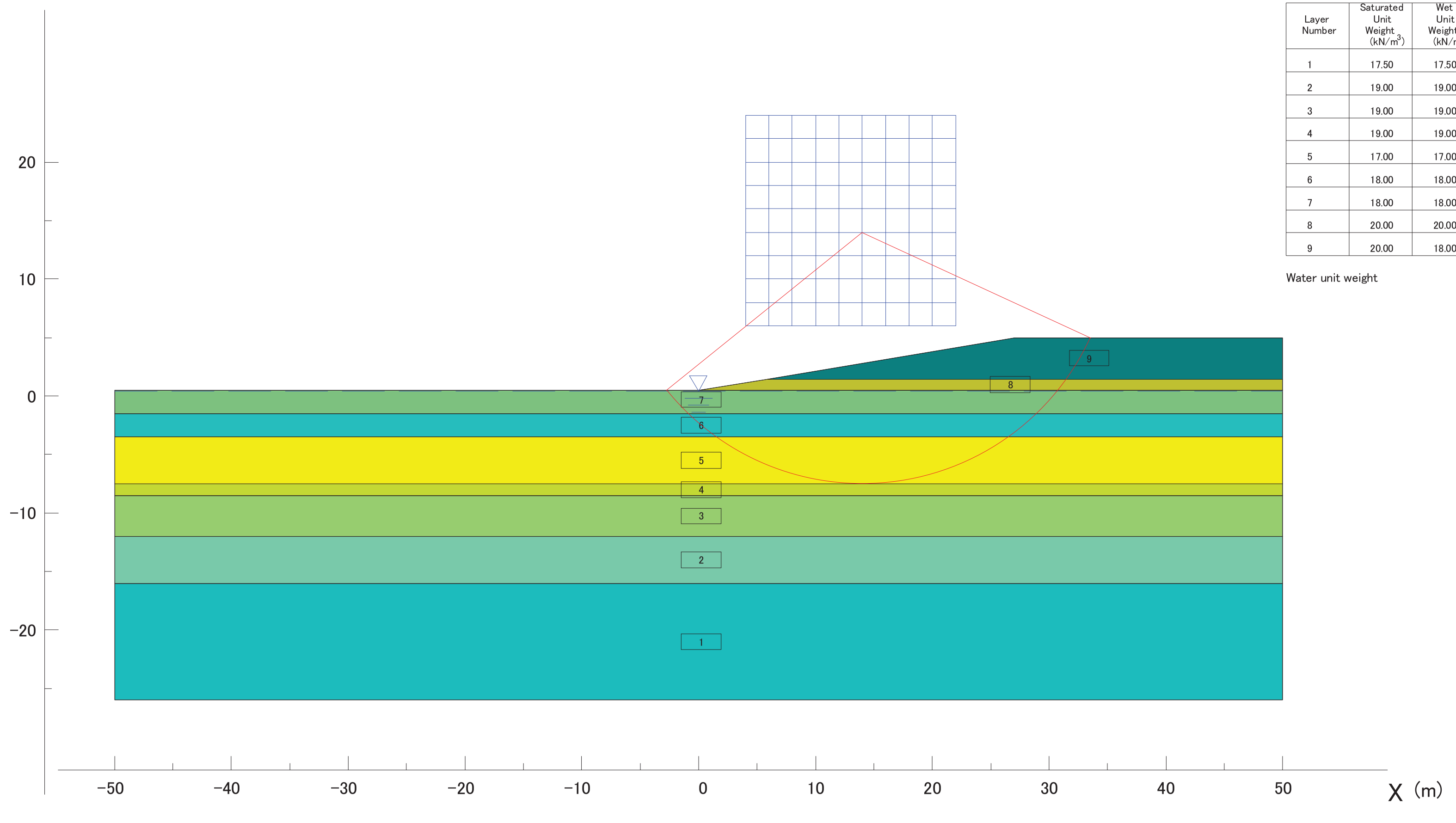
【Block−2】

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.136	
Center of arc	X	=	14.00	(m)
	Y	=	14.00	(m)
Radius	R	=	21.50	(m)
Resisting moment	M_R	=	12747.1	(kNm)
Sliding moment	M_D	=	11216.7	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	19.00	19.00	25.00	0.00	0.00	0.000	0.000
5	17.00	17.00	0.00	15.00	0.00	0.000	0.000
6	18.00	18.00	0.00	15.00	0.00	0.000	0.000
7	18.00	18.00	25.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

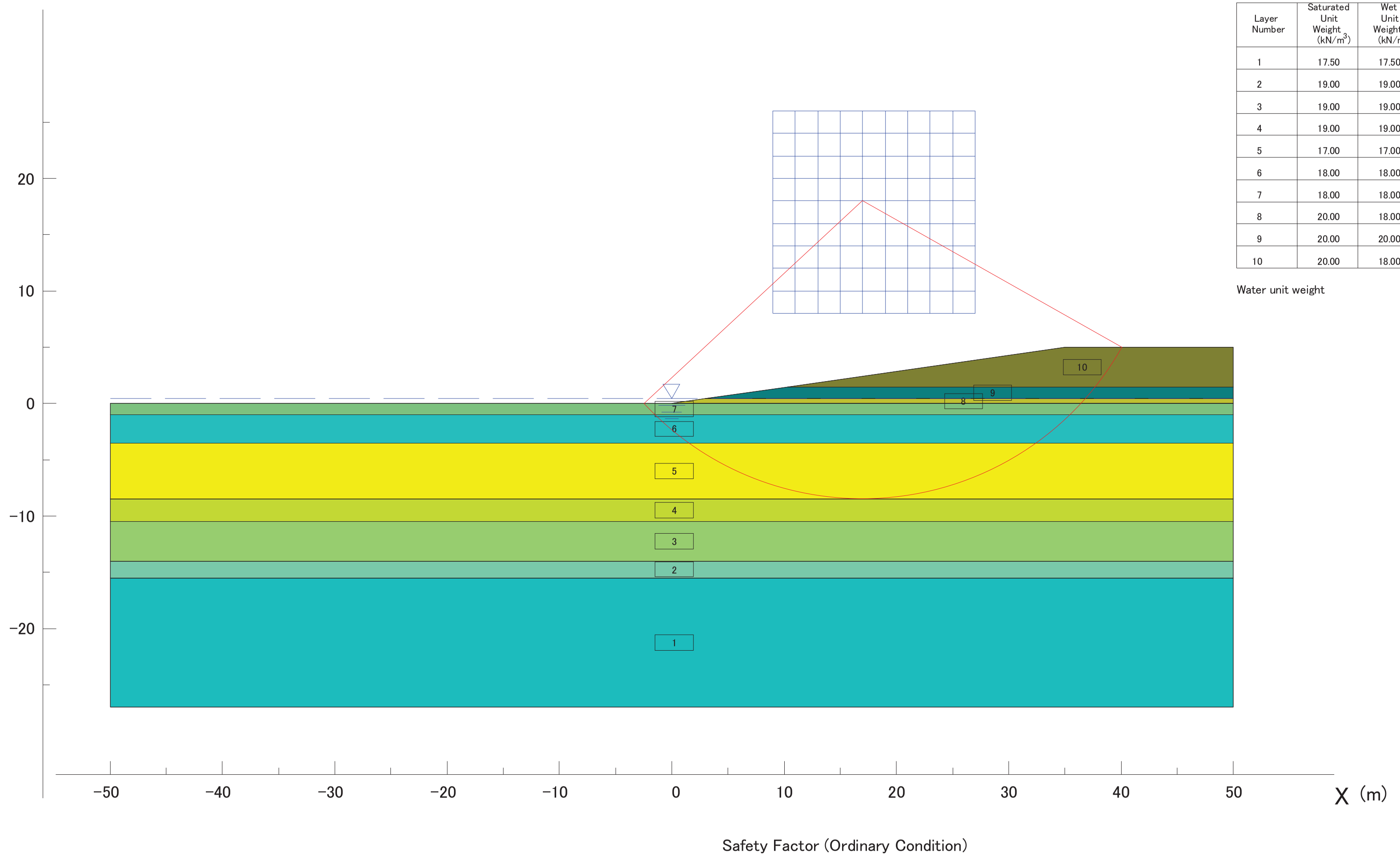
【Block-3】

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.162	
Center of arc	X	=	17.00	(m)
	Y	=	18.00	(m)
Radius	R	=	26.50	(m)
Resisting moment	M_R	=	18761.1	(kNm)
Sliding moment	M_D	=	16151.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	17.00	17.00	0.00	15.00	0.00	0.000	0.000
6	18.00	18.00	0.00	15.00	0.00	0.000	0.000
7	18.00	18.00	25.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000
9	20.00	20.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

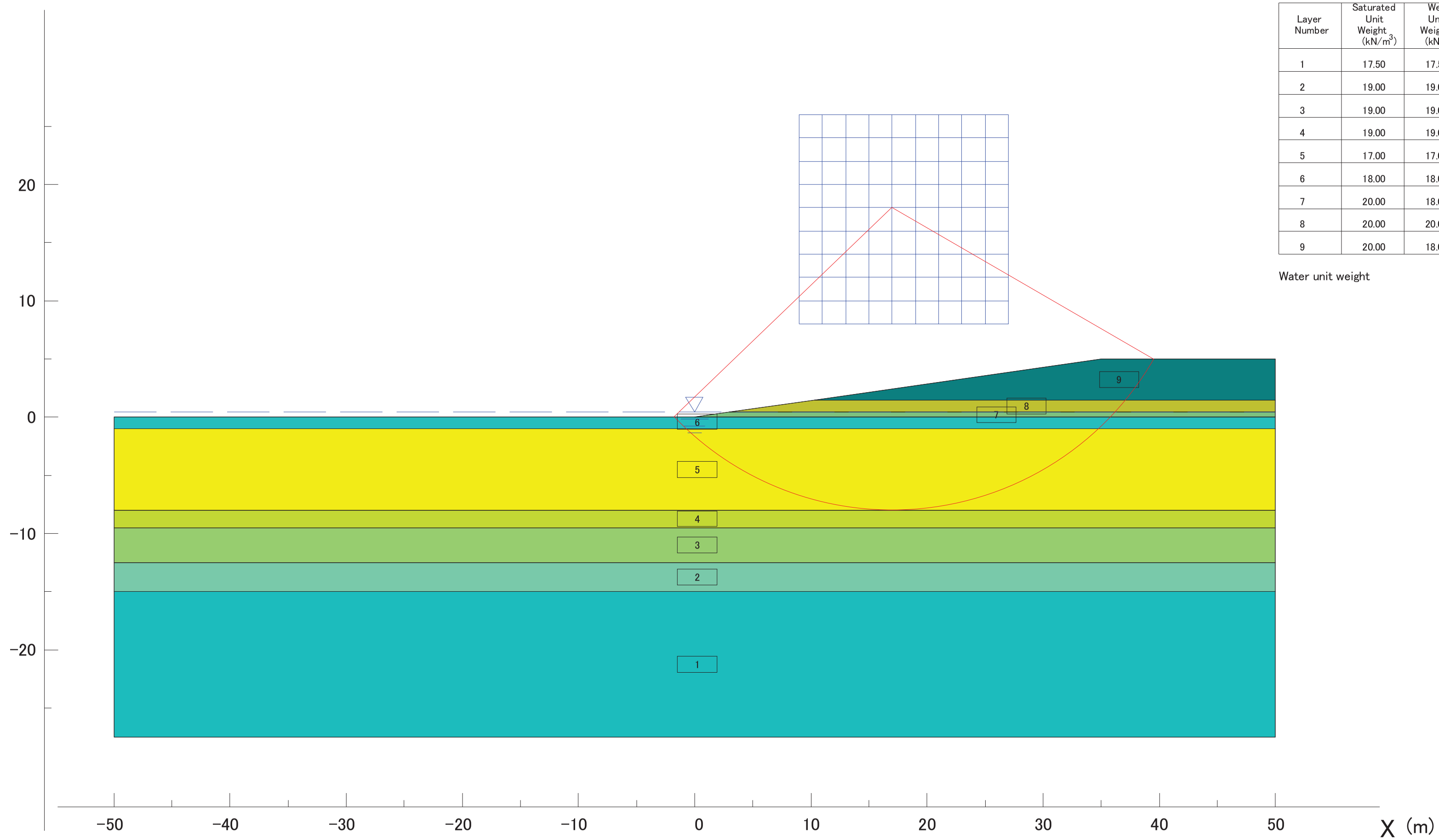
【Block-4】

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.190	
Center of arc	X	=	17.00	(m)
	Y	=	18.00	(m)
Radius	R	=	26.00	(m)
Resisting moment	M R	=	17834.3	(kNm)
Sliding moment	M D	=	14987.9	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	19.00	19.00	25.00	0.00	0.00	0.000	0.000
5	17.00	17.00	0.00	15.00	0.00	0.000	0.000
6	18.00	18.00	25.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

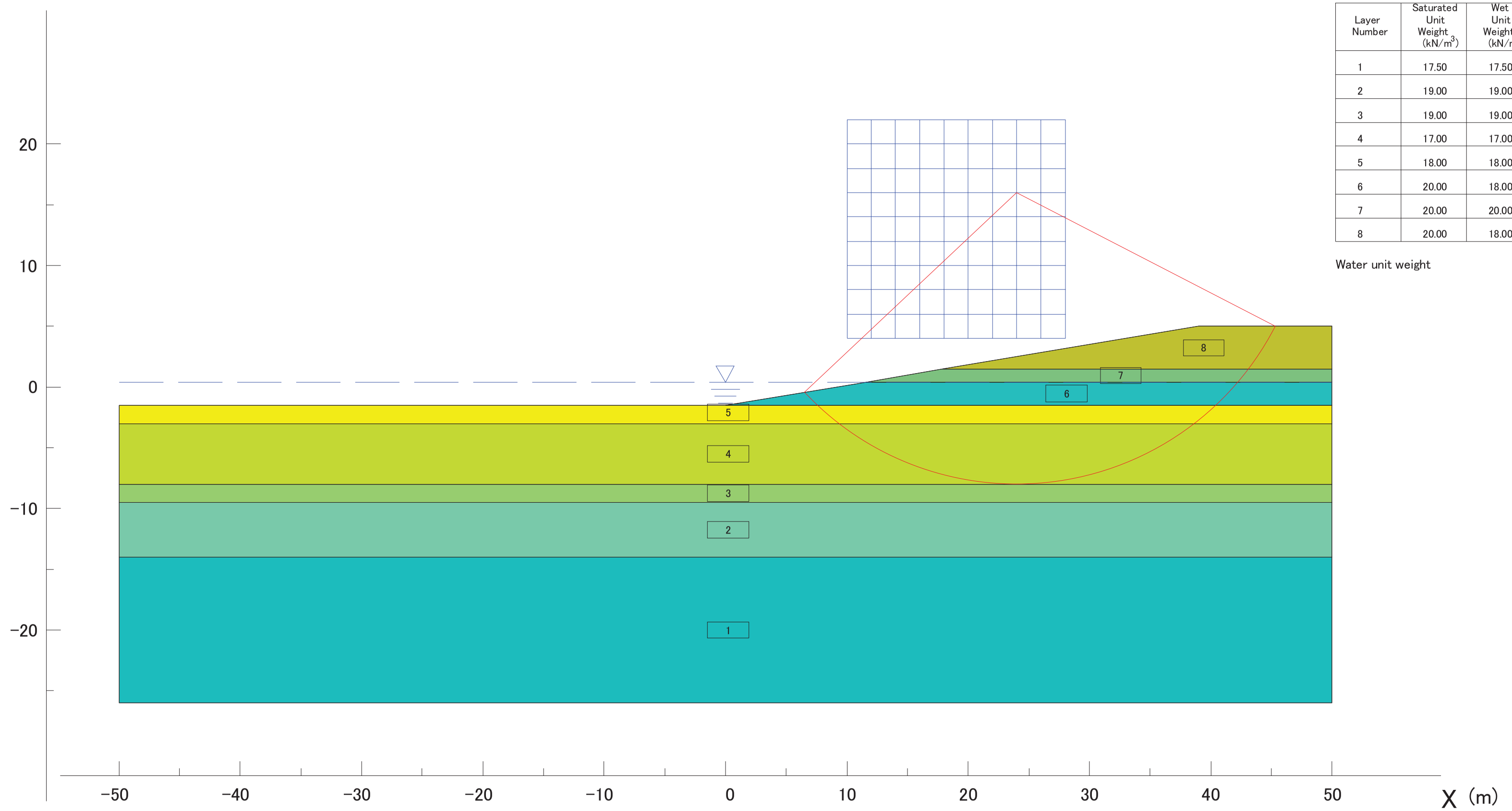
【Block−5】

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.104	
Center of arc	X	=	24.00	(m)
	Y	=	16.00	(m)
Radius	R	=	24.00	(m)
Resisting moment	M R	=	15880.4	(kNm)
Sliding moment	M D	=	14381.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	0.00	15.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

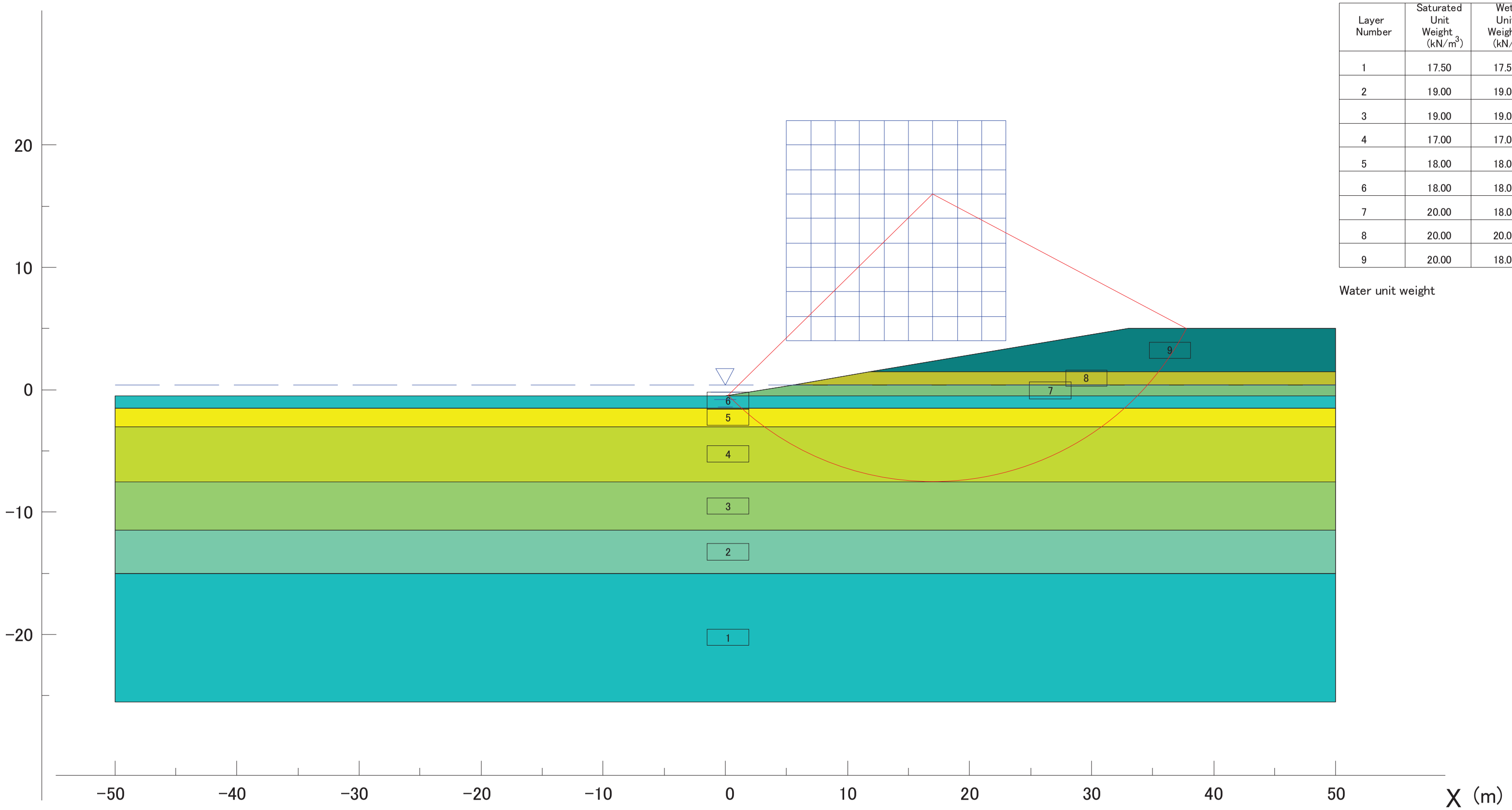
【Block-6】

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.118	
Center of arc	X	=	17.00	(m)
	Y	=	16.00	(m)
Radius	R	=	23.50	(m)
Resisting moment	M R	=	14842.6	(kNm)
Sliding moment	M D	=	13274.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	25.00	0.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	0.00	15.00	0.00	0.000	0.000
6	18.00	18.00	25.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

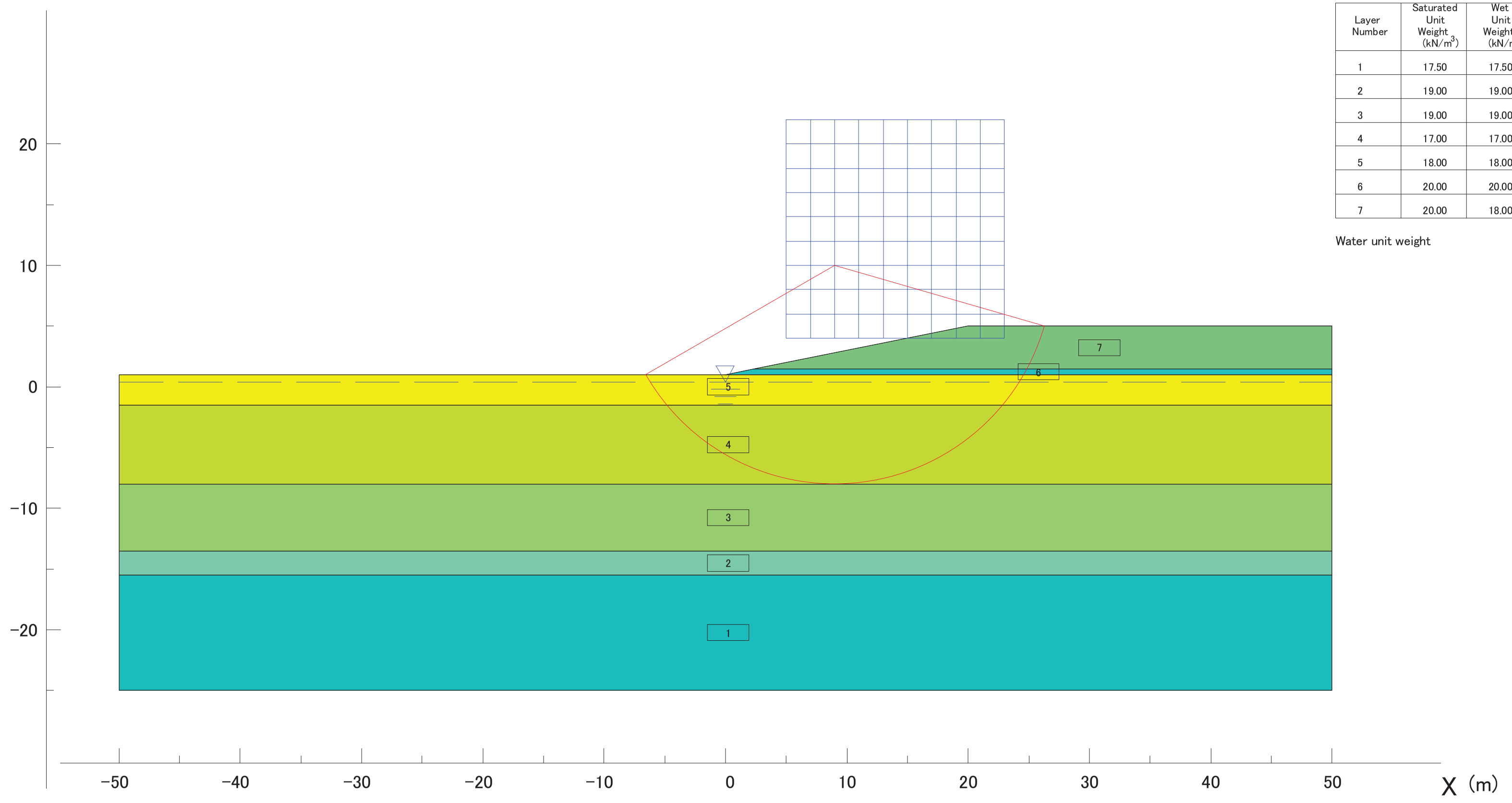
【Block−7】

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.117	
Center of arc	X	=	9.00	(m)
	Y	=	10.00	(m)
Radius	R	=	18.00	(m)
Resisting moment	M R	=	9721.5	(kNm)
Sliding moment	M D	=	8701.9	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	25.00	0.00	0.00	0.000	0.000
6	20.00	20.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

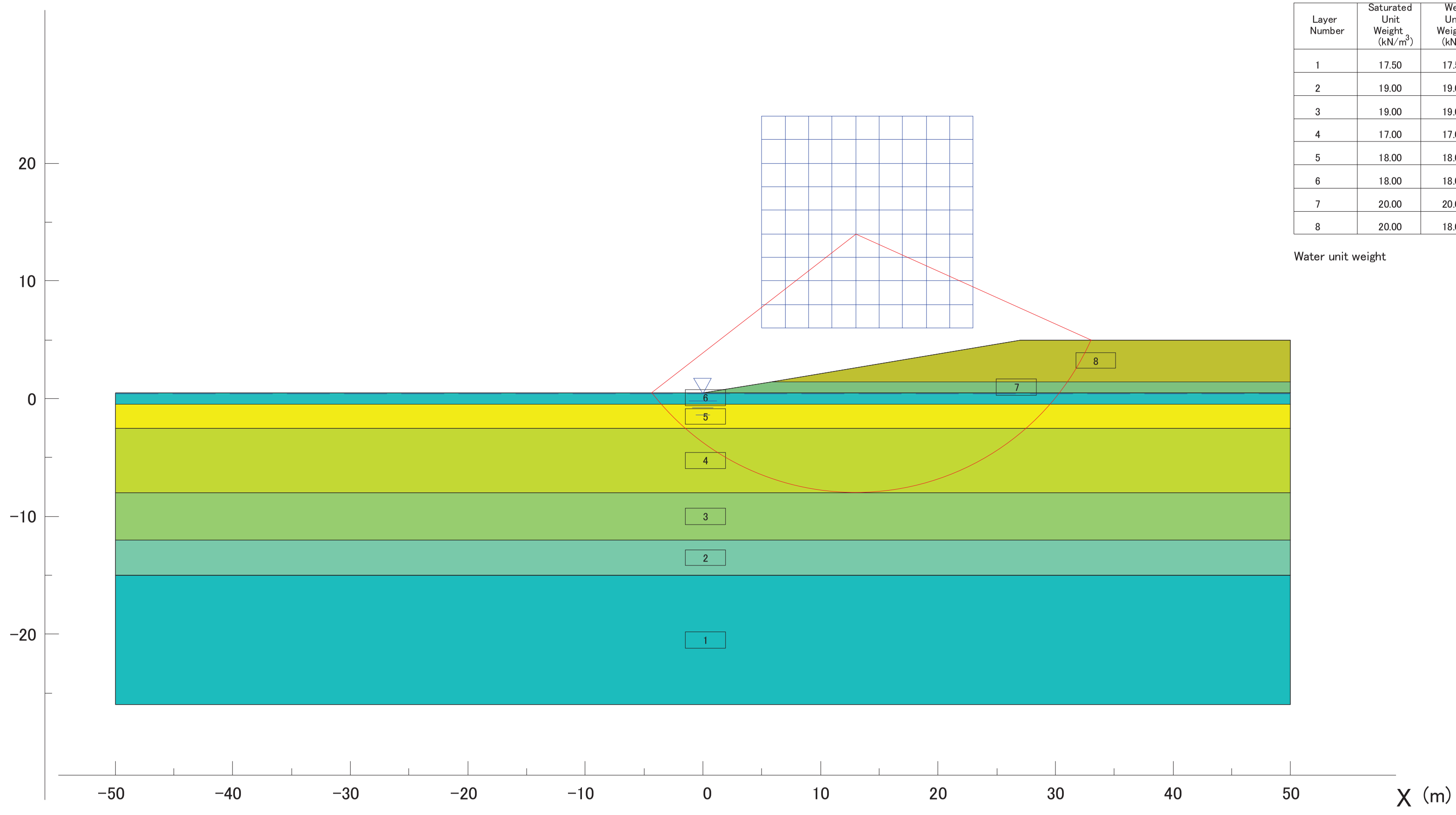
【Block−8】

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.128	
Center of arc	X	=	13.00	(m)
	Y	=	14.00	(m)
Radius	R	=	22.00	(m)
Resisting moment	M_R	=	13698.4	(kNm)
Sliding moment	M_D	=	12139.2	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	0.00	15.00	0.00	0.000	0.000
6	18.00	18.00	25.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

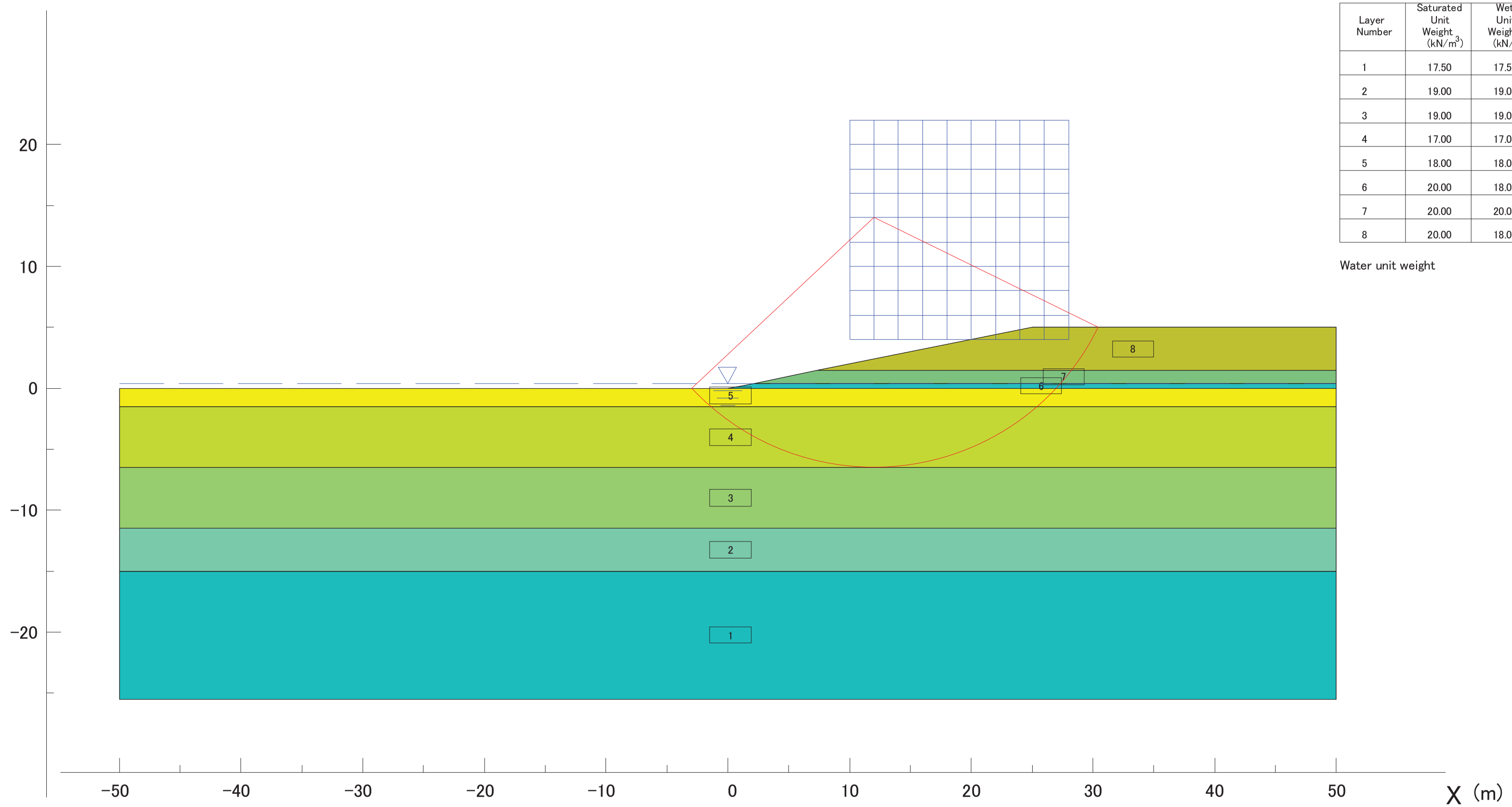
【Block-9】

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.100	
Center of arc	X	=	12.00	(m)
	Y	=	14.00	(m)
Radius	R	=	20.50	(m)
Resisting moment	M R	=	11570.2	(kNm)
Sliding moment	M D	=	10522.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	0.00	15.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

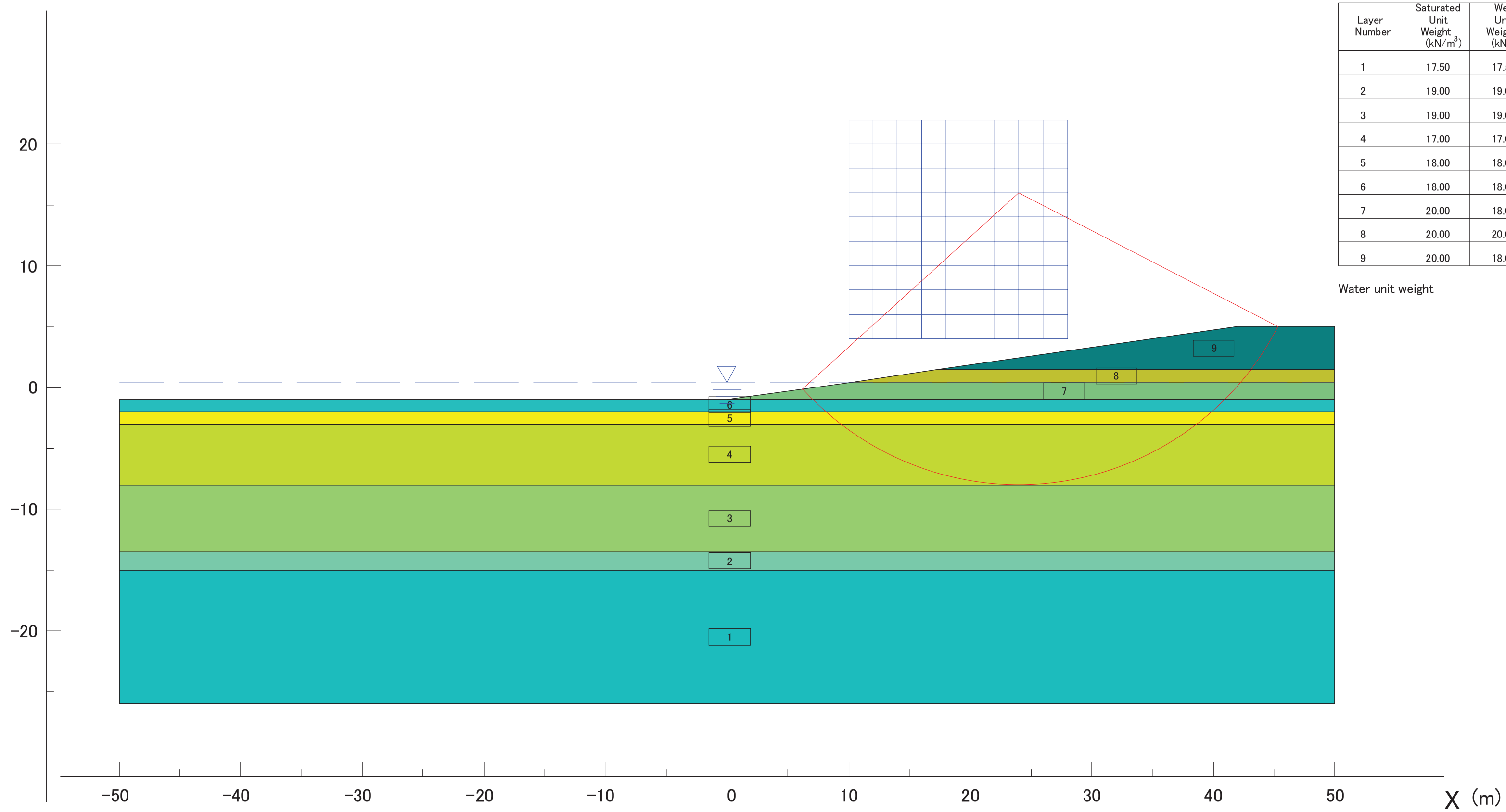
【Block-10】

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.174	
Center of arc	X	=	24.00	(m)
	Y	=	16.00	(m)
Radius	R	=	24.00	(m)
Resisting moment	M R	=	15412.9	(kNm)
Sliding moment	M D	=	13126.1	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	15.00	0.00	0.00	0.000	0.000
6	18.00	18.00	25.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

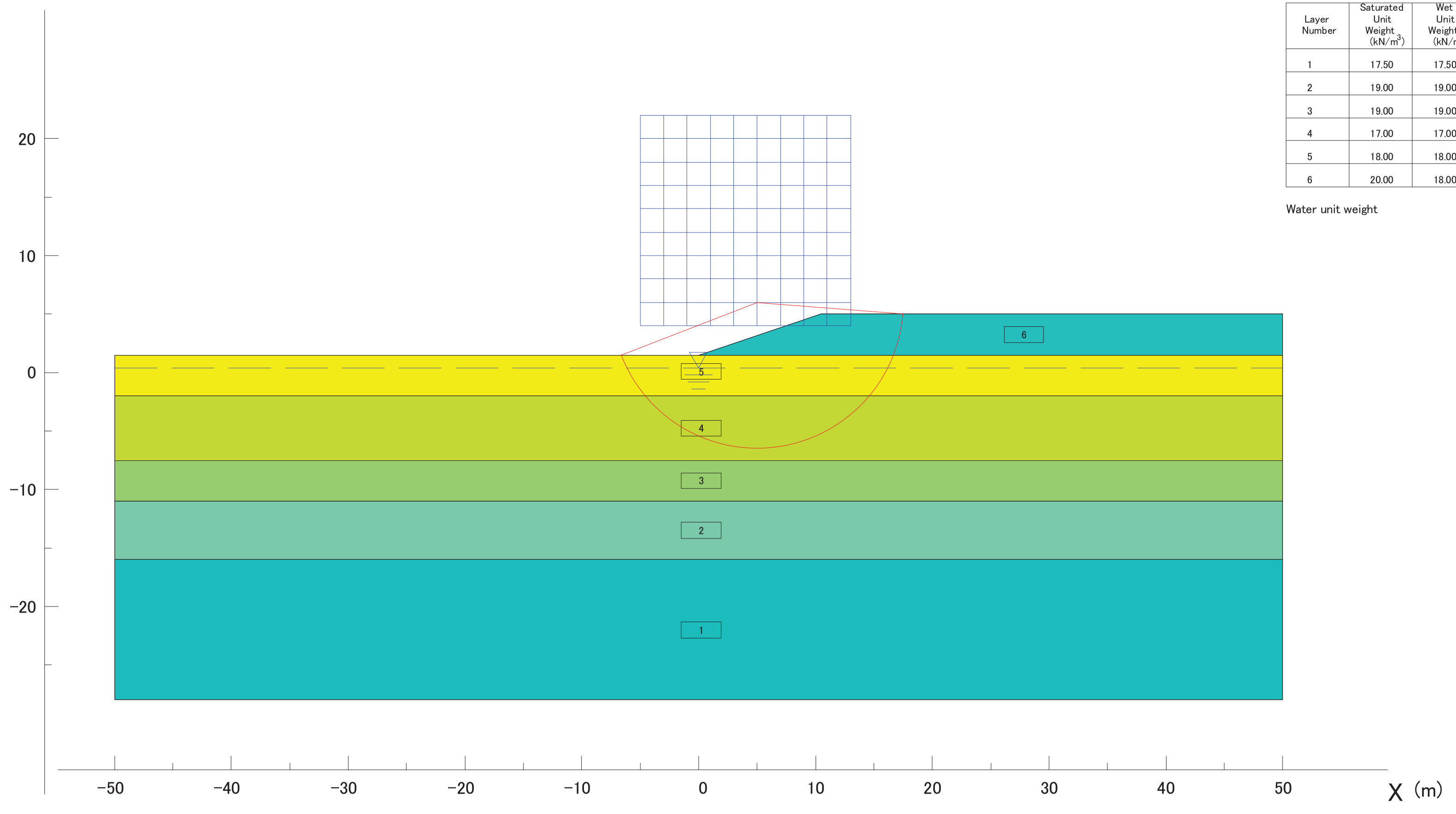
【Block-11】

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.122	
Center of arc	X	=	5.00	(m)
	Y	=	6.00	(m)
Radius	R	=	12.50	(m)
Resisting moment	M_R	=	4893.1	(kNm)
Sliding moment	M_D	=	4359.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	25.00	0.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	25.00	0.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

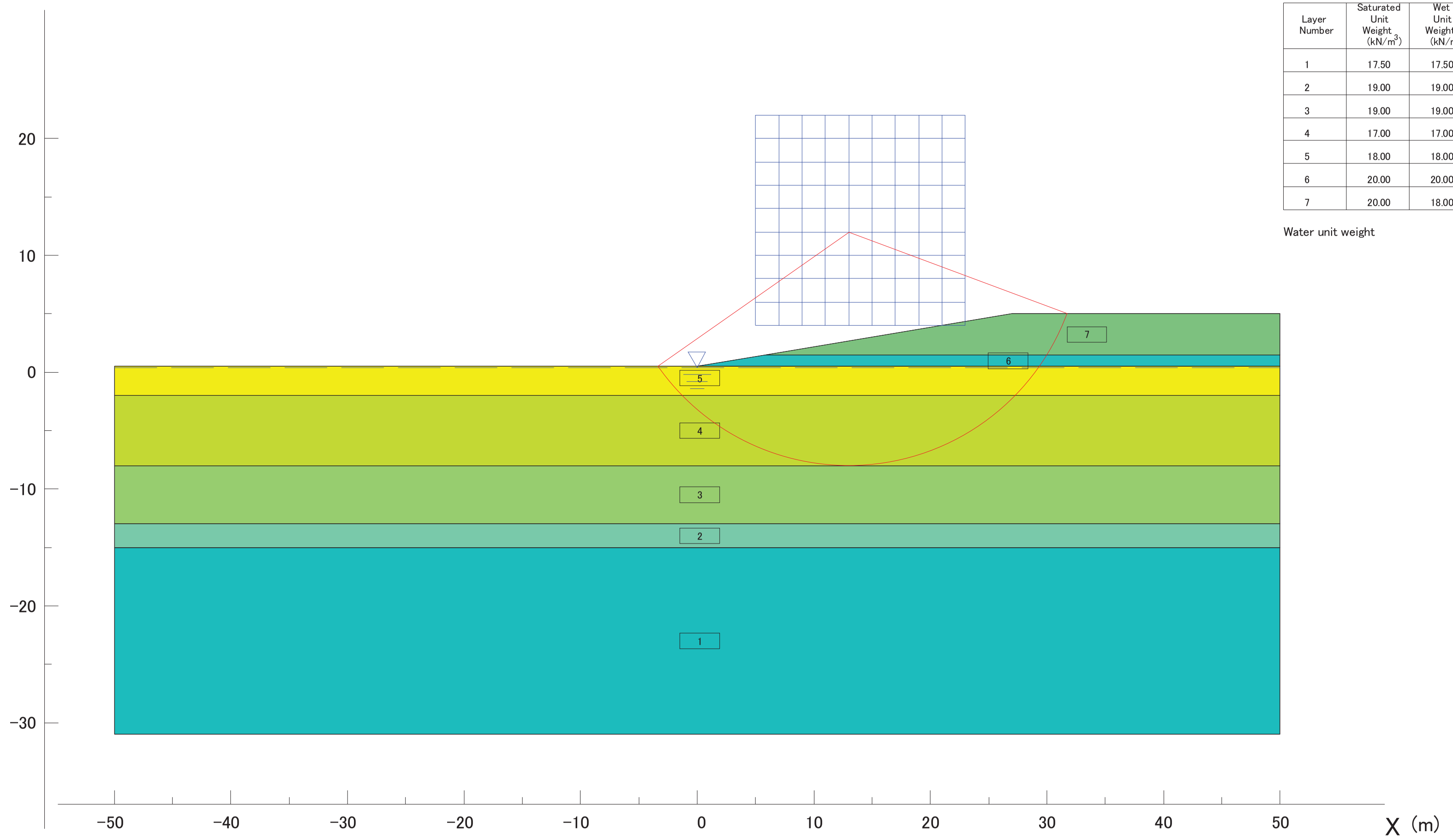
【Block-12】

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.109	
Center of arc	X	=	13.00	(m)
	Y	=	12.00	(m)
Radius	R	=	20.00	(m)
Resisting moment	M_R	=	11487.4	(kNm)
Sliding moment	M_D	=	10363.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	25.00	0.00	0.00	0.000	0.000
6	20.00	20.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

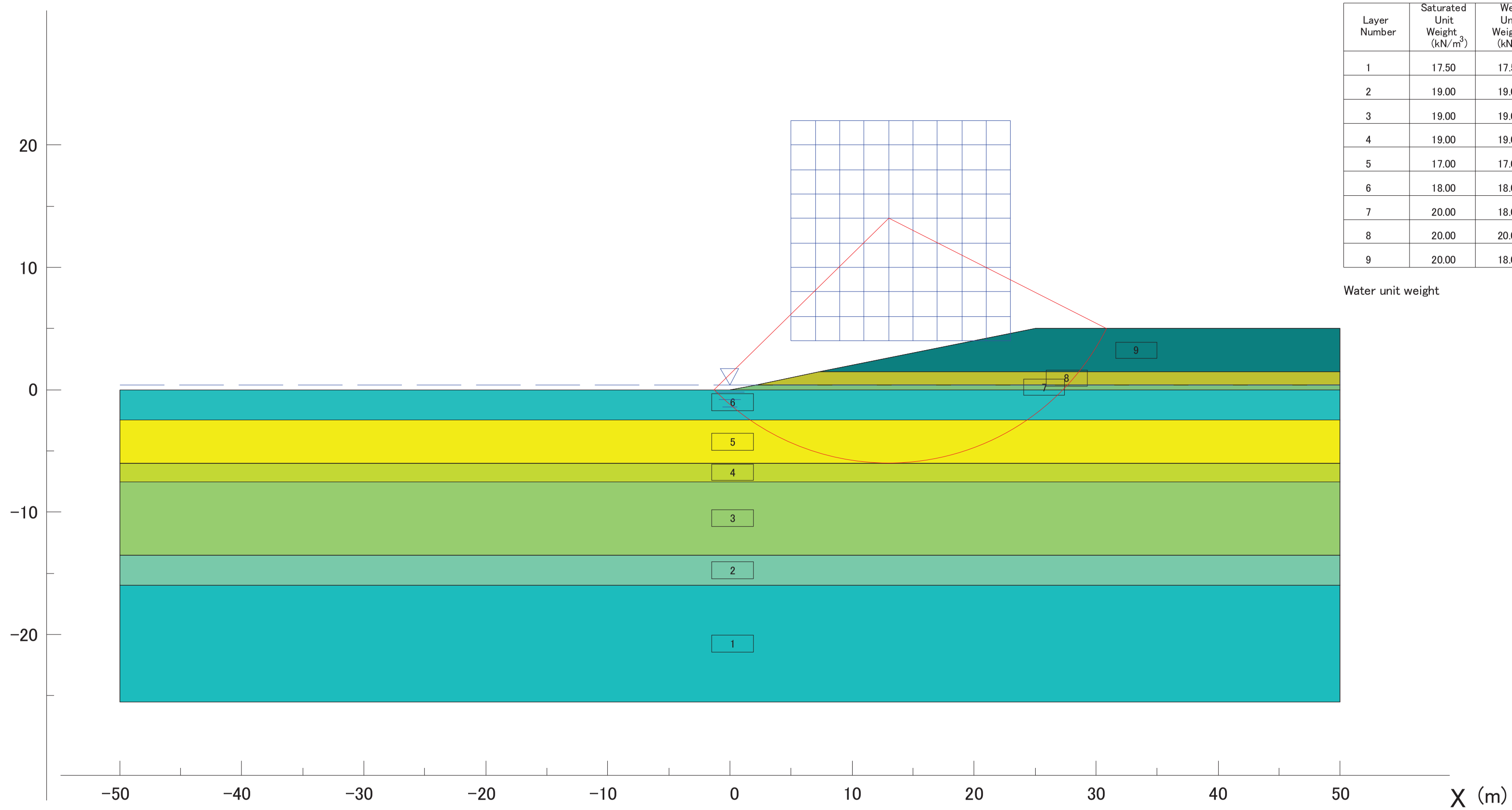
【Block−13】

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.124	
Center of arc	X	=	13.00	(m)
	Y	=	14.00	(m)
Radius	R	=	20.00	(m)
Resisting moment	M R	=	10841.2	(kNm)
Sliding moment	M D	=	9648.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	25.00	0.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	19.00	19.00	25.00	0.00	0.00	0.000	0.000
5	17.00	17.00	0.00	15.00	0.00	0.000	0.000
6	18.00	18.00	0.00	15.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

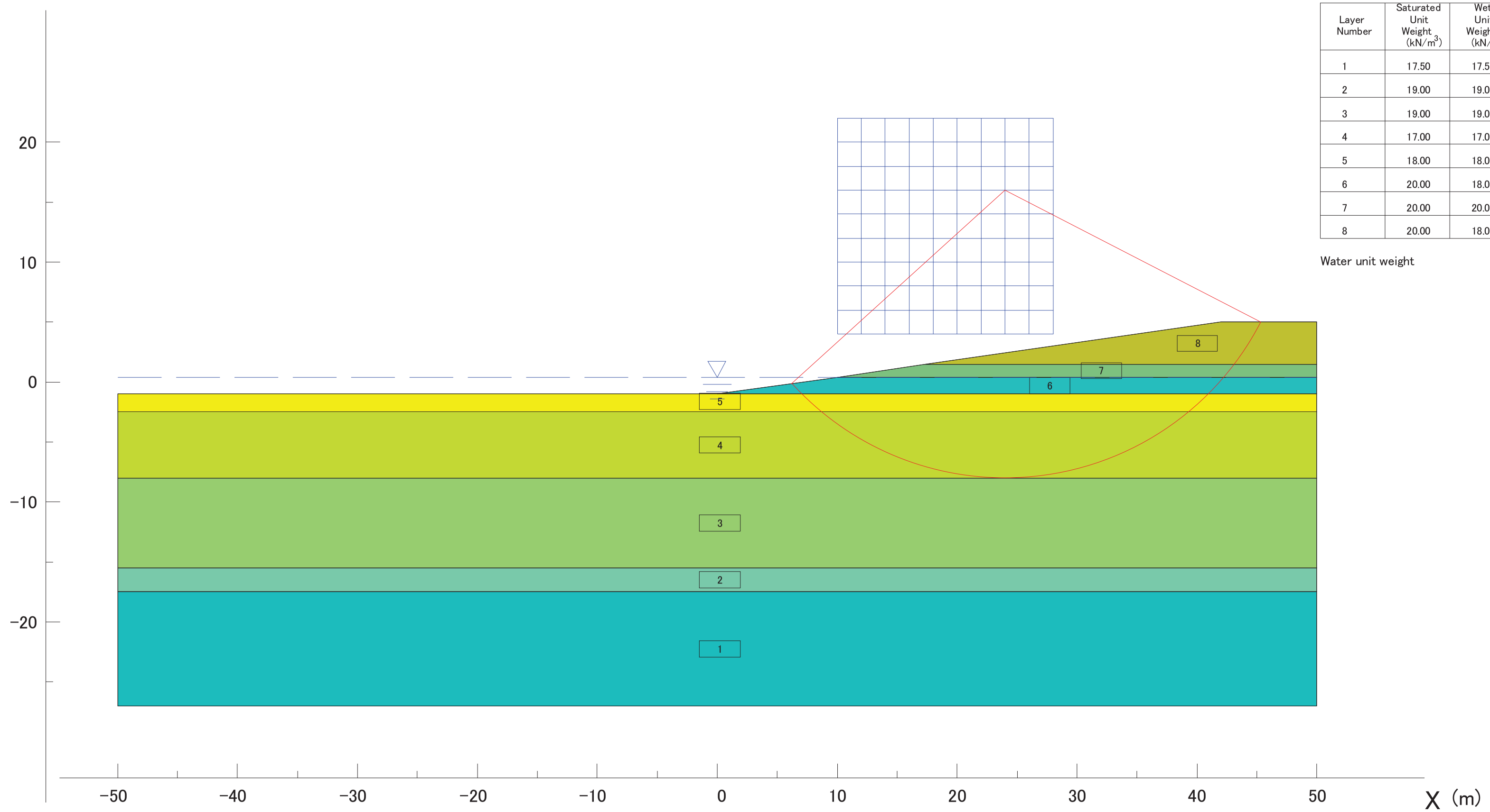
【Block-14】

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.207	
Center of arc	X	=	24.00	(m)
	Y	=	16.00	(m)
Radius	R	=	24.00	(m)
Resisting moment	M R	=	15839.1	(kNm)
Sliding moment	M D	=	13126.1	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	25.00	0.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	25.00	0.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

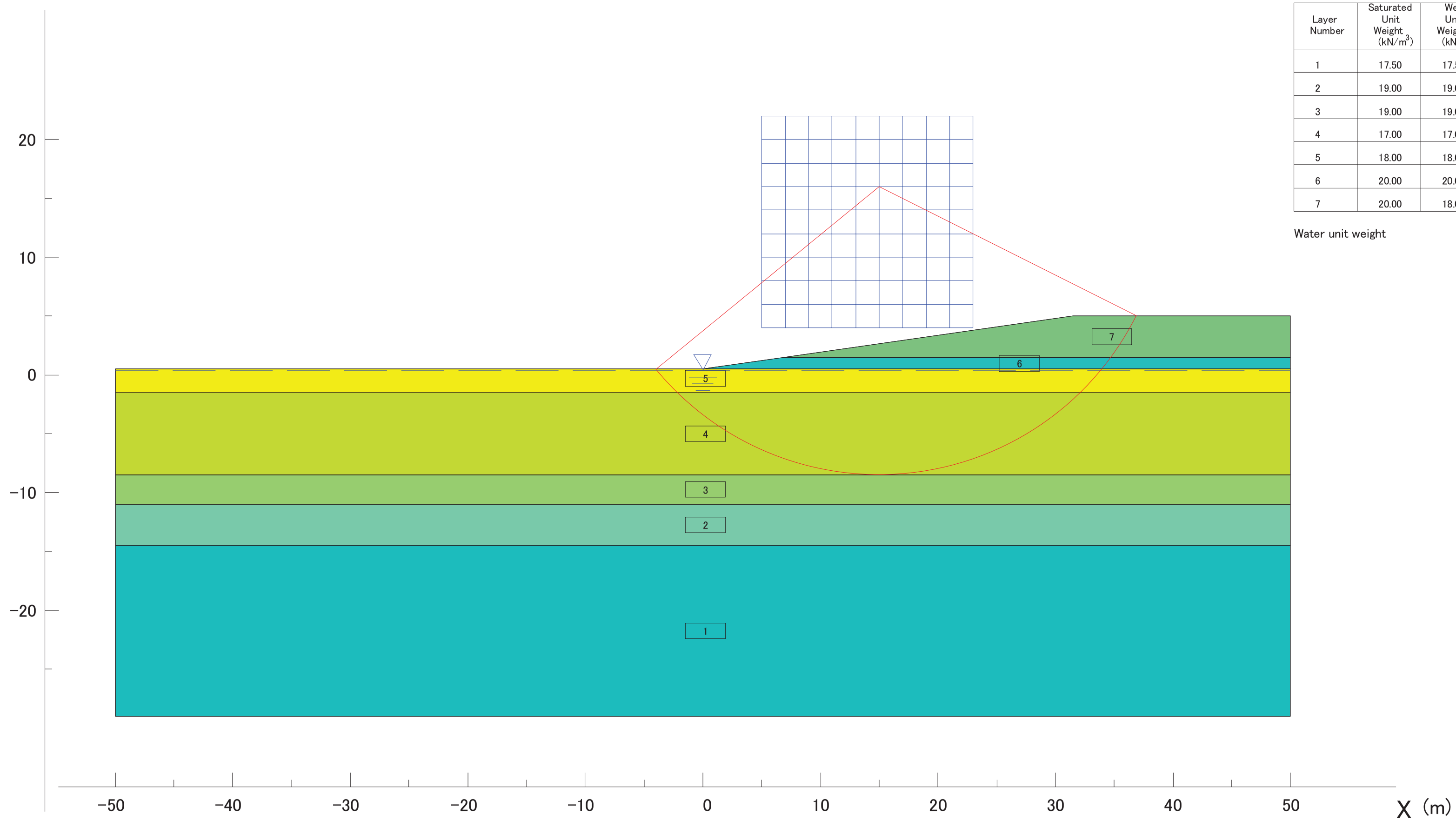
【Block-15】

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.175	
Center of arc	X	=	15.00	(m)
	Y	=	16.00	(m)
Radius	R	=	24.50	(m)
Resisting moment	M R	=	16431.0	(kNm)
Sliding moment	M D	=	13987.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	25.00	0.00	0.00	0.000	0.000
6	20.00	20.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

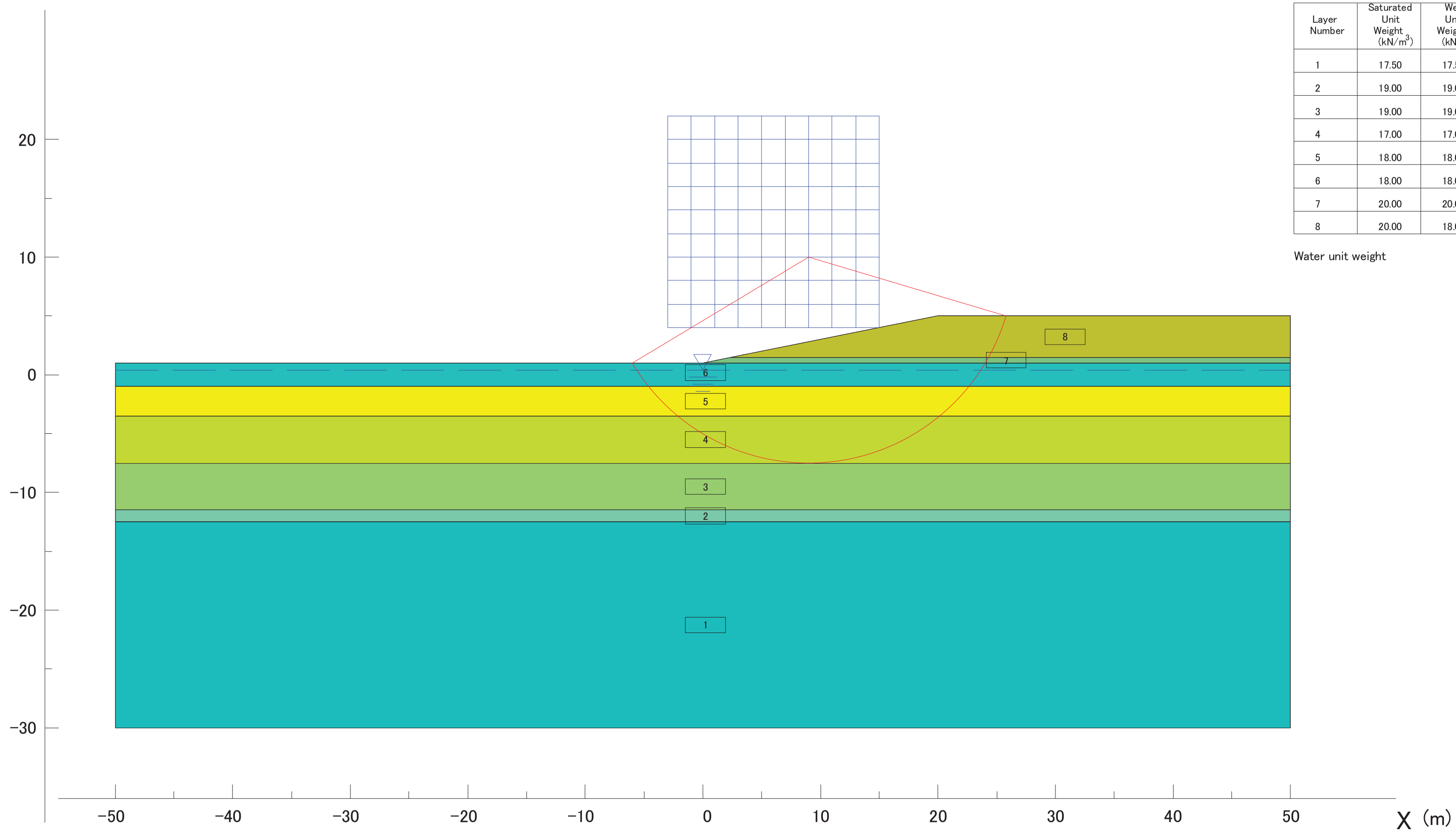
【Block-16】

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.137	
Center of arc	X	=	9.00	(m)
	Y	=	10.00	(m)
Radius	R	=	17.50	(m)
Resisting moment	M_R	=	9161.8	(kNm)
Sliding moment	M_D	=	8054.6	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.50	17.50	0.00	40.00	0.00	0.000	0.000
2	19.00	19.00	0.00	50.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.00	17.00	0.00	15.00	0.00	0.000	0.000
5	18.00	18.00	0.00	15.00	0.00	0.000	0.000
6	18.00	18.00	25.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

Phụ lục 7-2

Kết quả tính toán xử lý nền đất yếu cho khu vực đê chắn sóng và khu vực kè hạ lưu

Appendix 7-2

1) Location Map of Sections for Slope Stability and Consolidation Settlement Analysis at Inner Revetment and Outer Revetment A

2) Slope Stability Analysis Result for Inner Revetment

3) Settlement-Time Curves with PVD for Inner Revetment

4) Subsoil Improvement Procedure with PVD and Preload Method for Inner Revetment

5) Economical Comparison between PVD+Preload Method and Sand Replacement Method for Outer Revetment A

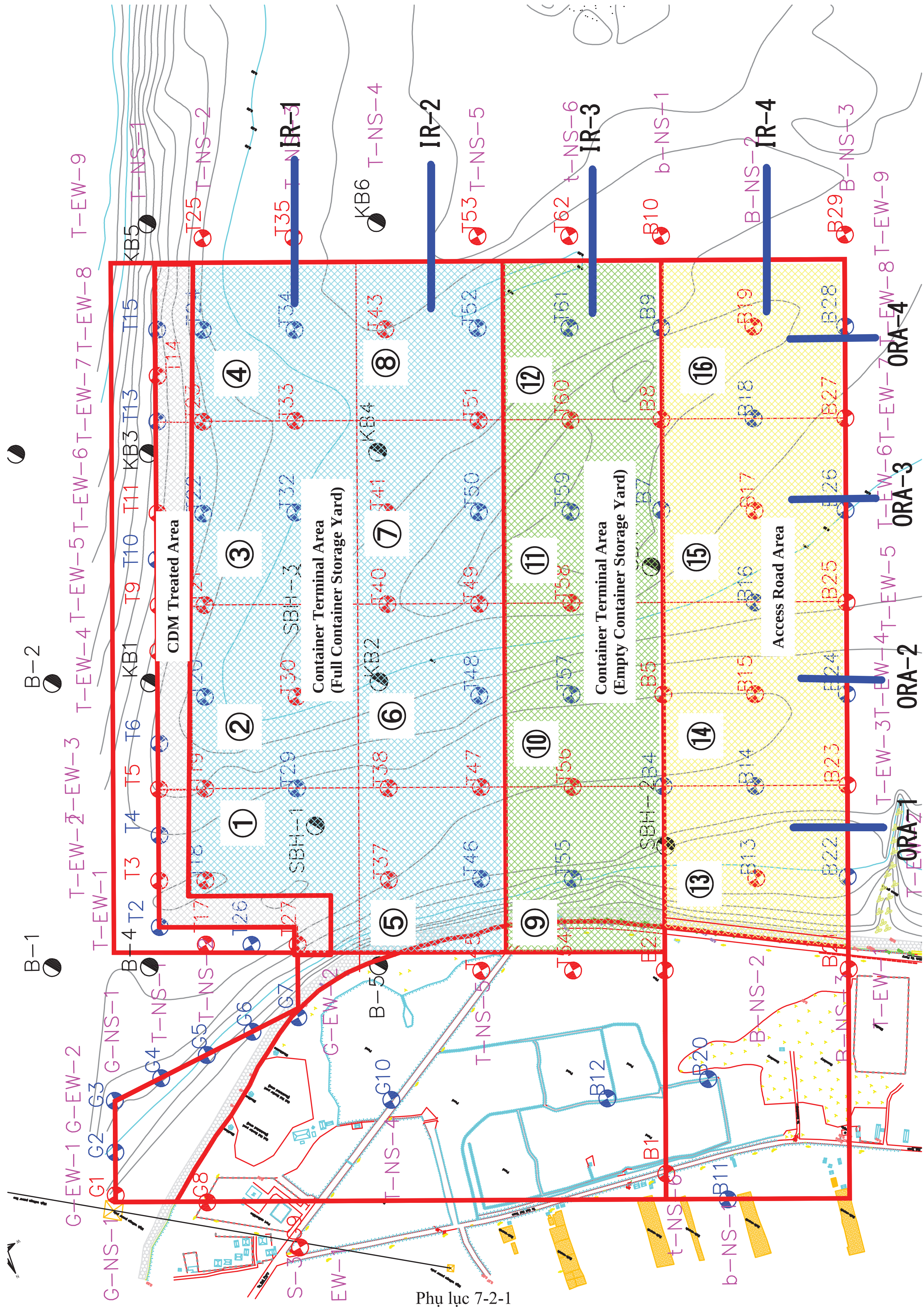
6) Slope Stability Analysis Result and Settlement-Time Curves with Sand Replacement Method for Outer Revetment A

7) Slope Stability Analysis Result for Outer Revetment A

8) Settlement-Time Curves with PVD for Outer Revetment A

9) Subsoil Improvement Procedure with PVD and Preload Method for Outer Revetment A

1) Location Map of Sections for Slope Stability and Consolidation Settlement Analysis at Inner Revetment and Outer Revetment A


CDM Treated Area
Container Terminal Area
(Full Container Storage Yard)
Container Terminal Area
(Empty Container Storage Yard)
Access Road Area
IR-1
IR-2
IR-3
IR-4
ORA-1
ORA-2
ORA-3
ORA-4

Phụ lục 7-2-1

2) Slope Stability Analysis Result for Inner Revetment

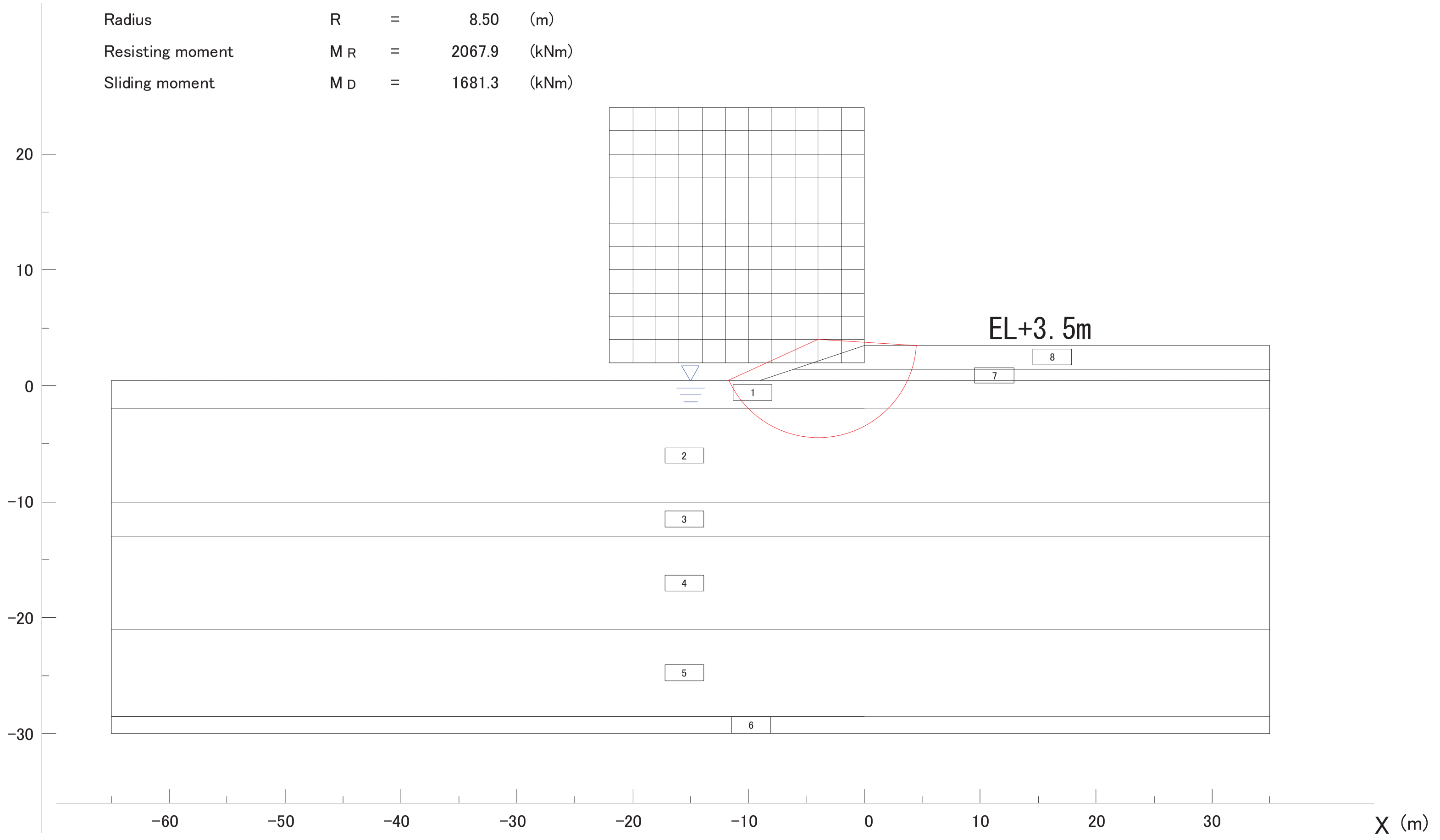
Inner Revetment-1 (1st)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.230	
Center of arc	X	=	−4.00	(m)
	Y	=	4.00	(m)
Radius	R	=	8.50	(m)
Resisting moment	M_R	=	2067.9	(kNm)
Sliding moment	M_D	=	1681.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

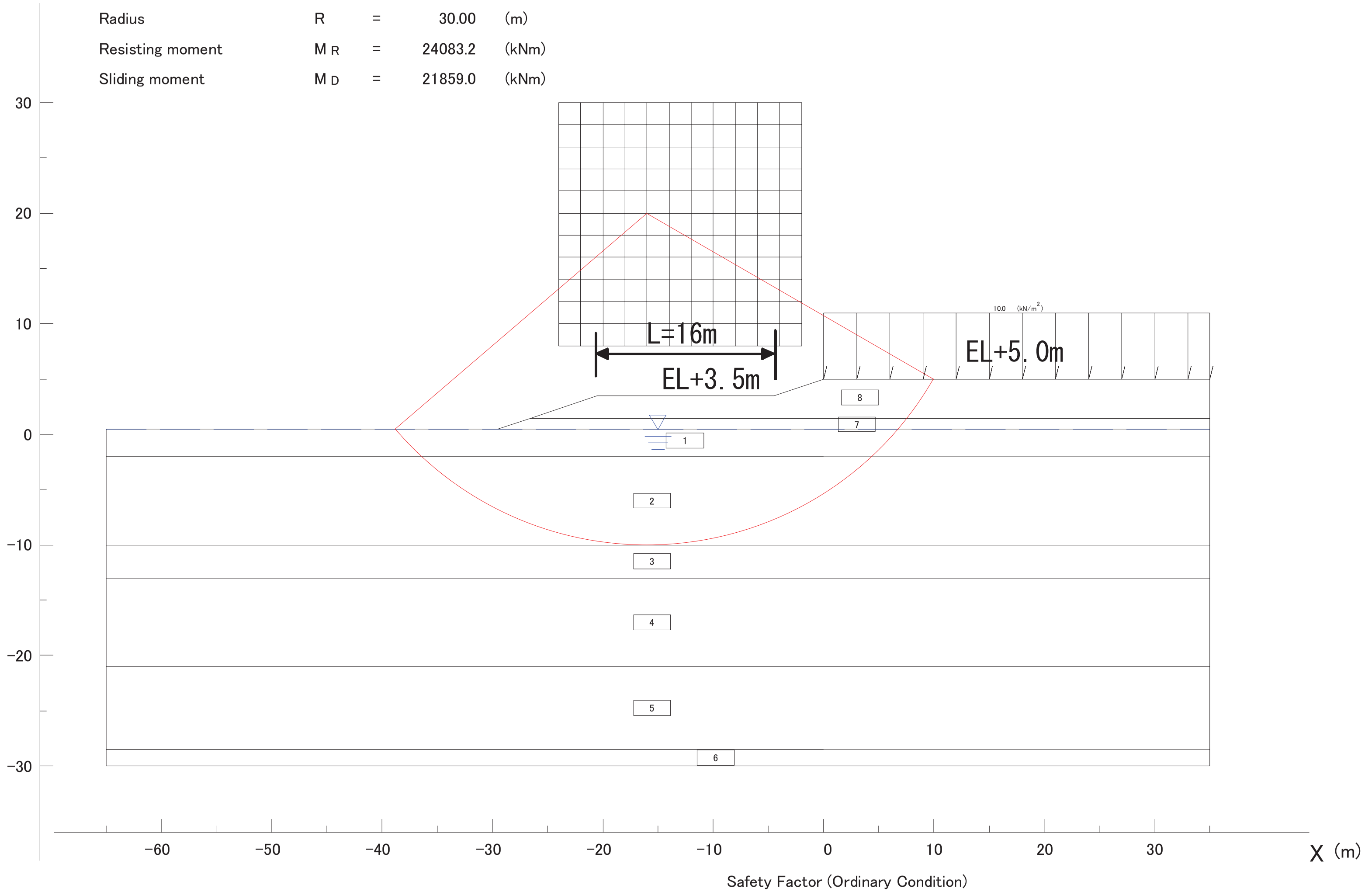
Inner Revetment-1 (2nd)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.102	
Center of arc	X	=	−16.00	(m)
	Y	=	20.00	(m)
Radius	R	=	30.00	(m)
Resisting moment	M_R	=	24083.2	(kNm)
Sliding moment	M_D	=	21859.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



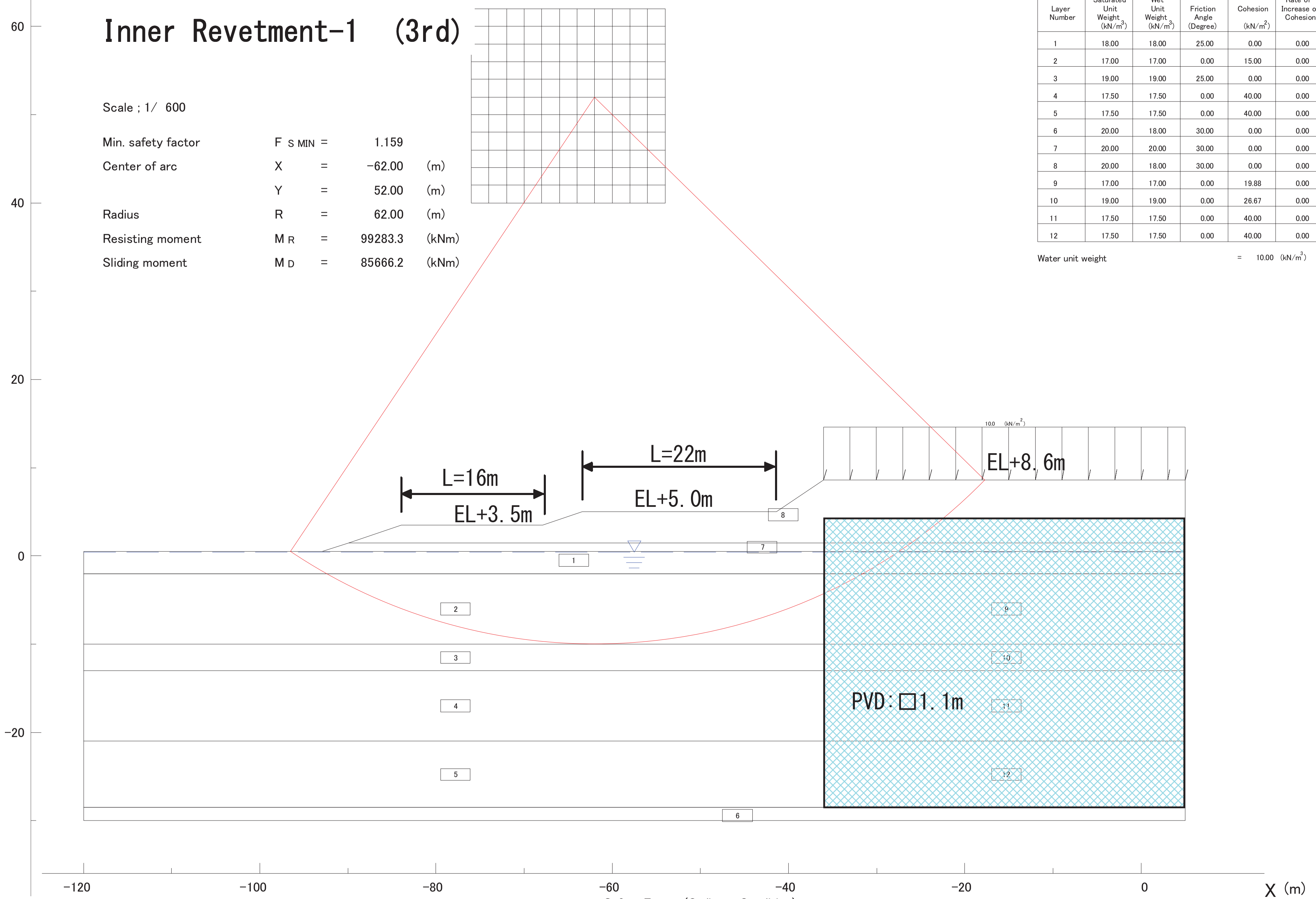
Inner Revetment-1 (3rd)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.159	
Center of arc	X	=	−62.00	(m)
	Y	=	52.00	(m)
Radius	R	=	62.00	(m)
Resisting moment	M R	=	99283.3	(kNm)
Sliding moment	M D	=	85666.2	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000
9	17.00	17.00	0.00	19.88	0.00	0.000	0.000
10	19.00	19.00	0.00	26.67	0.00	0.000	0.000
11	17.50	17.50	0.00	40.00	0.00	0.000	0.000
12	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

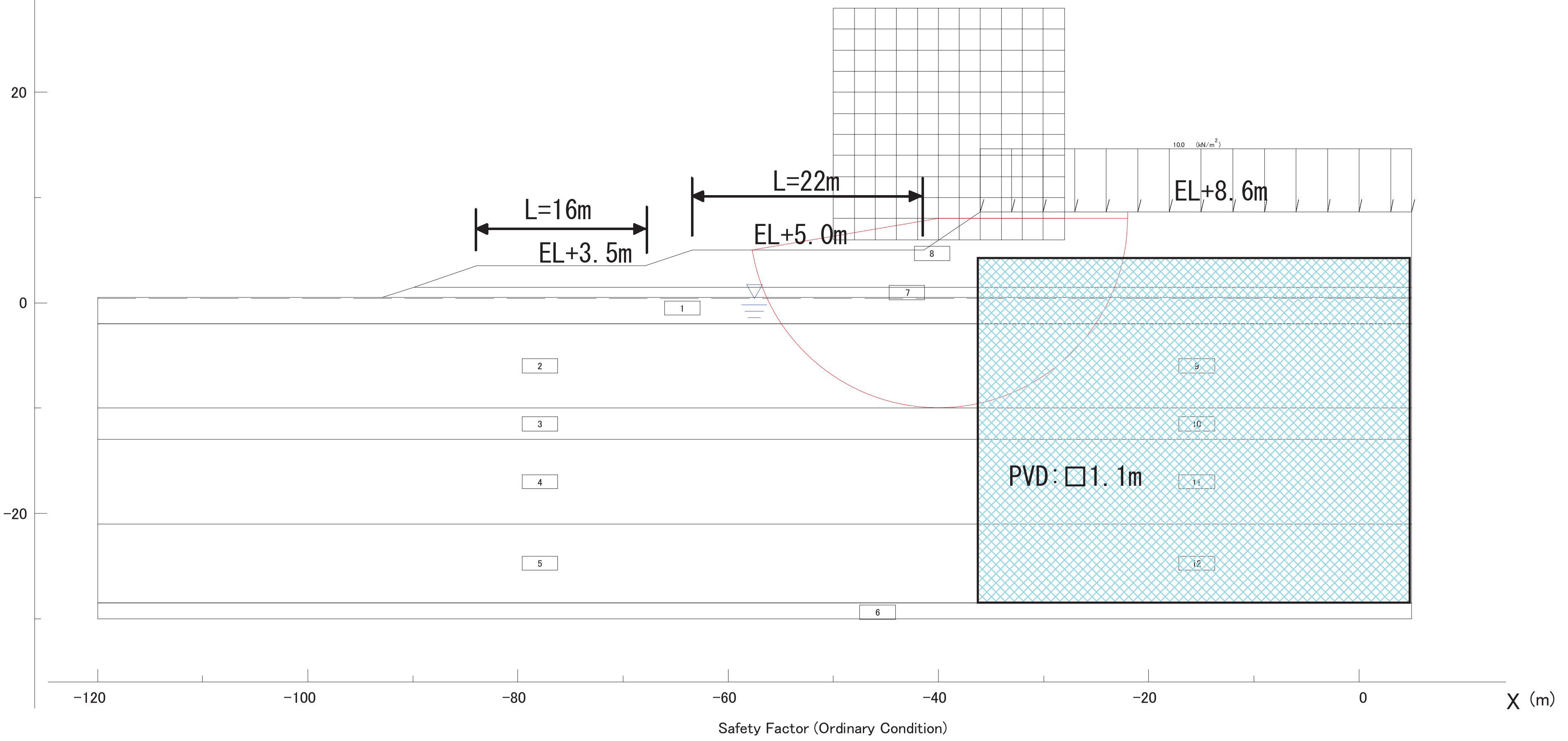
Inner Revetment-1 (3rd)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.100	
Center of arc	X	=	-40.00	(m)
	Y	=	8.00	(m)
Radius	R	=	18.00	(m)
Resisting moment	M_R	=	13001.1	(kNm)
Sliding moment	M_D	=	11821.8	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000
9	17.00	17.00	0.00	19.88	0.00	0.000	0.000
10	19.00	19.00	0.00	26.67	0.00	0.000	0.000
11	17.50	17.50	0.00	40.00	0.00	0.000	0.000
12	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



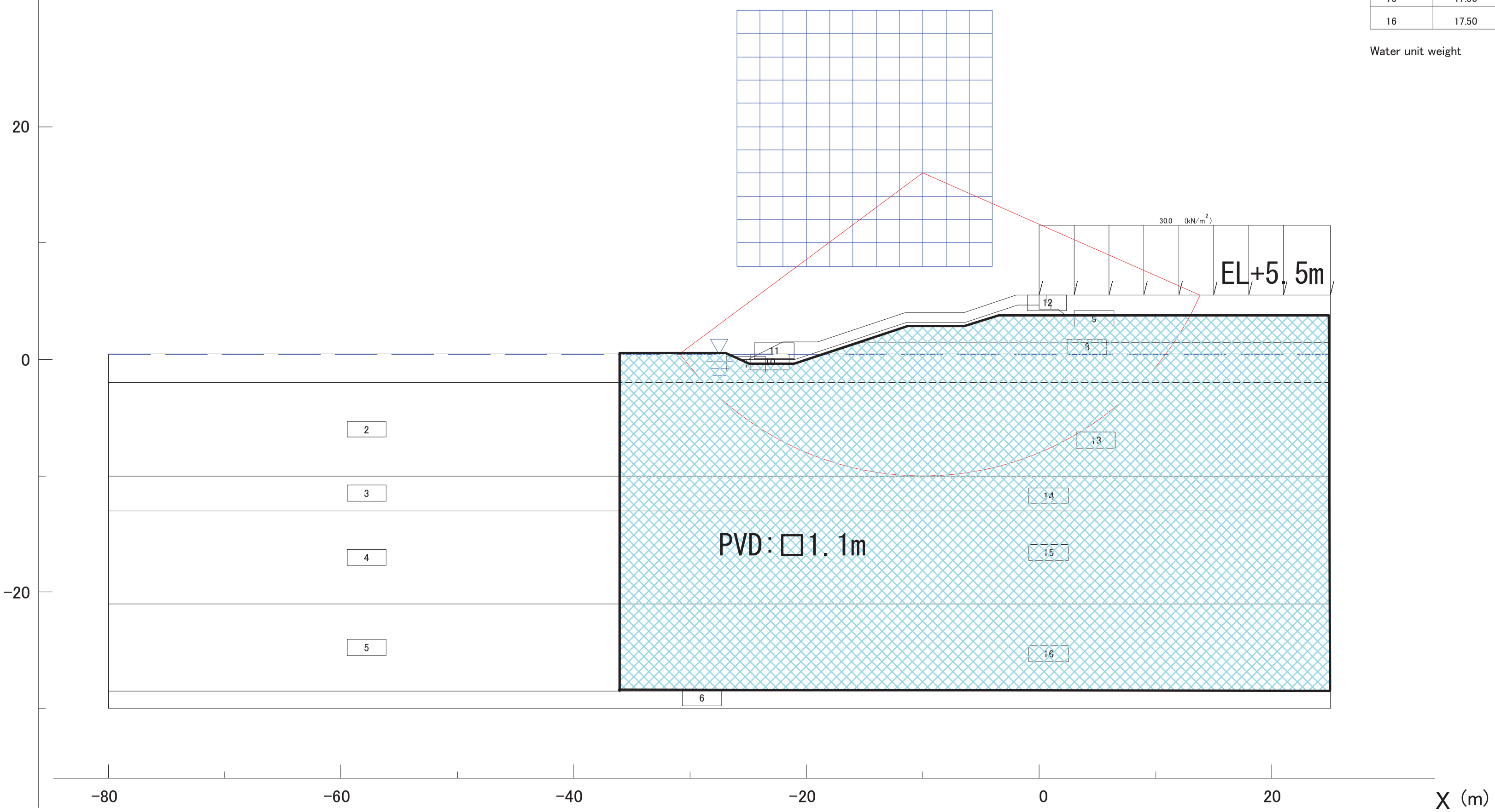
Inner Revetment-1 (After completion of Revetment Construction)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.318	
Center of arc	X	=	−10.00	(m)
	Y	=	16.00	(m)
Radius	R	=	26.00	(m)
Resisting moment	M_R	=	36201.2	(kNm)
Sliding moment	M_D	=	27459.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	17.00	17.00	0.00	30.42	0.00	0.000	0.000
14	19.00	19.00	0.00	35.22	0.00	0.000	0.000
15	17.50	17.50	0.00	44.38	0.00	0.000	0.000
16	17.50	17.50	0.00	43.46	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

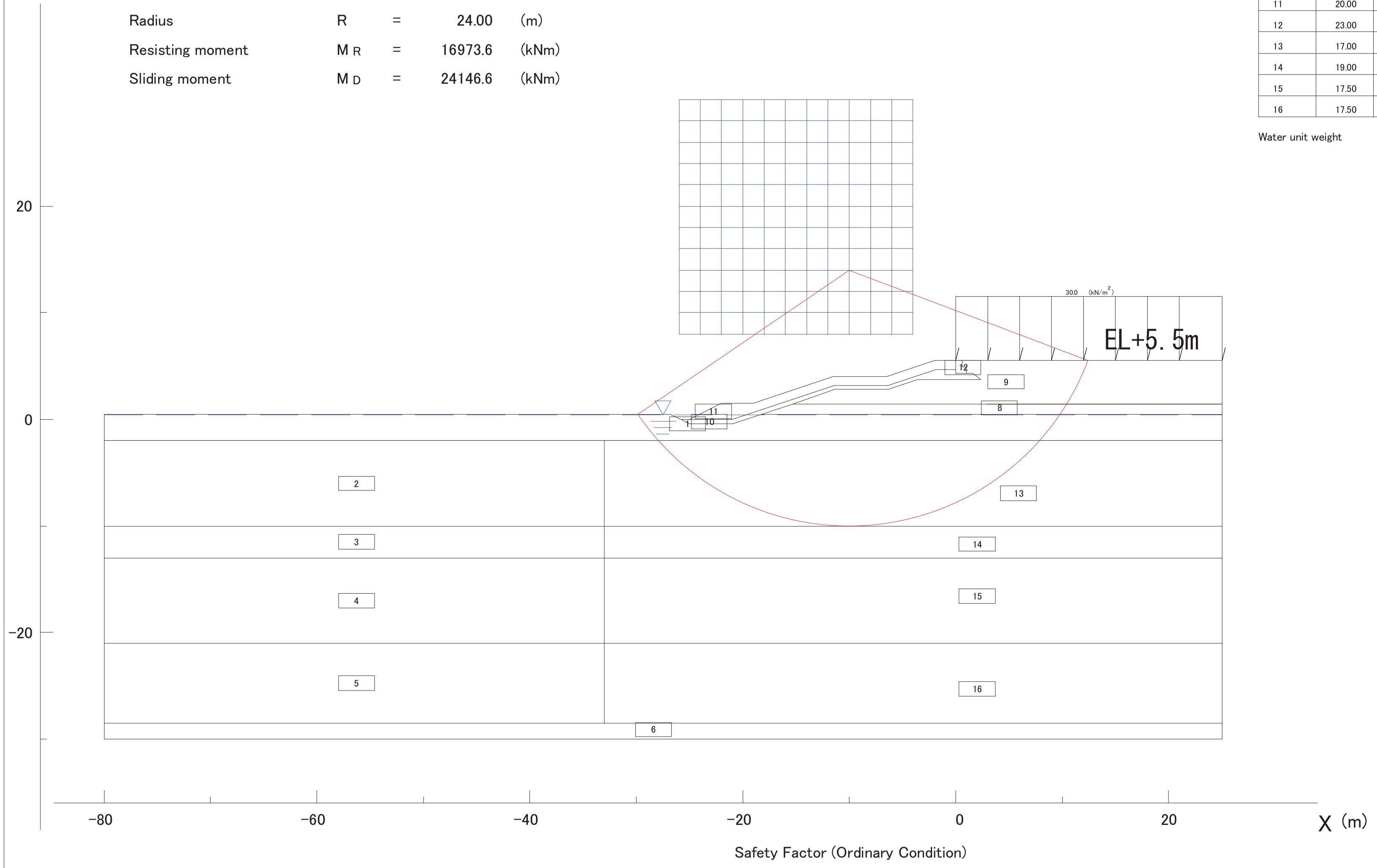
Inner Revetment-1 (Without Subsoil Improvement)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	0.703	
Center of arc	X	=	−10.00	(m)
	Y	=	14.00	(m)
Radius	R	=	24.00	(m)
Resisting moment	M_R	=	16973.6	(kNm)
Sliding moment	M_D	=	24146.6	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	17.00	17.00	0.00	15.00	0.00	0.000	0.000
14	19.00	19.00	0.00	25.00	0.00	0.000	0.000
15	17.50	17.50	0.00	40.00	0.00	0.000	0.000
16	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)

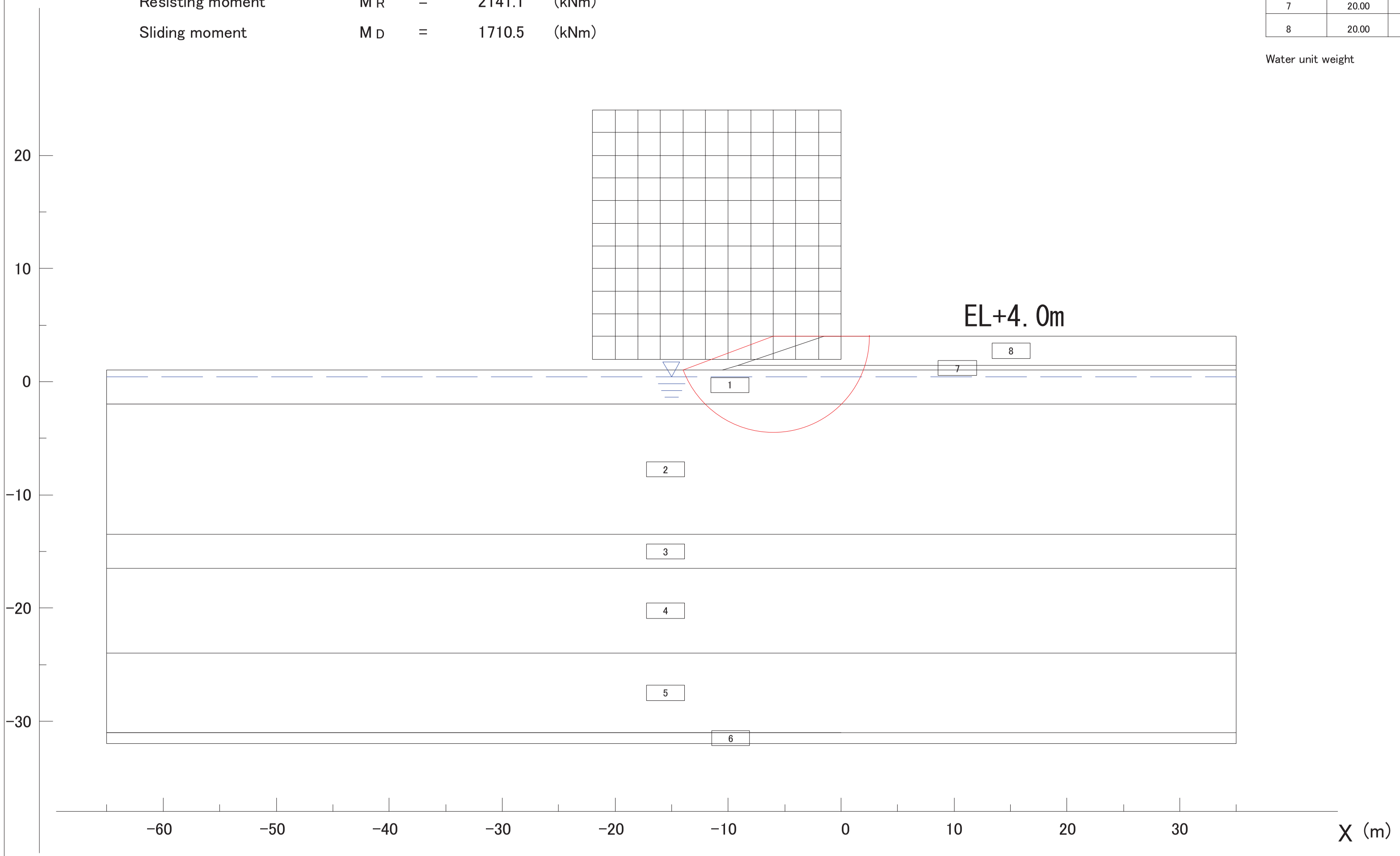


Inner Revetment-2 (1st)

Min. safety factor	$F_{S\,MIN}$	=	1.252	
Center of arc	X	=	-6.00	(m)
	Y	=	4.00	(m)
Radius	R	=	8.50	(m)
Resisting moment	M_R	=	2141.1	(kNm)
Sliding moment	M_D	=	1710.5	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



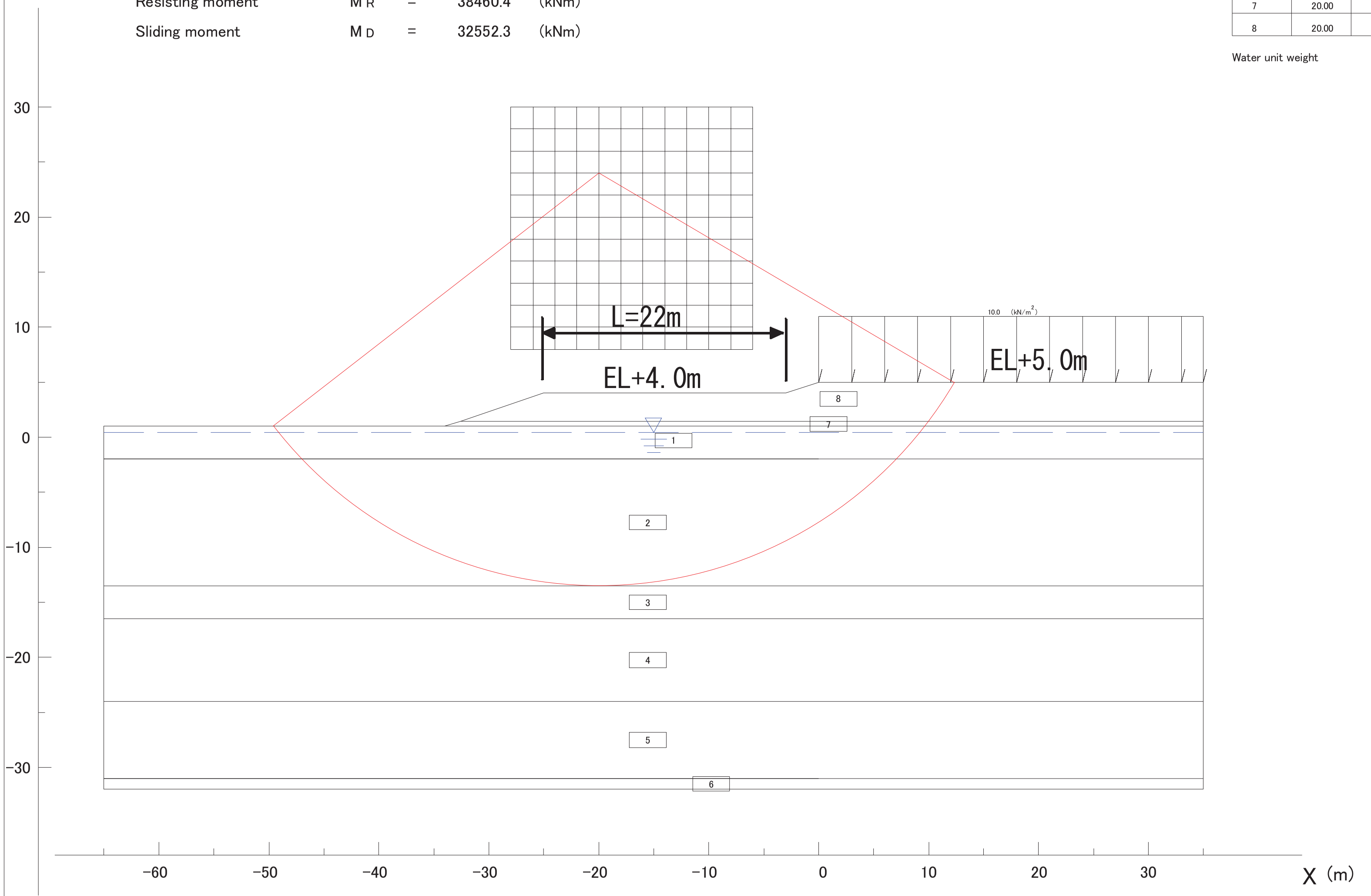
Safety Factor (Ordinary Condition)

Inner Revetment-2 (2nd)

Min. safety factor	$F_{S\,MIN}$	=	1.181	
Center of arc	X	=	-20.00	(m)
	Y	=	24.00	(m)
Radius	R	=	37.50	(m)
Resisting moment	M_R	=	38460.4	(kNm)
Sliding moment	M_D	=	32552.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



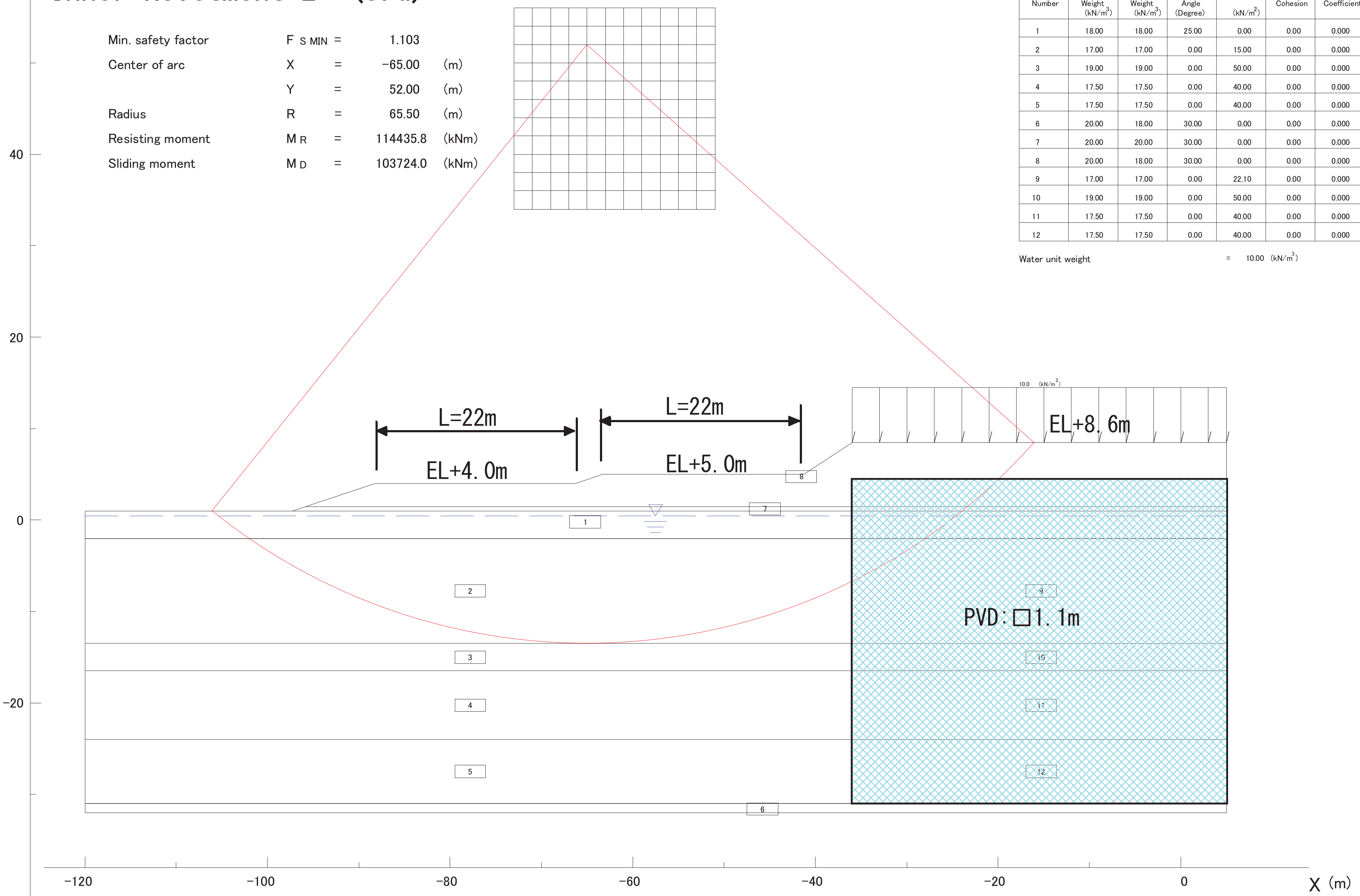
Safety Factor (Ordinary Condition)

Inner Revetment-2 (3rd)

Min. safety factor	$F_{S\,MIN}$	=	1.103	
Center of arc	X	=	−65.00	(m)
	Y	=	52.00	(m)
Radius	R	=	65.50	(m)
Resisting moment	M_R	=	114435.8	(kNm)
Sliding moment	M_D	=	103724.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000
9	17.00	17.00	0.00	22.10	0.00	0.000	0.000
10	19.00	19.00	0.00	50.00	0.00	0.000	0.000
11	17.50	17.50	0.00	40.00	0.00	0.000	0.000
12	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



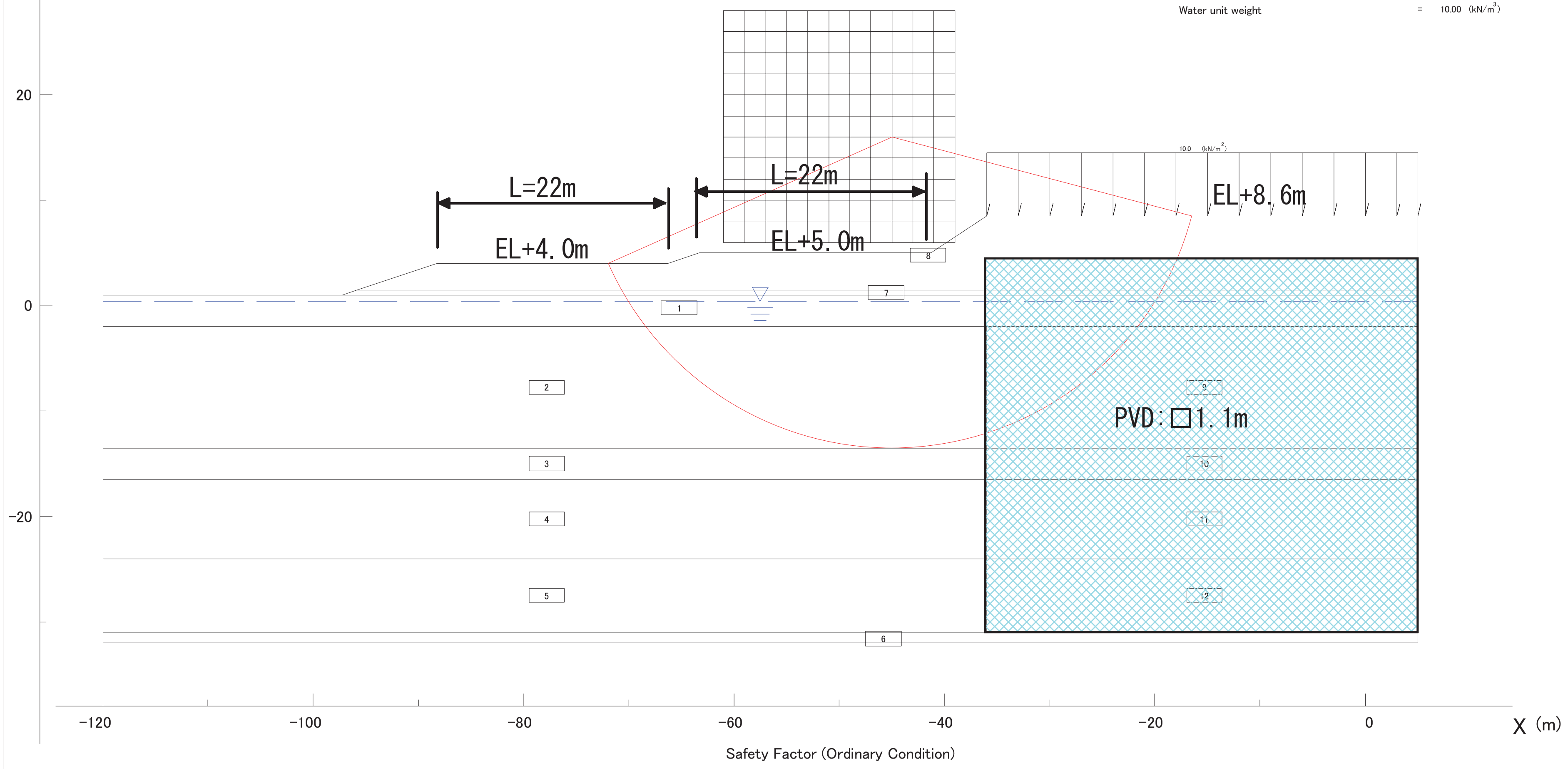
Safety Factor (Ordinary Condition)

Inner Revetment-2 (3rd)

Min. safety factor	$F_{S\,MIN}$	=	1.105	
Center of arc	X	=	−45.00	(m)
	Y	=	16.00	(m)
Radius	R	=	29.50	(m)
Resisting moment	M_R	=	33290.7	(kNm)
Sliding moment	M_D	=	30119.2	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000
9	17.00	17.00	0.00	22.10	0.00	0.000	0.000
10	19.00	19.00	0.00	50.00	0.00	0.000	0.000
11	17.50	17.50	0.00	40.00	0.00	0.000	0.000
12	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)

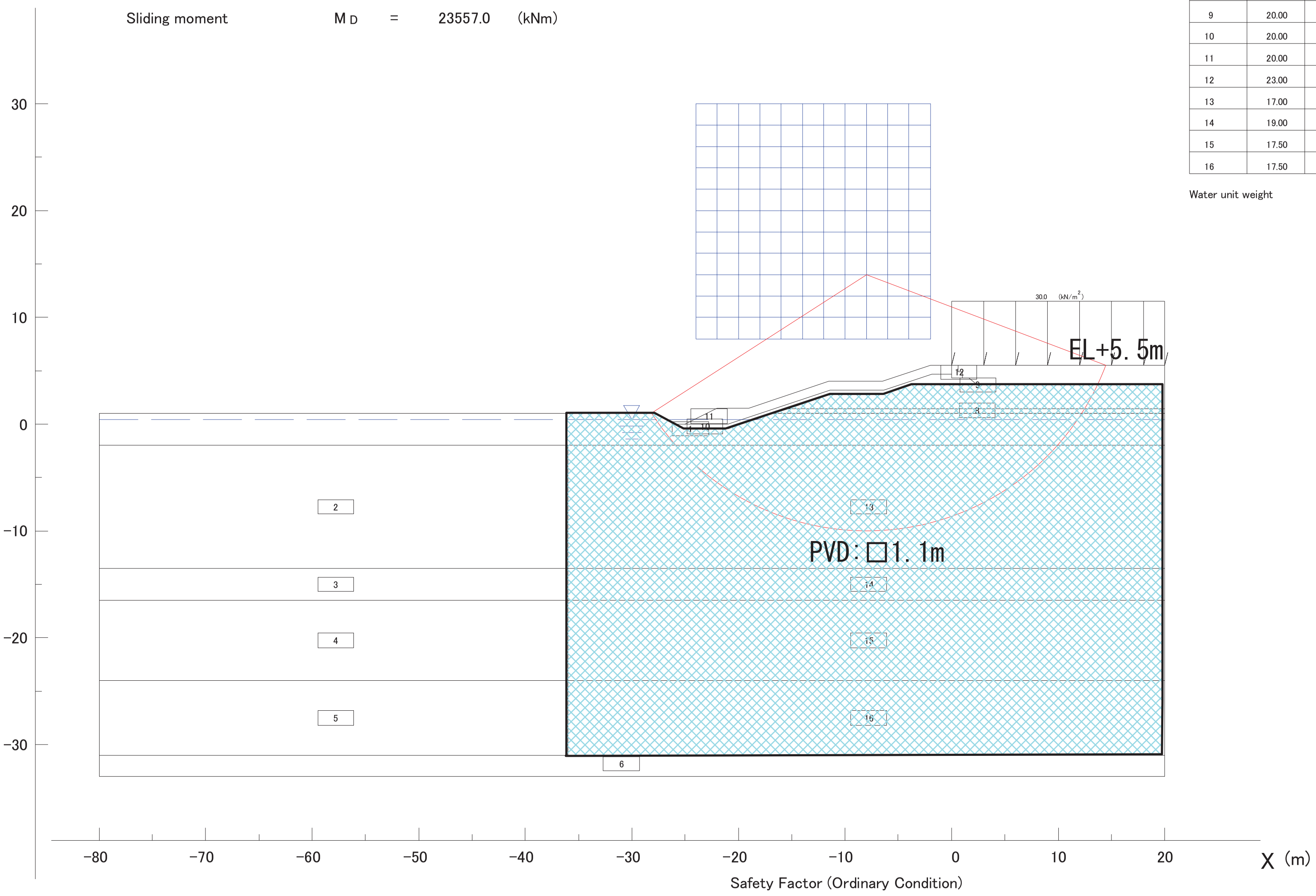


Inner Revetment-2 (After completion of Revetment Construction)

Min. safety factor	$F_{S\,MIN}$	=	1.430	
Center of arc	X	=	−8.00	(m)
	Y	=	14.00	(m)
Radius	R	=	24.00	(m)
Resisting moment	M_R	=	33682.1	(kNm)
Sliding moment	M_D	=	23557.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	17.00	17.00	0.00	32.28	0.00	0.000	0.000
14	19.00	19.00	0.00	50.00	0.00	0.000	0.000
15	17.50	17.50	0.00	43.66	0.00	0.000	0.000
16	17.50	17.50	0.00	42.95	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)

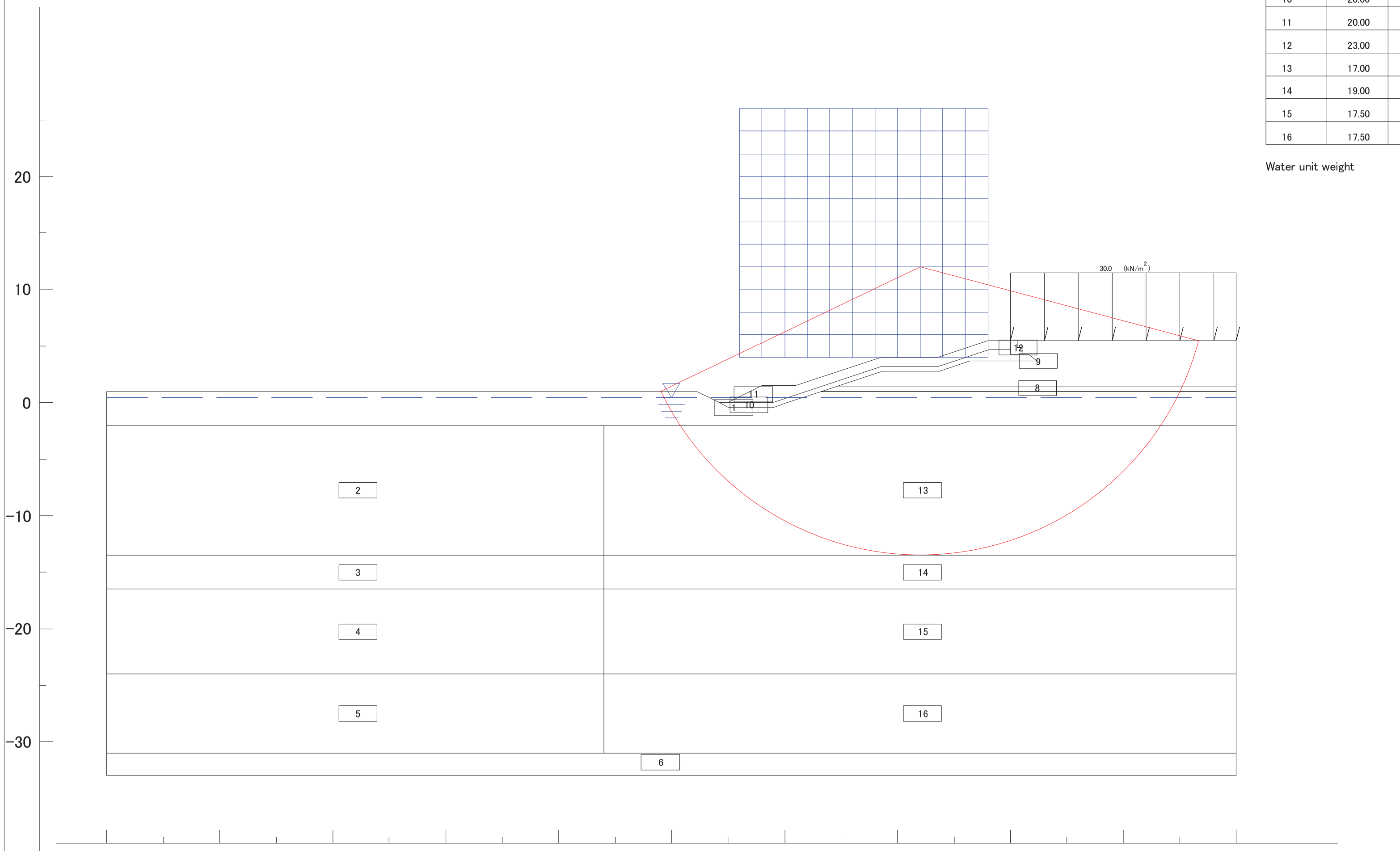


Inner Revetment-2 (Without Subsoil Improvement)

Min. safety factor	$F_{S\,MIN}$	=	0.702	
Center of arc	X	=	−8.00	(m)
	Y	=	12.00	(m)
Radius	R	=	25.50	(m)
Resisting moment	M_R	=	20890.3	(kNm)
Sliding moment	M_D	=	29764.2	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	17.00	17.00	0.00	15.00	0.00	0.000	0.000
14	19.00	19.00	0.00	50.00	0.00	0.000	0.000
15	17.50	17.50	0.00	40.00	0.00	0.000	0.000
16	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

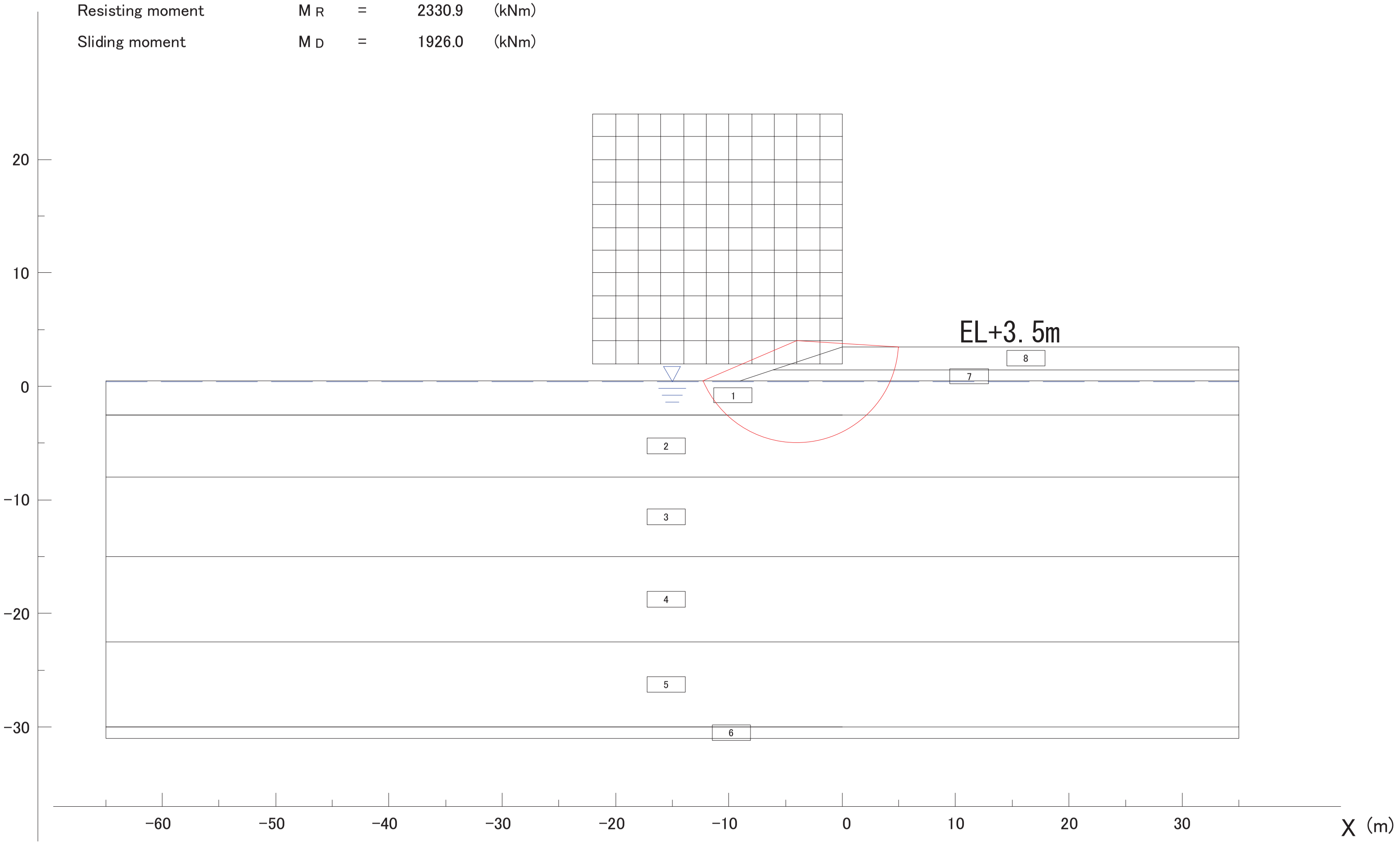
Inner Revetment-3 (1st)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.210	
Center of arc	X	=	-4.00	(m)
	Y	=	4.00	(m)
Radius	R	=	9.00	(m)
Resisting moment	M_R	=	2330.9	(kNm)
Sliding moment	M_D	=	1926.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

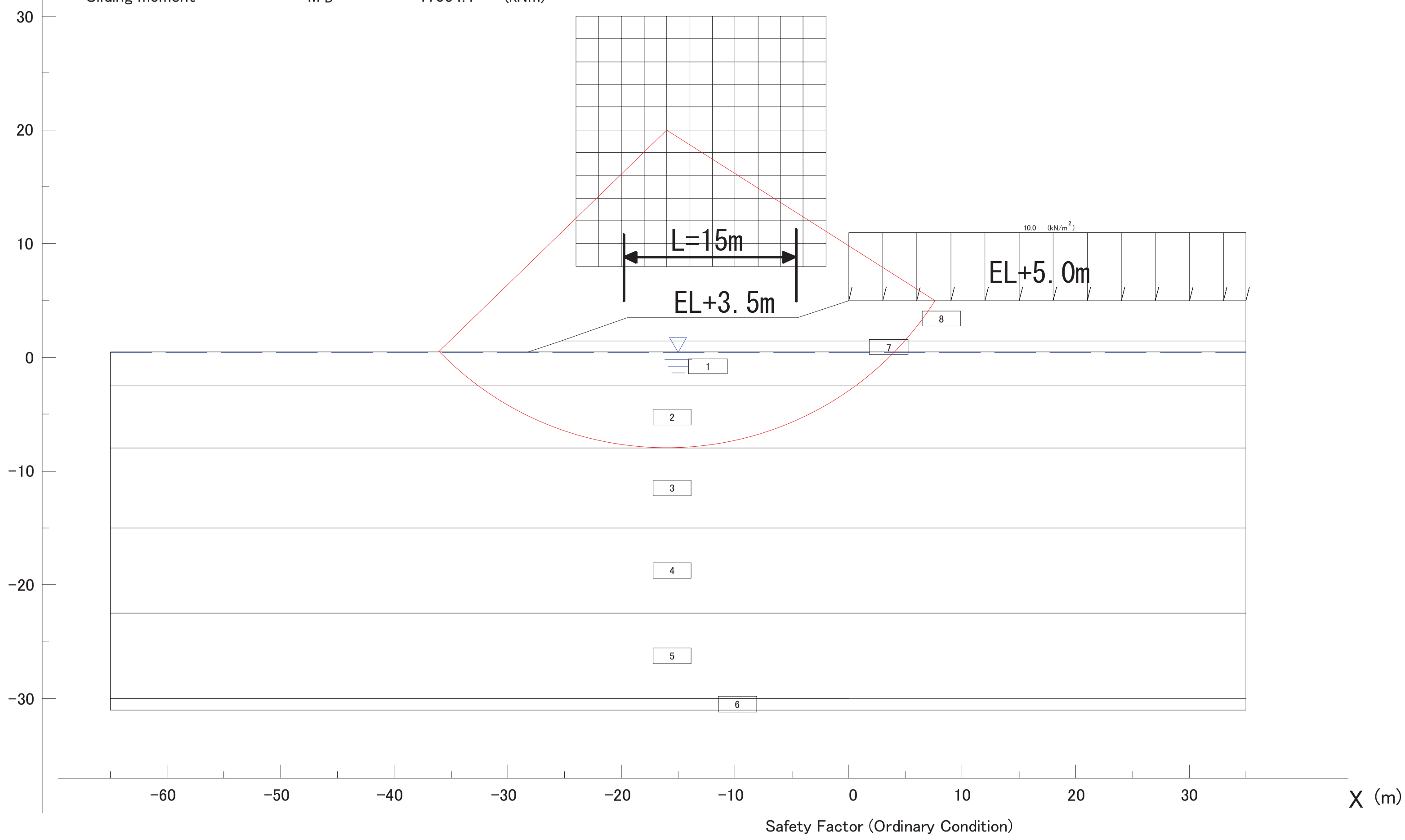
Inner Revetment-3 (2nd)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.192	
Center of arc	X	=	−16.00	(m)
	Y	=	20.00	(m)
Radius	R	=	28.00	(m)
Resisting moment	M_R	=	20324.7	(kNm)
Sliding moment	M_D	=	17054.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



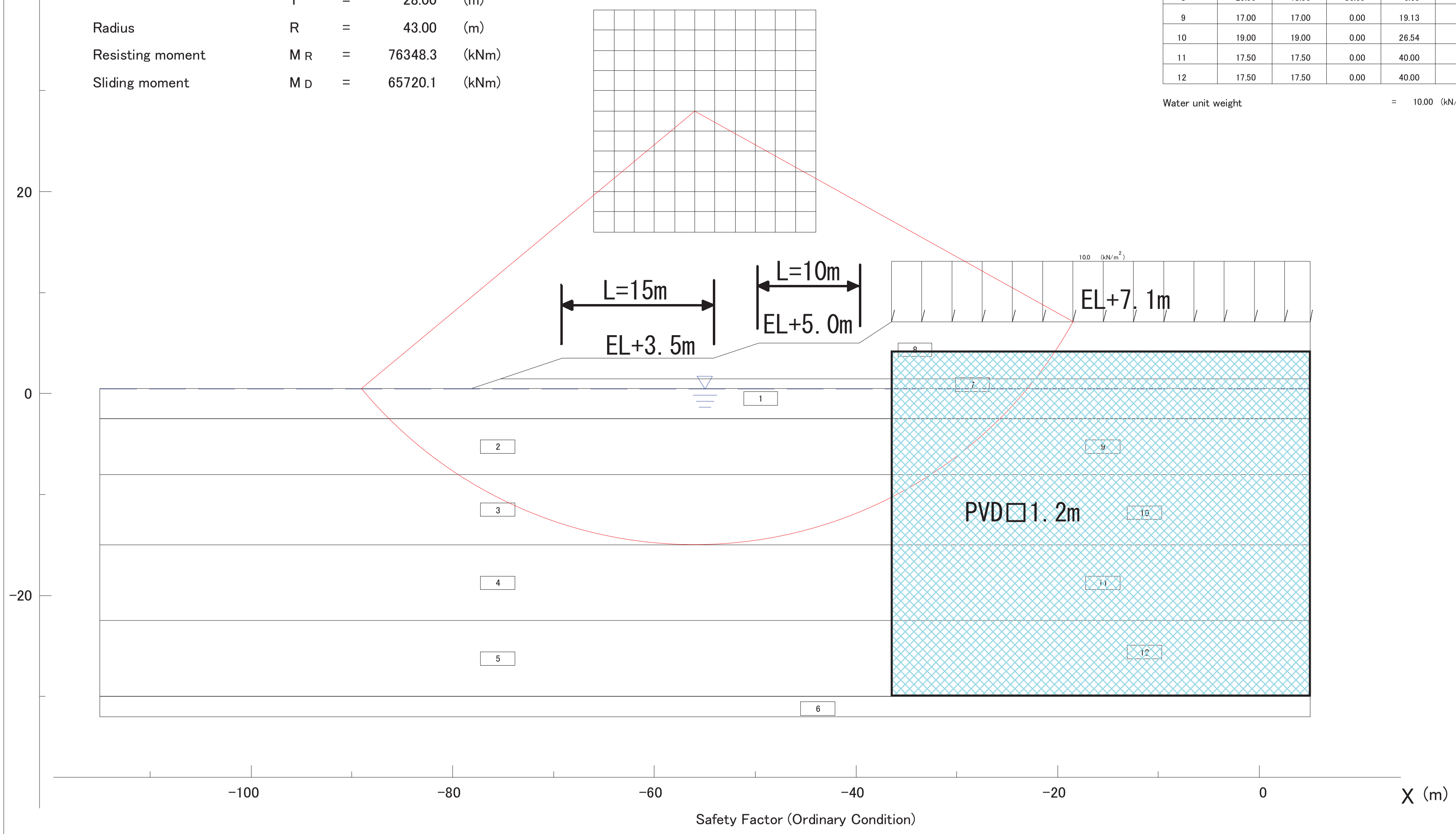
Inner Revetment-3　(3rd)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$ =	1.162	
Center of arc	X =	−56.00	(m)
	Y =	28.00	(m)
Radius	R =	43.00	(m)
Resisting moment	M_R =	76348.3	(kNm)
Sliding moment	M_D =	65720.1	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000
9	17.00	17.00	0.00	19.13	0.00	0.000	0.000
10	19.00	19.00	0.00	26.54	0.00	0.000	0.000
11	17.50	17.50	0.00	40.00	0.00	0.000	0.000
12	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



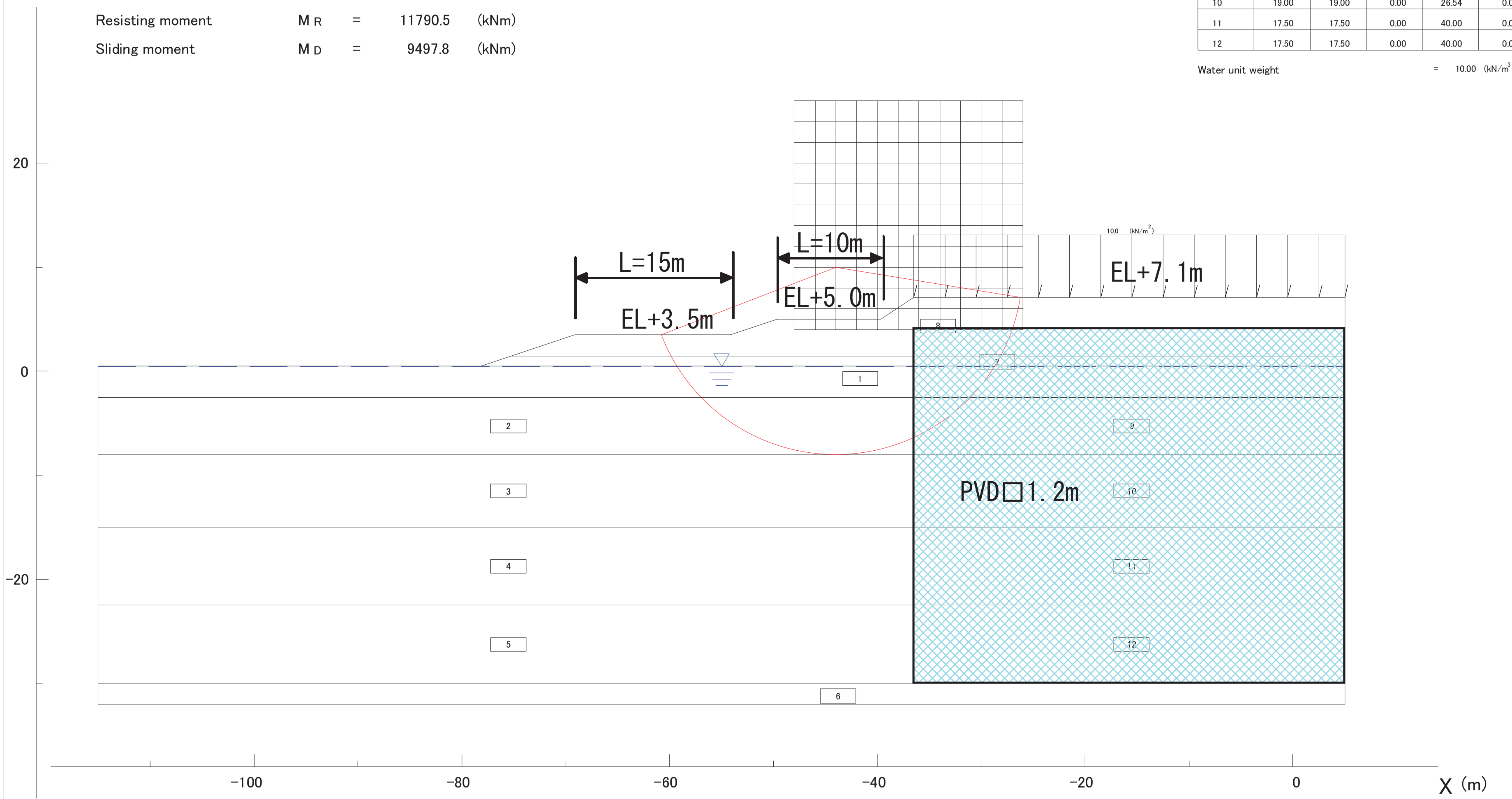
Inner Revetment-3 (3rd)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.241	
Center of arc	X	=	−44.00	(m)
	Y	=	10.00	(m)
Radius	R	=	18.00	(m)
Resisting moment	M_R	=	11790.5	(kNm)
Sliding moment	M_D	=	9497.8	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	20.00	30.00	0.00	0.00	0.000	0.000
8	20.00	18.00	30.00	0.00	0.00	0.000	0.000
9	17.00	17.00	0.00	19.13	0.00	0.000	0.000
10	19.00	19.00	0.00	26.54	0.00	0.000	0.000
11	17.50	17.50	0.00	40.00	0.00	0.000	0.000
12	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

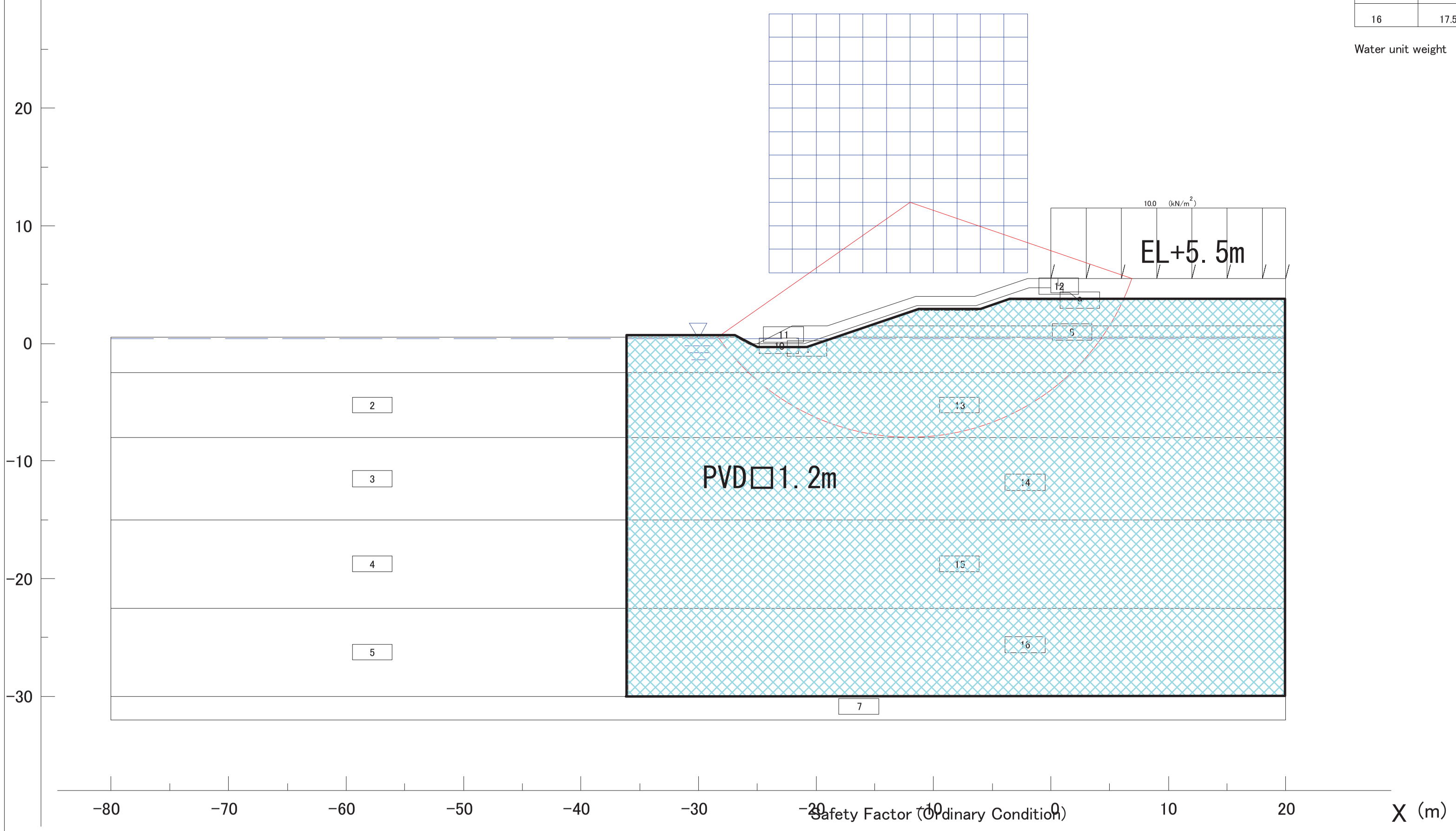
Inner Revetment-3 (After completion of Revetment Construction)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.329	
Center of arc	X	=	−12.00	(m)
	Y	=	12.00	(m)
Radius	R	=	20.00	(m)
Resisting moment	M_R	=	17802.3	(kNm)
Sliding moment	M_D	=	13397.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	17.00	17.00	0.00	24.98	0.00	0.000	0.000
14	19.00	19.00	0.00	31.19	0.00	0.000	0.000
15	17.50	17.50	0.00	40.44	0.00	0.000	0.000
16	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



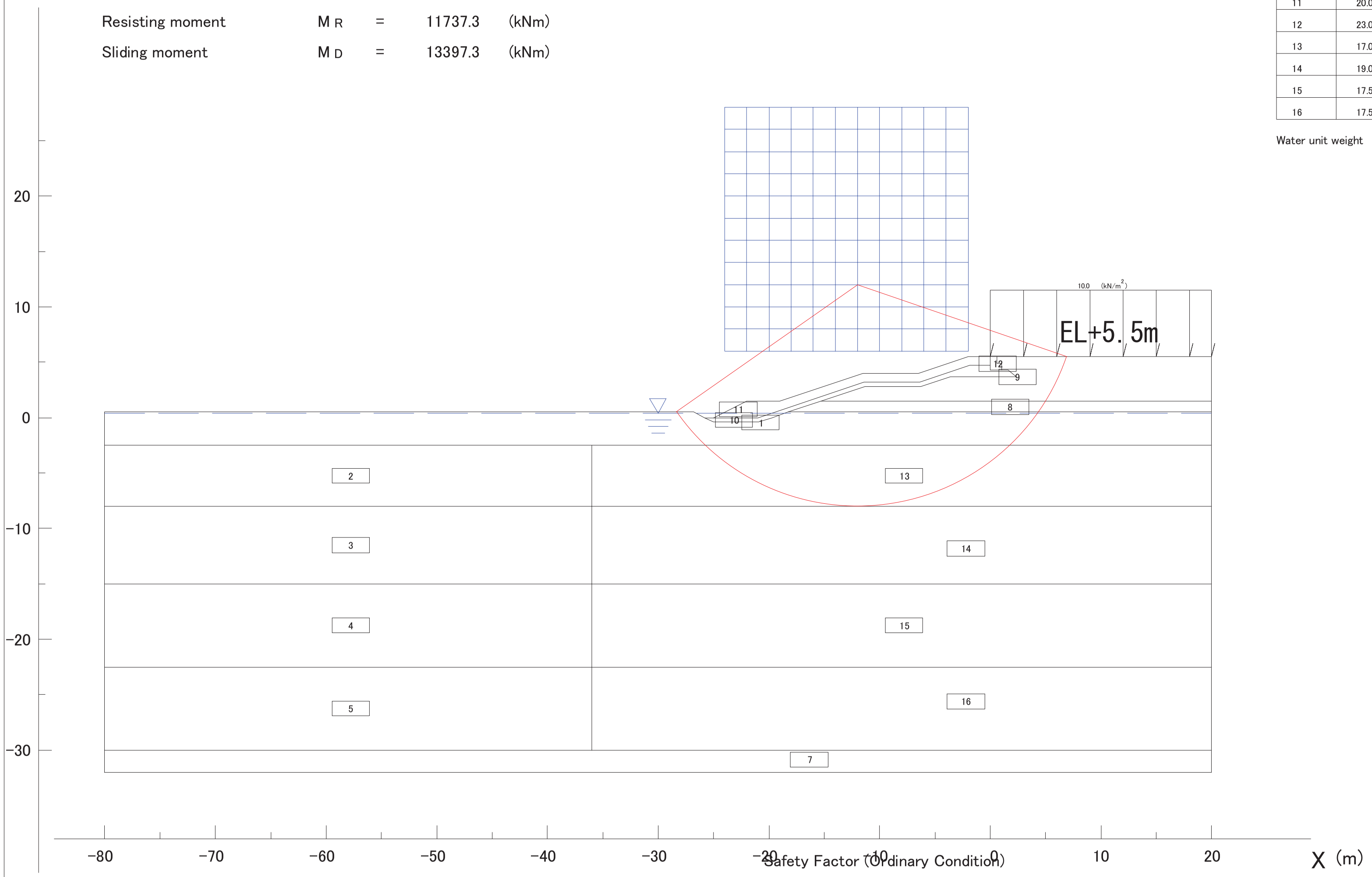
Inner Revetment-3 (Without Subsoil Improvement)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	0.876	
Center of arc	X	=	−12.00	(m)
	Y	=	12.00	(m)
Radius	R	=	20.00	(m)
Resisting moment	M_R	=	11737.3	(kNm)
Sliding moment	M_D	=	13397.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	17.00	17.00	0.00	15.00	0.00	0.000	0.000
14	19.00	19.00	0.00	25.00	0.00	0.000	0.000
15	17.50	17.50	0.00	40.00	0.00	0.000	0.000
16	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



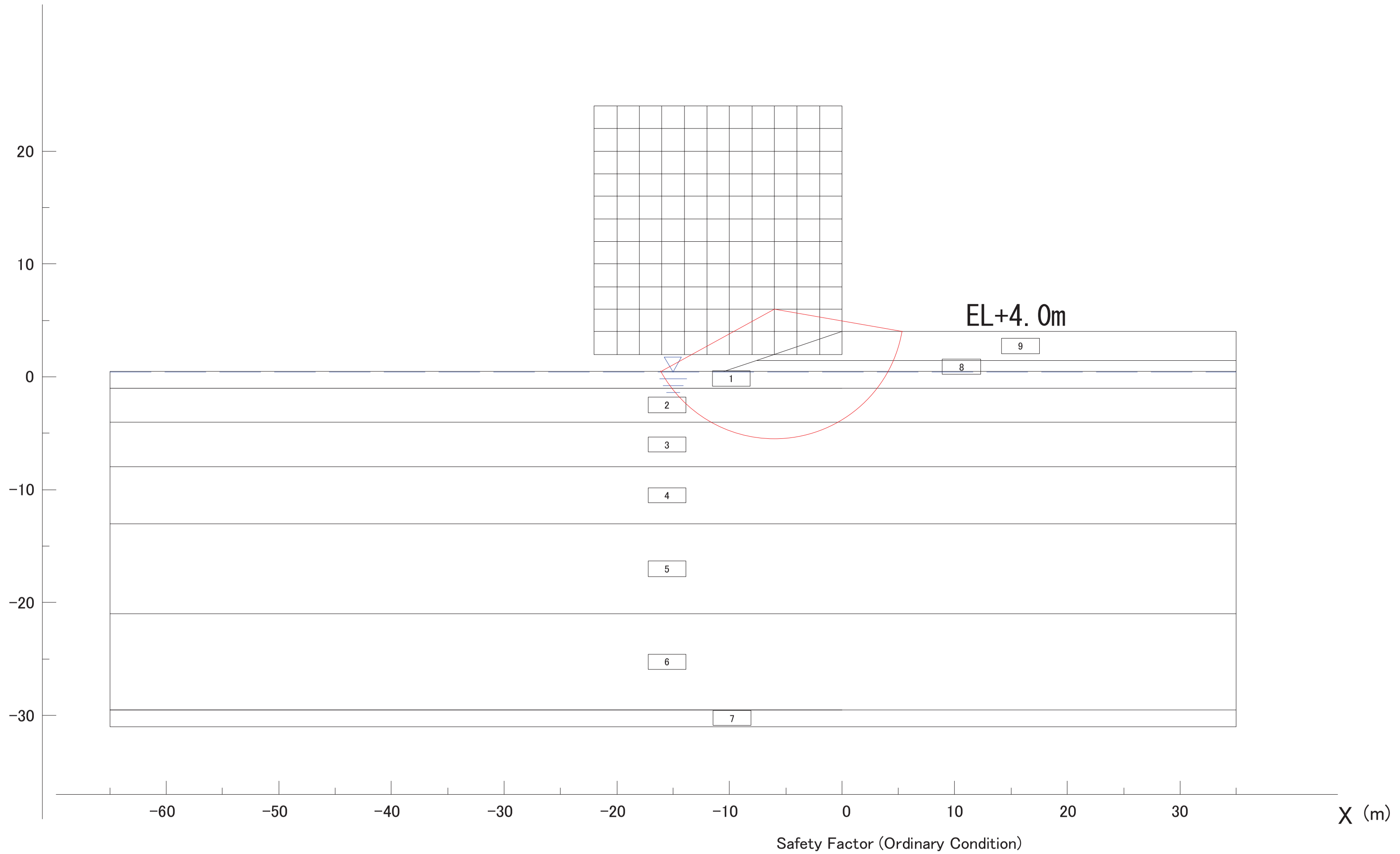
ラックフェン港-内側護岸-4 1段目:限界盛土H=+4.10m

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.145	
Center of arc	X	=	−6.00	(m)
	Y	=	6.00	(m)
Radius	R	=	11.50	(m)
Resisting moment	M_R	=	3981.8	(kNm)
Sliding moment	M_D	=	3477.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



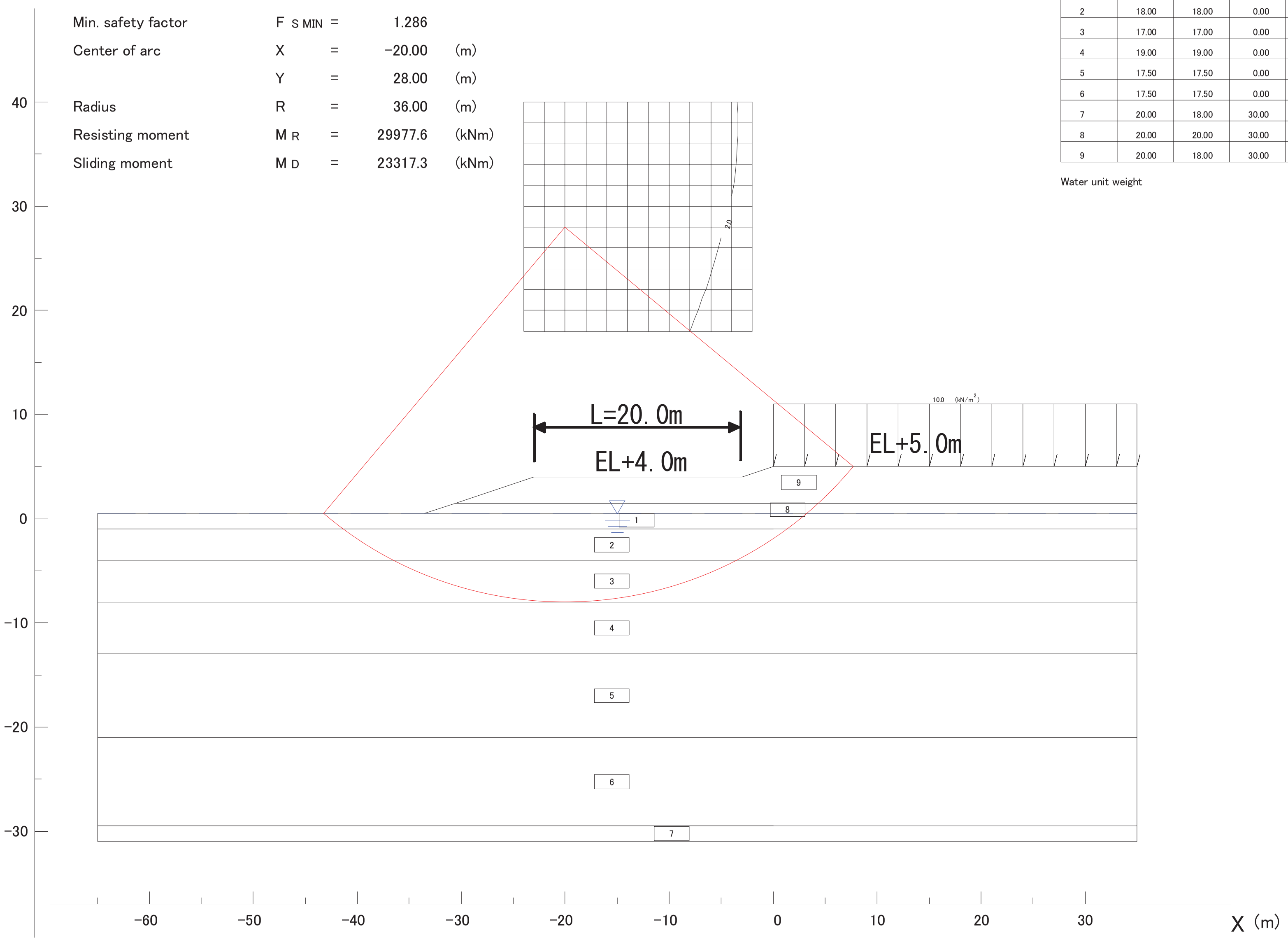
ラックフェン港-内側護岸-4 1段目:+5.00m(小段H=4.1m　L=14m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.286	
Center of arc	X	=	-20.00	(m)
	Y	=	28.00	(m)
Radius	R	=	36.00	(m)
Resisting moment	M_R	=	29977.6	(kNm)
Sliding moment	M_D	=	23317.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



Contour Diagram (Ordinary Condition)

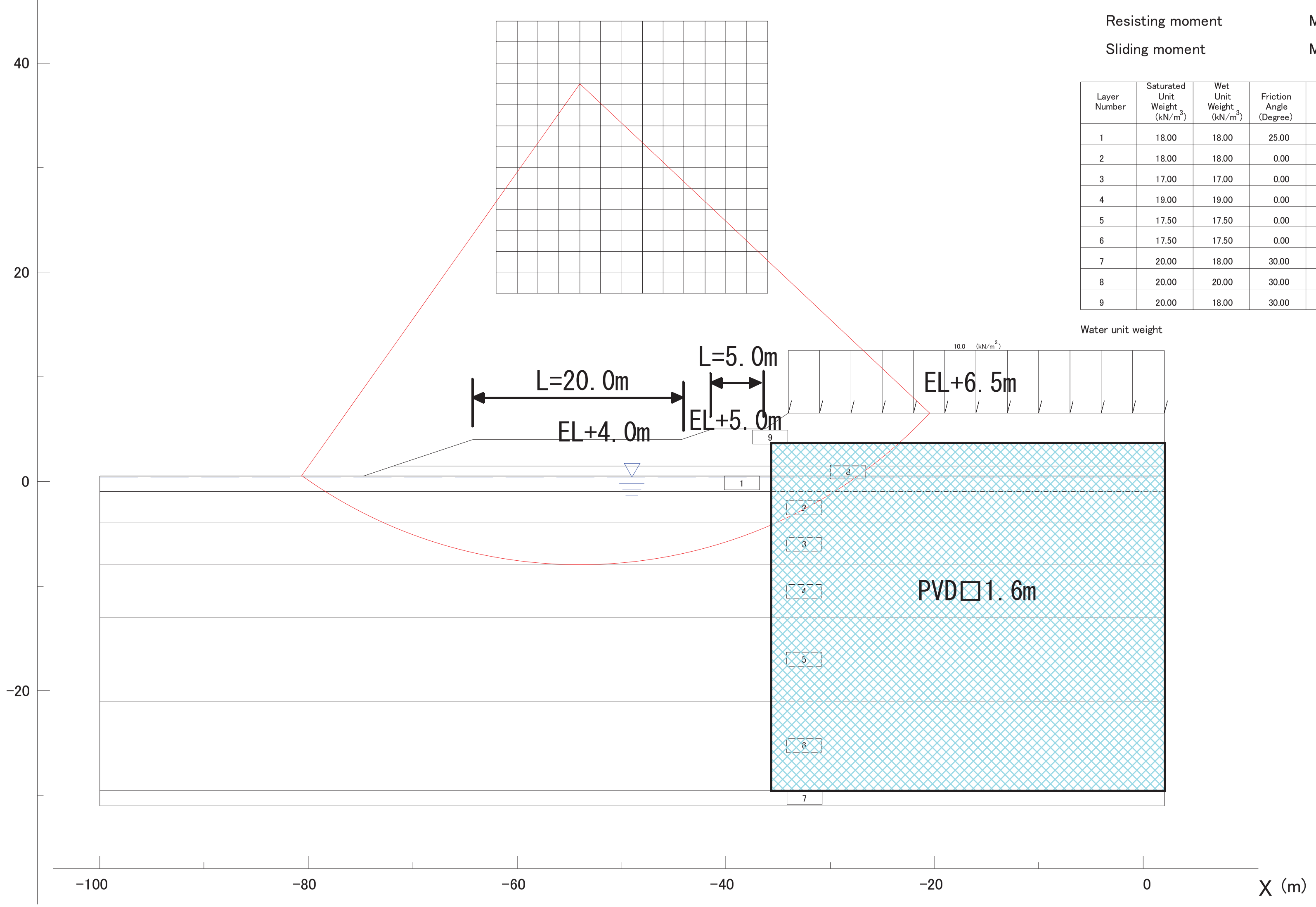
Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.216	
Center of arc	X	=	−54.00	(m)
	Y	=	38.00	(m)
Radius	R	=	46.00	(m)
Resisting moment	M R	=	48622.9	(kNm)
Sliding moment	M D	=	39985.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)

ラックフェン港−内側護岸−4 2段目:+6.20m(小段H=5.0m L=7m)



Contour Diagram (Ordinary Condition)

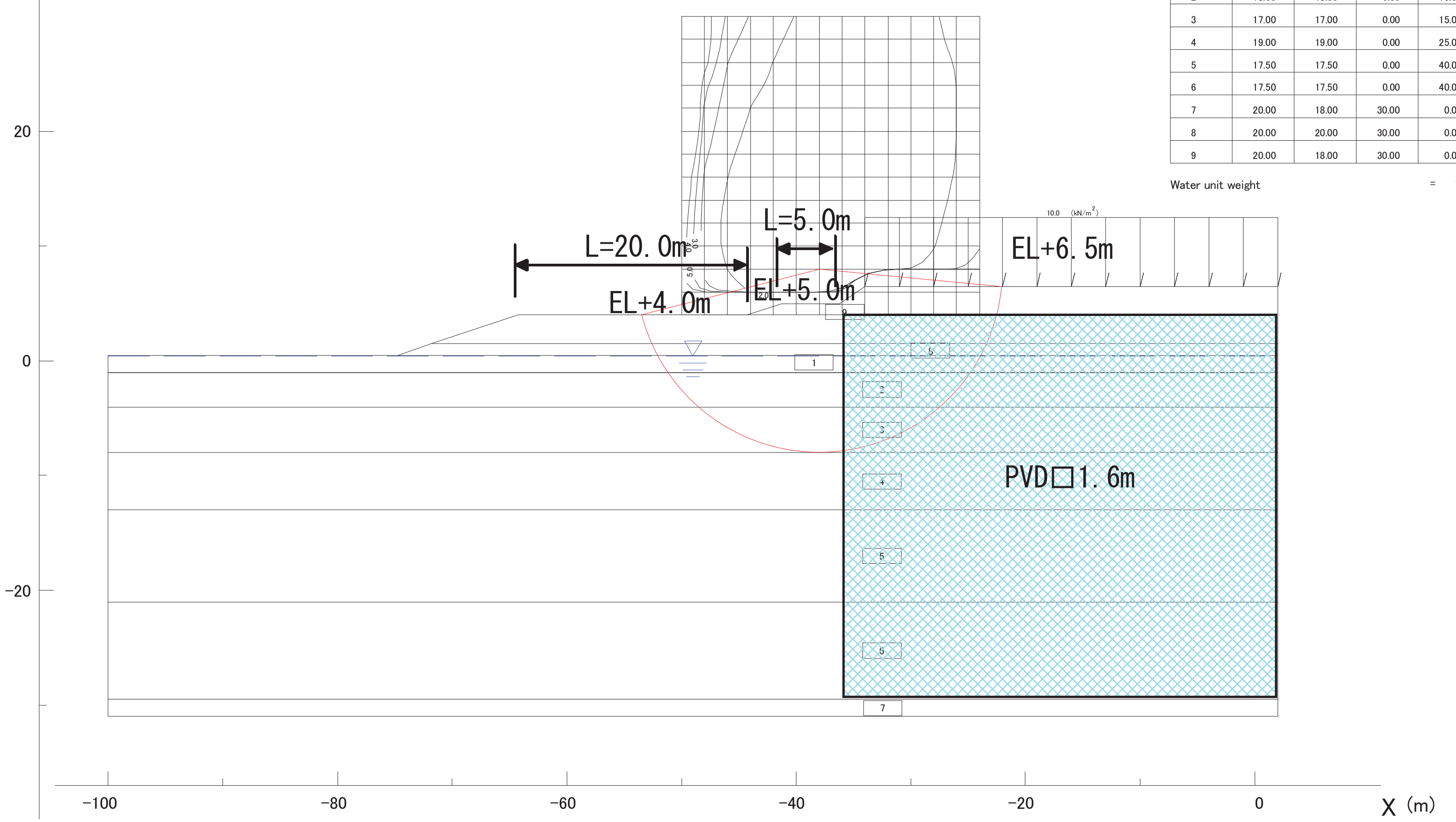
ラックフェン港−内側護岸−4 2段目:+6.20m(小段H=5.0m L=7m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.355	
Center of arc	X	=	−38.00	(m)
	Y	=	8.00	(m)
Radius	R	=	16.00	(m)
Resisting moment	M_R	=	8727.0	(kNm)
Sliding moment	M_D	=	6438.9	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Contour Diagram (Ordinary Condition)

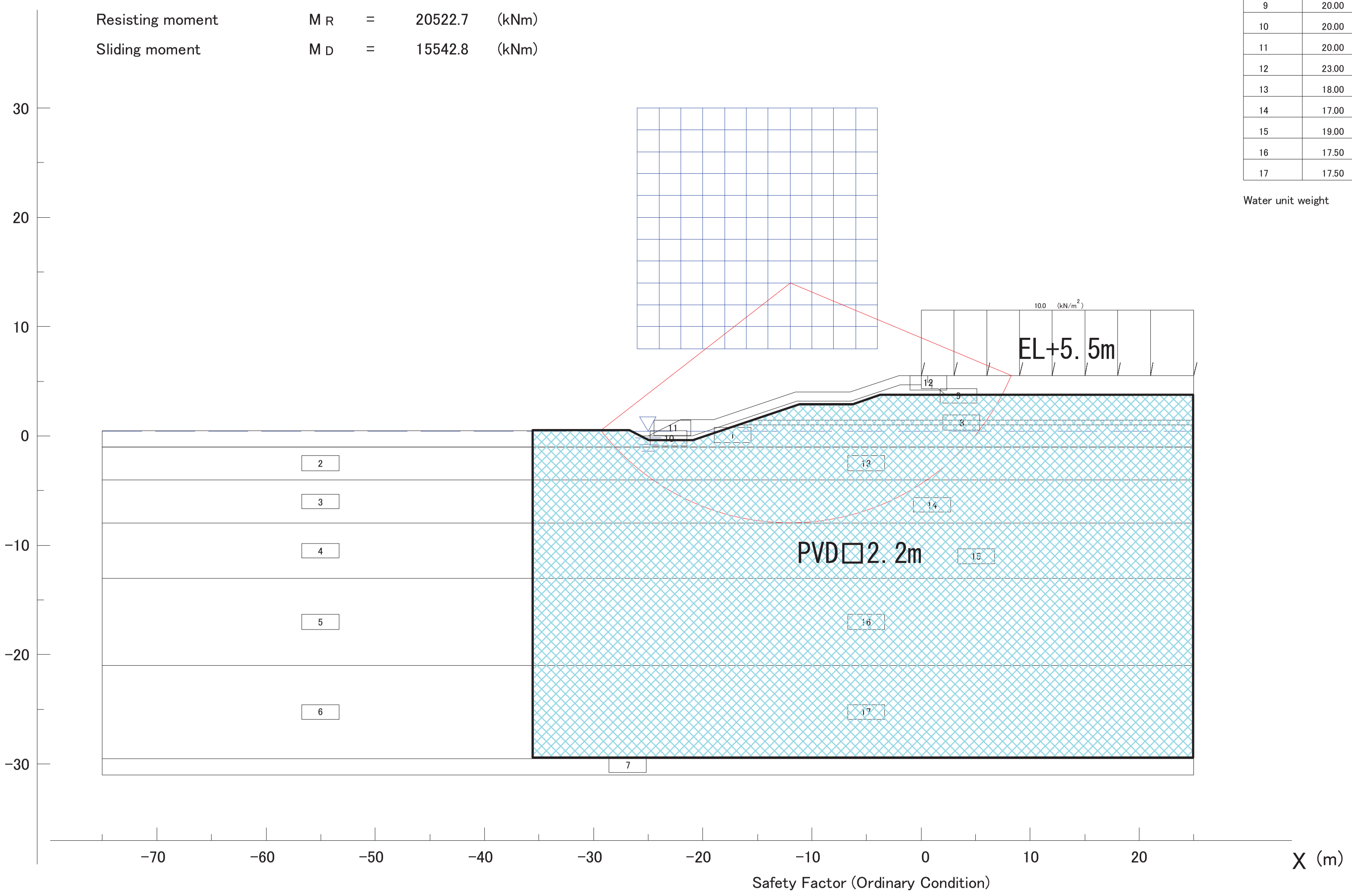
ラックフェン港-内側護岸-4 完成時(1段+2段:+6.2m)

Scale ; 1/ 600

Min. safety factor	F S MIN =	1.320	
Center of arc	X =	−12.00	(m)
	Y =	14.00	(m)
Radius	R =	22.00	(m)
Resisting moment	M R =	20522.7	(kNm)
Sliding moment	M D =	15542.8	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	18.00	18.00	0.00	20.22	0.00	0.000	0.000
14	17.00	17.00	0.00	24.63	0.00	0.000	0.000
15	19.00	19.00	0.00	30.46	0.00	0.000	0.000
16	17.50	17.50	0.00	40.19	0.00	0.000	0.000
17	17.50	17.50	0.00	40.19	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



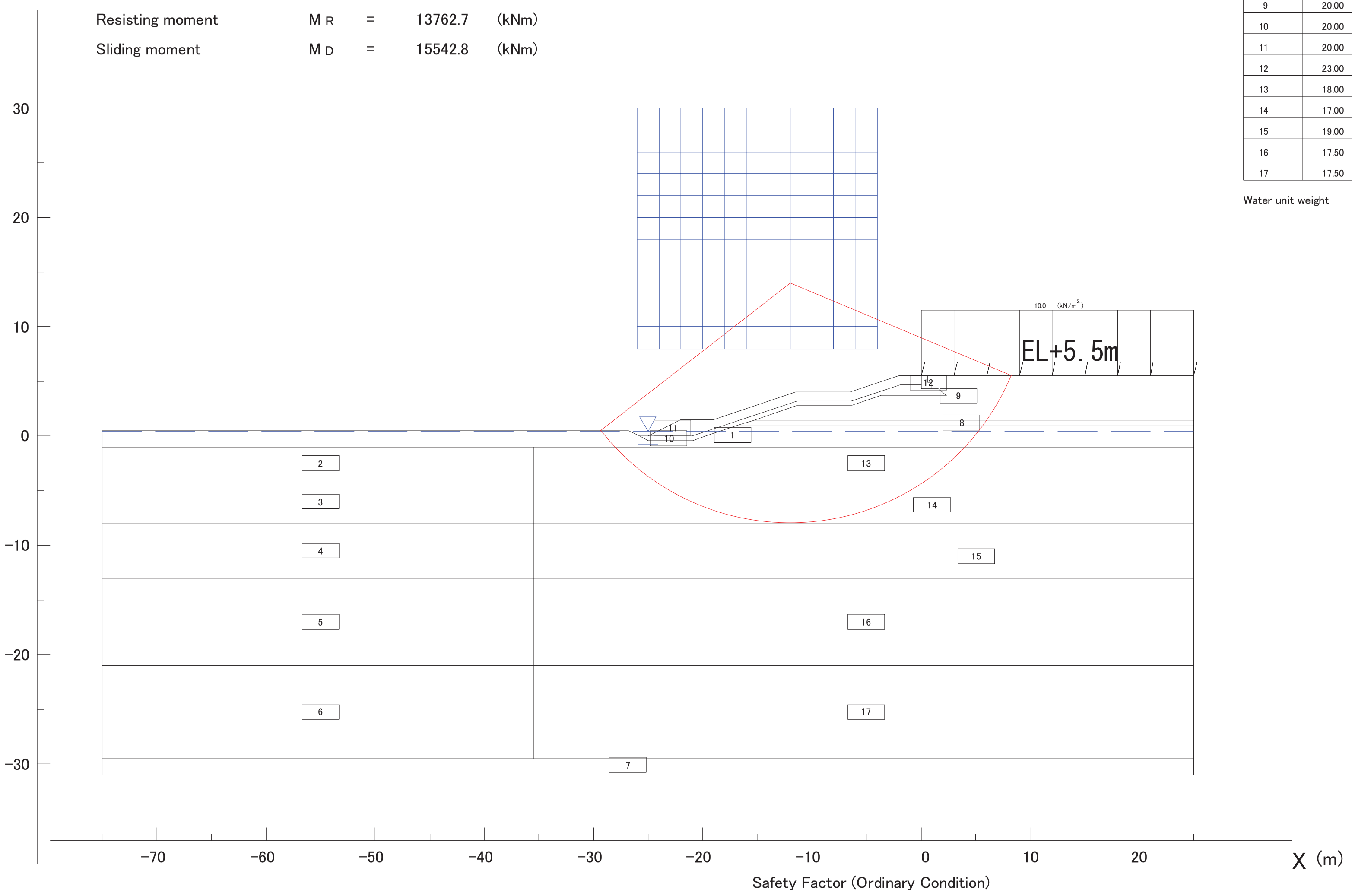
ラックフェン港-内側護岸-4 完成時(無対策)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	0.885	
Center of arc	X	=	−12.00	(m)
	Y	=	14.00	(m)
Radius	R	=	22.00	(m)
Resisting moment	M R	=	13762.7	(kNm)
Sliding moment	M D	=	15542.8	(kNm)

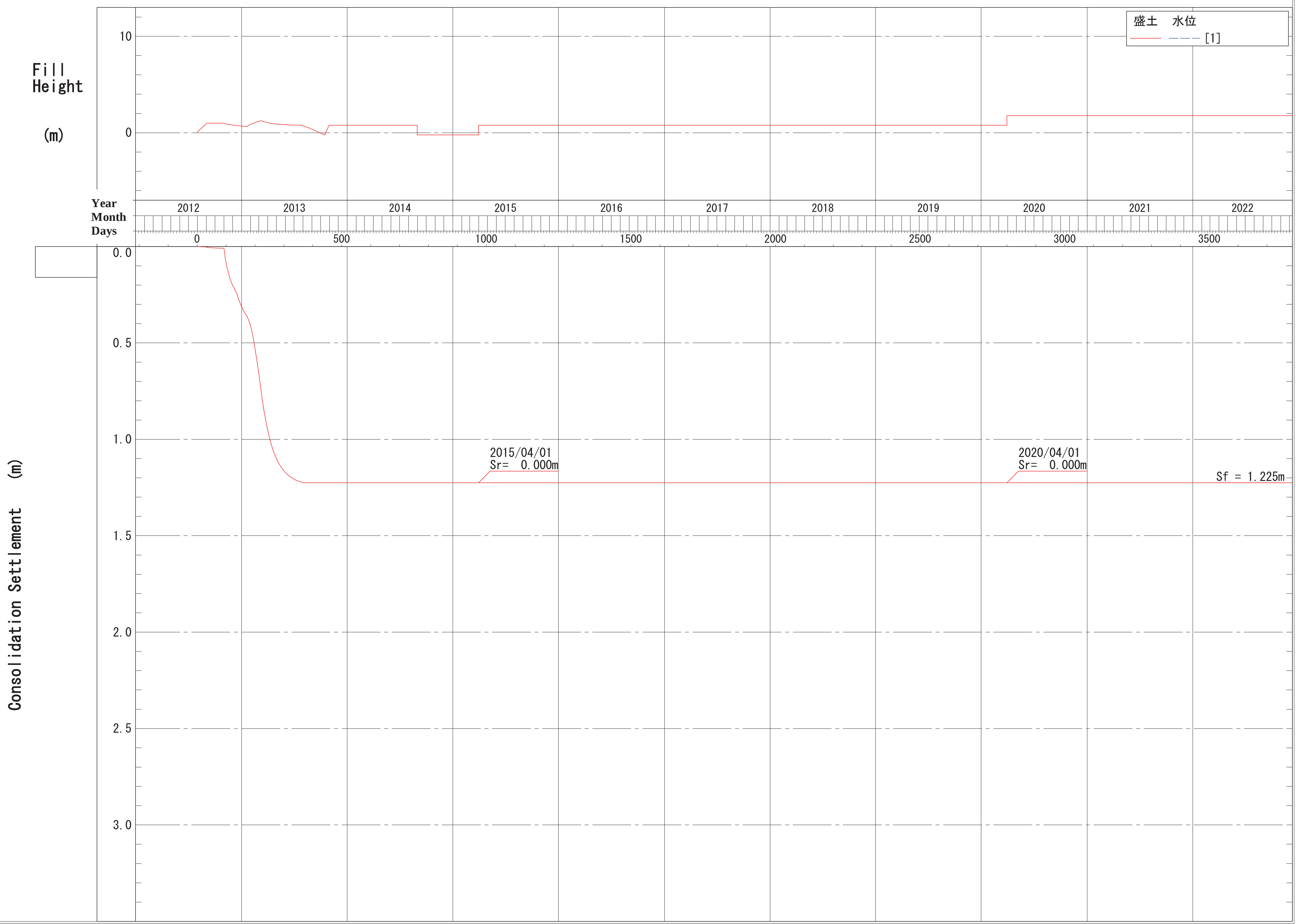
Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	18.00	18.00	0.00	15.00	0.00	0.000	0.000
14	17.00	17.00	0.00	15.00	0.00	0.000	0.000
15	19.00	19.00	0.00	25.00	0.00	0.000	0.000
16	17.50	17.50	0.00	40.00	0.00	0.000	0.000
17	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



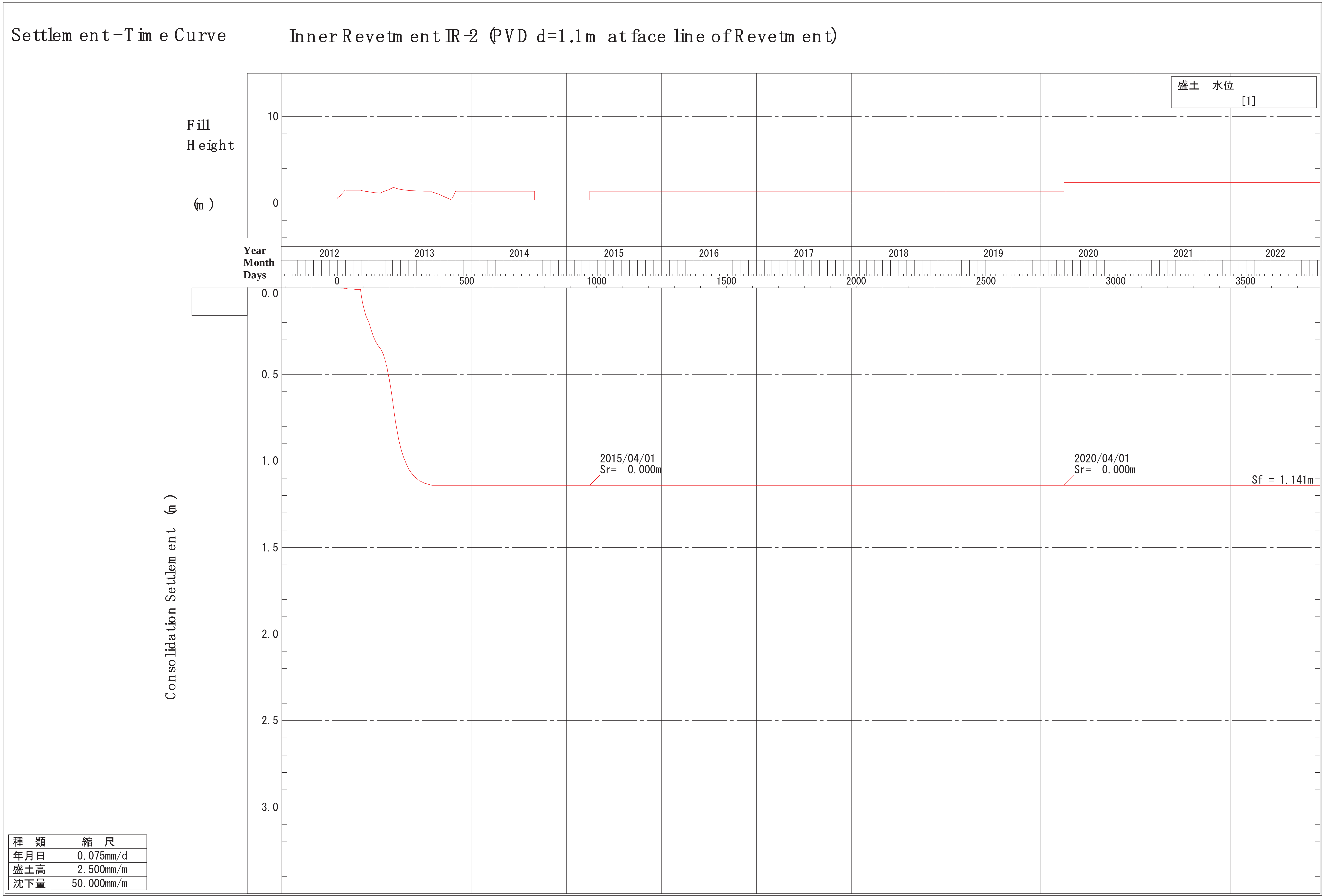
3) Settlement-Time Curves with PVD for Inner Revetment

Settlement - Time Curve Inner Revetment IR-1 (PVD d=1.1m at face line of Revetment)



種 類	縮 尺
年月日	0.075mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[IR-1-ｄ□=1.1m-法線.Ptw]

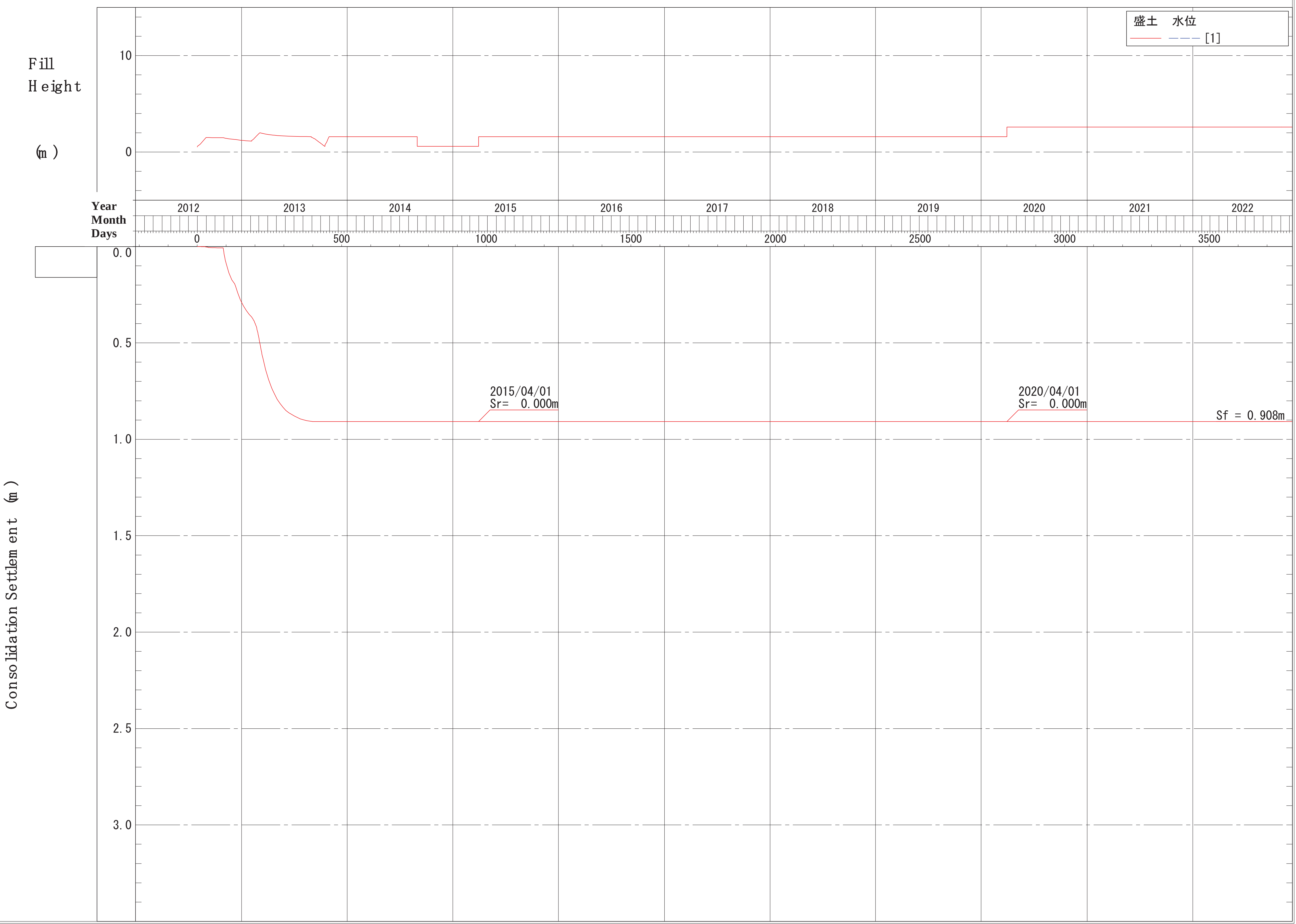


種 類	縮 尺
年月日	0.075mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[IR-2-ｄ□=1.1m-法線.Ptw]

Settlement-Time Curve

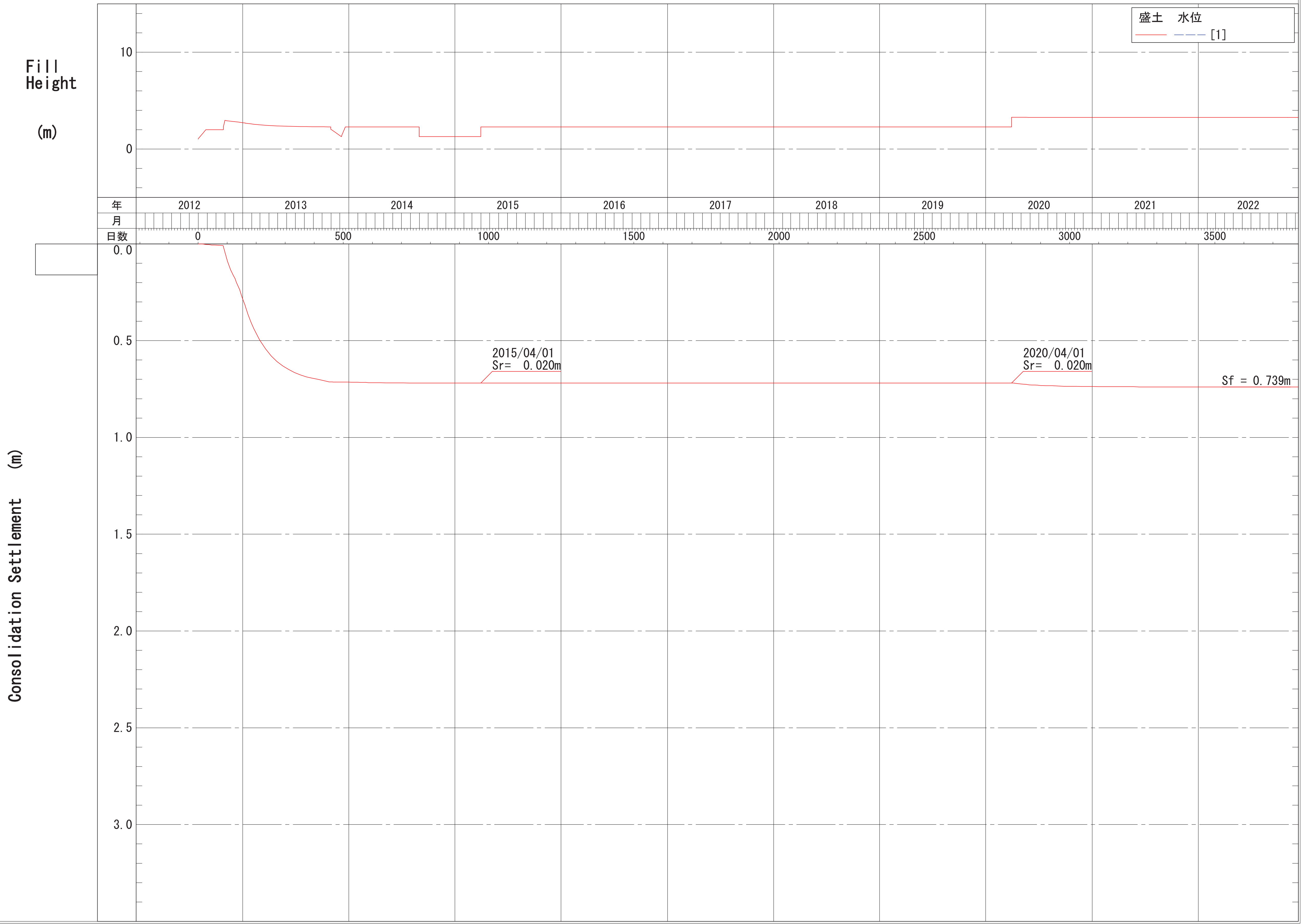
Inner Revetment IR-3 (PVD d=1.2m at face line of Revetment)



種　類	縮　尺
年月日	0.075mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[IR-3-ｄ□=1.2m-法線.Ptw]

Settlement - Time Curve   Inner Revetment IR-4 (PVD d=1.6m at face line of Revetment)

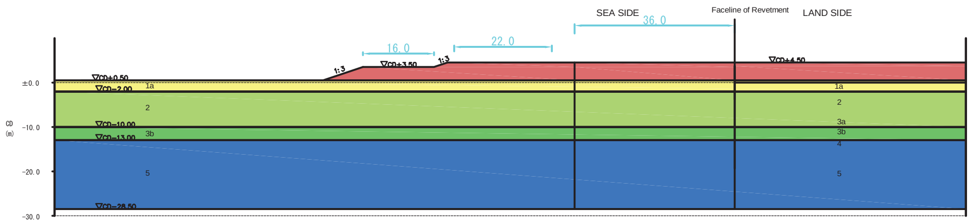


種 類	縮 尺
年月日	0.075mm/d
盛土高	2.500mm/m
沈下量	50.000mm/m

ファイル名 1:[IR-4-d□=1.6m-法線.Ptw]

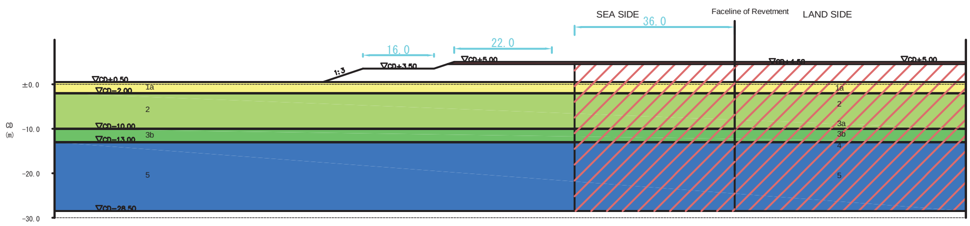
4) Subsoil Improvement Procedure with PVD and Preload Method for Inner Revetment

Inner Revetment IR-1



Step 1 (1.5 months)

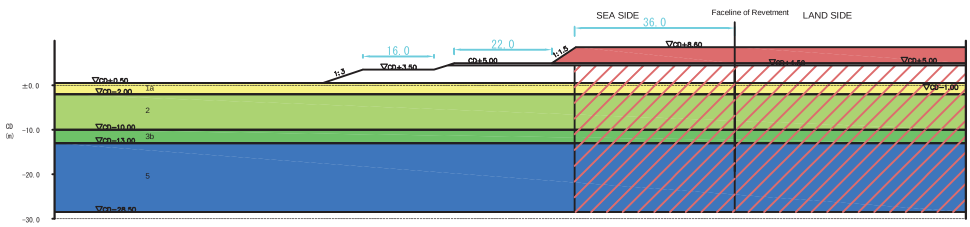
Fill and Sand Mat. (+4.0 ~ +4.5m)



Step 2 (2 months)

Soil Improvement (PVD d=□1.1m)
Cover sand (+4.5m ~ 5.0m)

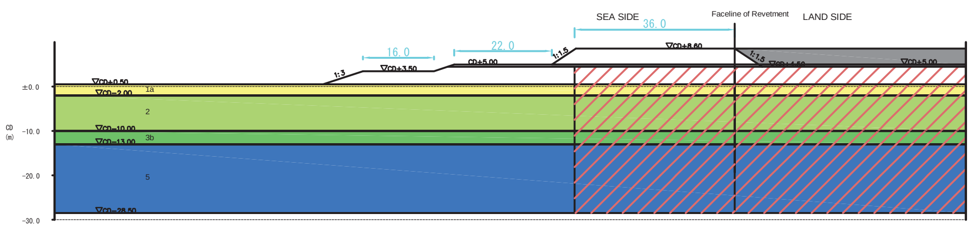
Retaining period (4 months)



Step 3 (1.5 months)

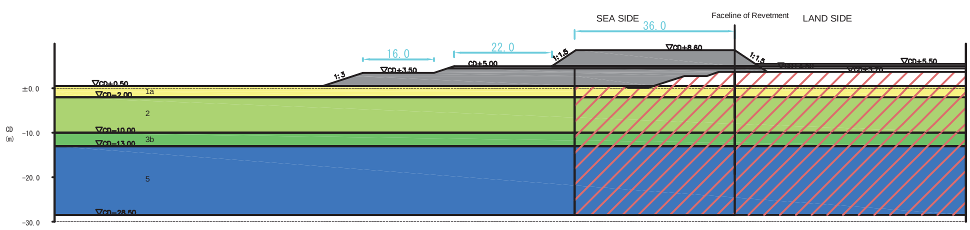
Preload (+8.6m)

Retaining period (4.0 months)



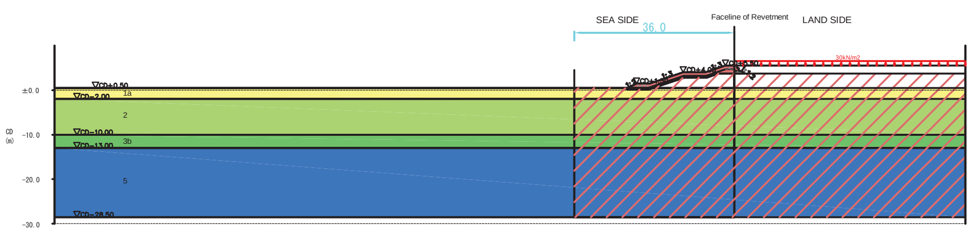
Step 4 (1 month)

Removal of preload (Only Lanside)



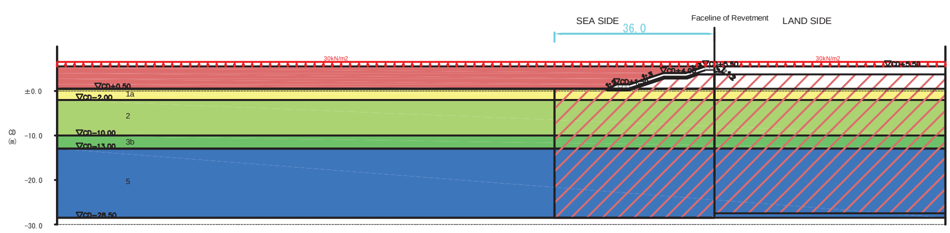
Step 5 (1 month)

Removal of Fill and Preload



Step 6 (6 months)

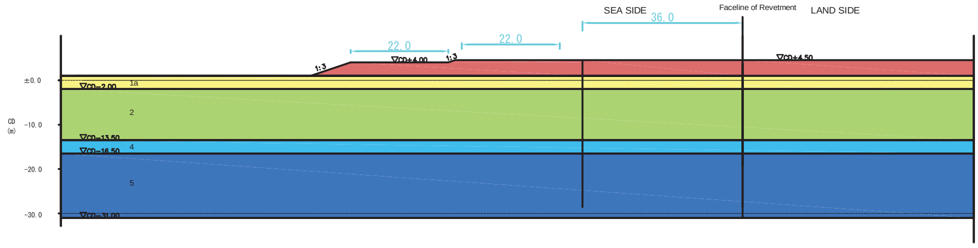
Pavement and Inner Revetment construction



Step 7 (5 years later)

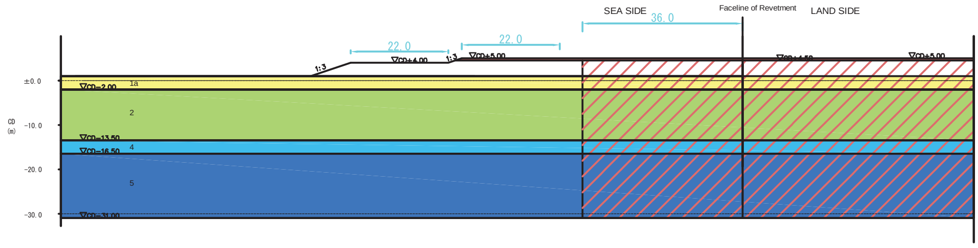
Fill for Port extension area

Inner Revetment IR-2



Step 1 (1.5 months)

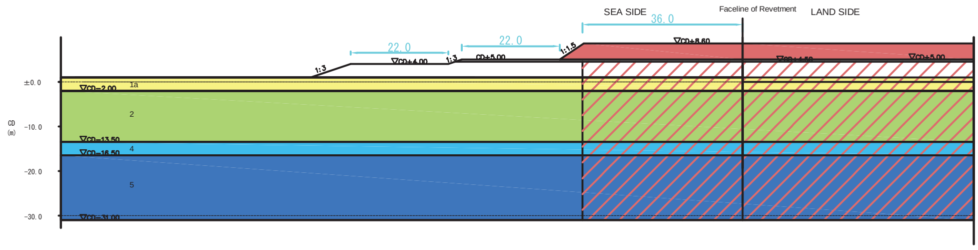
Fill and Sand Mat. (+4.0 ~ +4.5m)



Step 2 (2 months)

Soil Improvement (PVD d=□1.1m)
Cover sand (+4.5m ~ 5.0m)

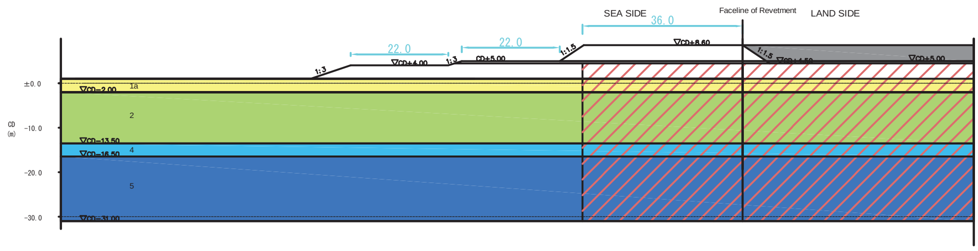
Retaining period (4 months)



Step 3 (1.5 months)

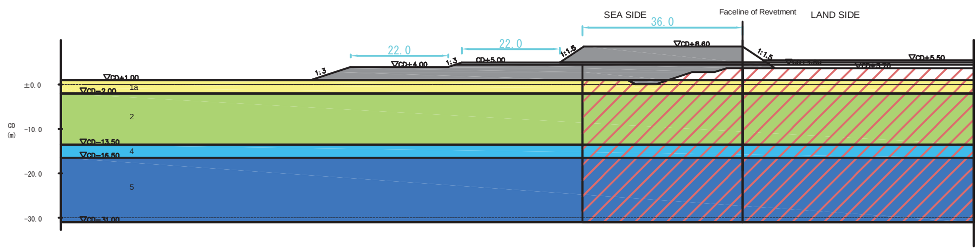
Preload (+8.6m)

Retaining period (4.0 months)



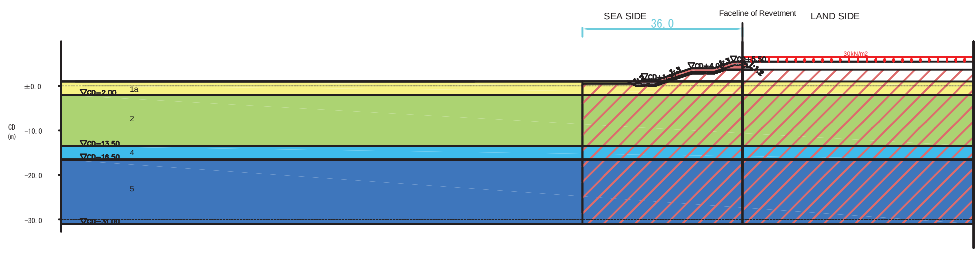
Step 4 (1 month)

Removal of preload (Only Lanside)



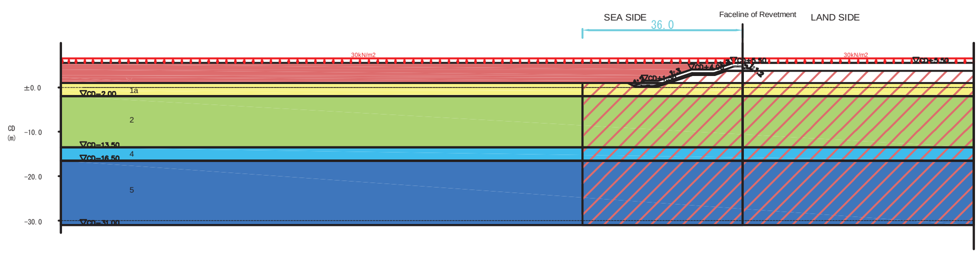
Step 5 (1 month)

Removal of Fill and Preload



Step 6 (6 months)

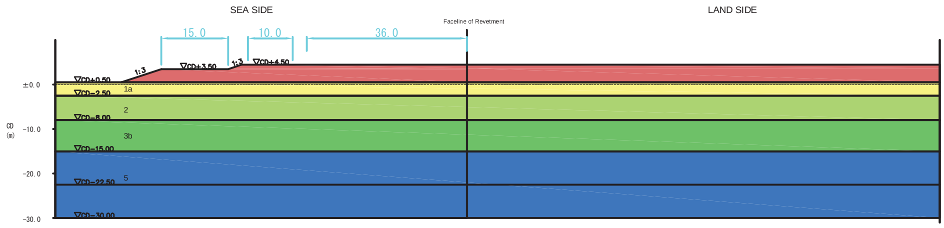
Pavement and Inner Revetment construction



Step 7 (5 years later)

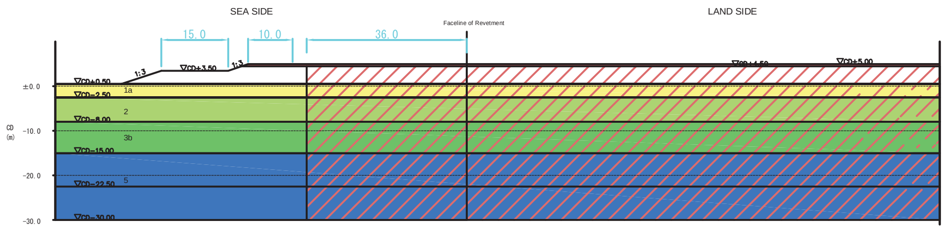
Fill for Port extension area

Inner Revetment IR-3



Step 1 (1.5 months)

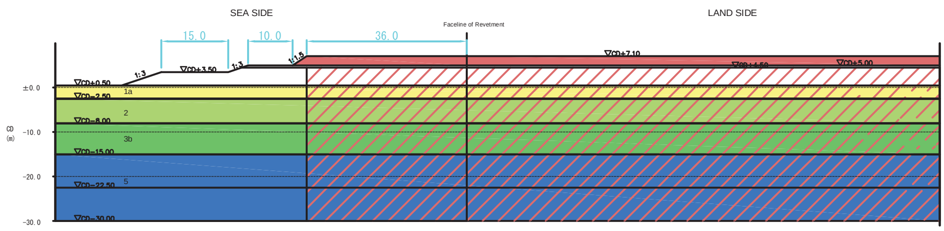
Fill and Sand Mat. (+4.0 ~ +4.5m)



Step 2 (2 months)

Soil Improvement (PVD d=□1.2m)
Cover sand (+4.5m ~ 5.0m)

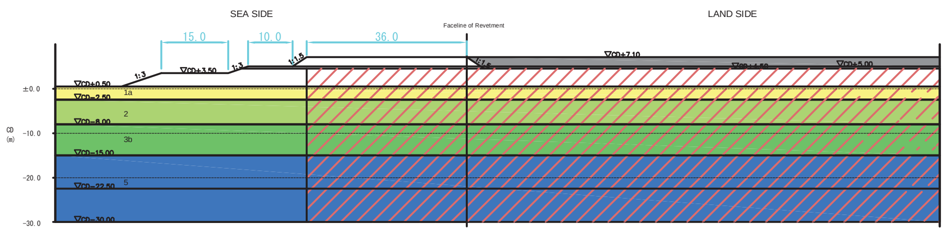
Retaining period (4 months)



Step 3 (1.5 months)

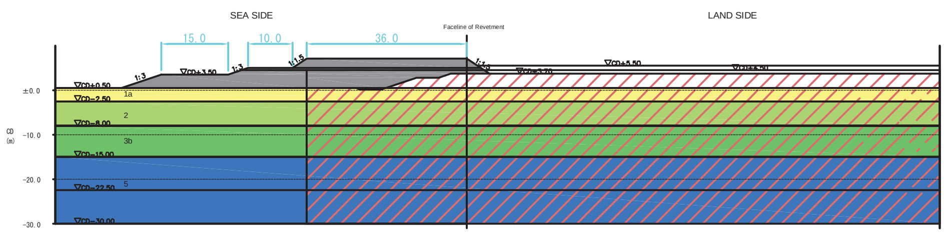
Preload (+7.1m)

Retaining period (4.0 months)



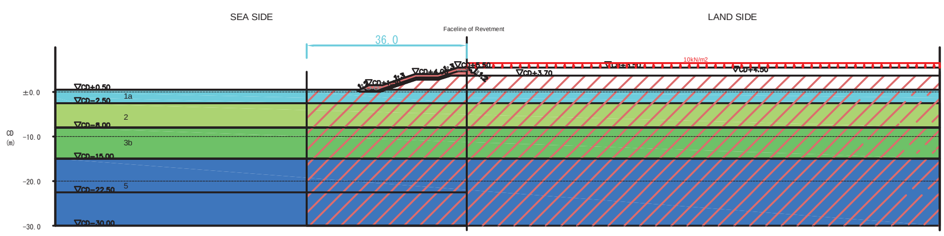
Step 4 (1 month)

Removal of preload (Only Lanside)



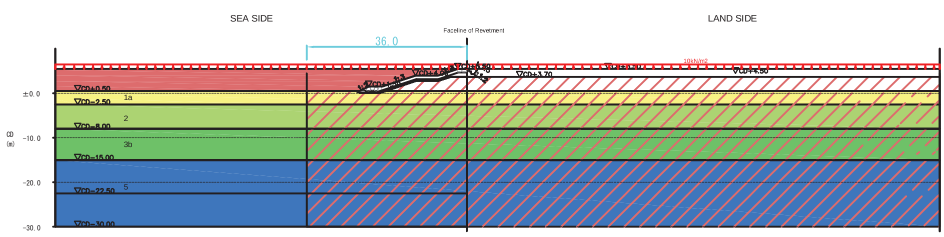
Step 5 (1 month)

Removal of Fill and Preload



Step 6 (6 months)

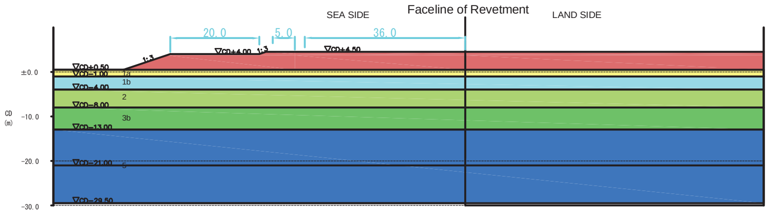
Pavement and Inner Revetment construction



Step 7 (5 years later)

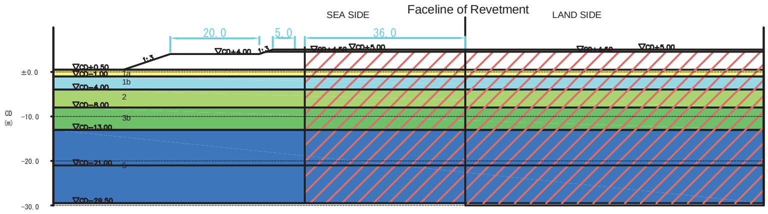
Fill for Port extension area

Inner Revetment IR-4



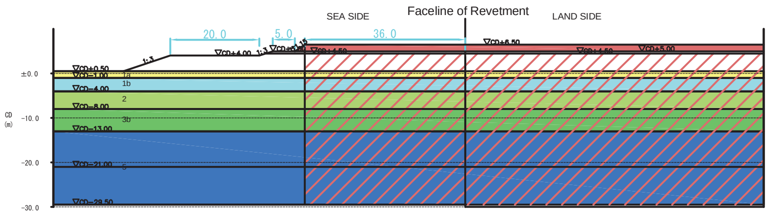
Step 1 (1.5 months)

Fill and Sand Mat. (+4.0 ~ +4.5m)



Step 2 (2 months)

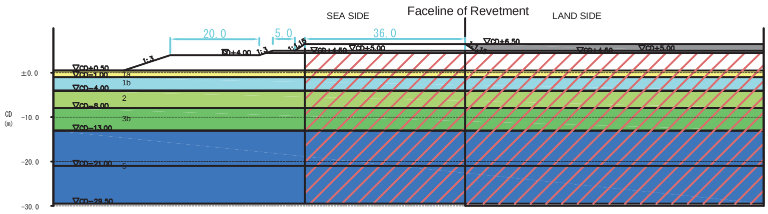
Soil Improvement (PVD d=□2.2m)
Cover sand (+4.5m ~ 5.0m)



Step 3 (0.5 months)

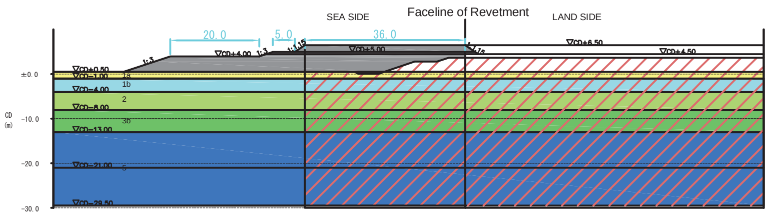
Preload (+6.5m)

Retaining period (12 months)



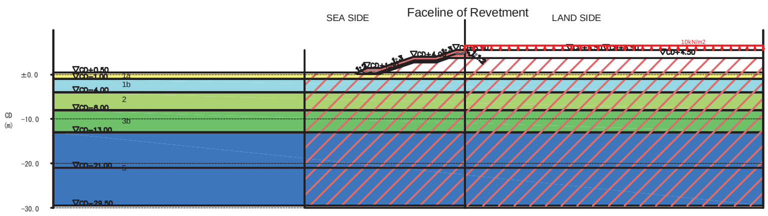
Step 4 (0.5 month)

Removal of preload (Only Lanside)



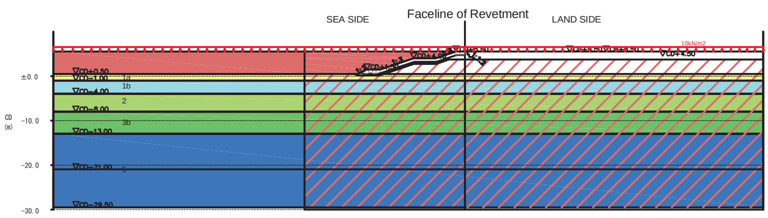
Step 5 (1 month)

Removal of Fill and Preload



Step 6 (6 months)

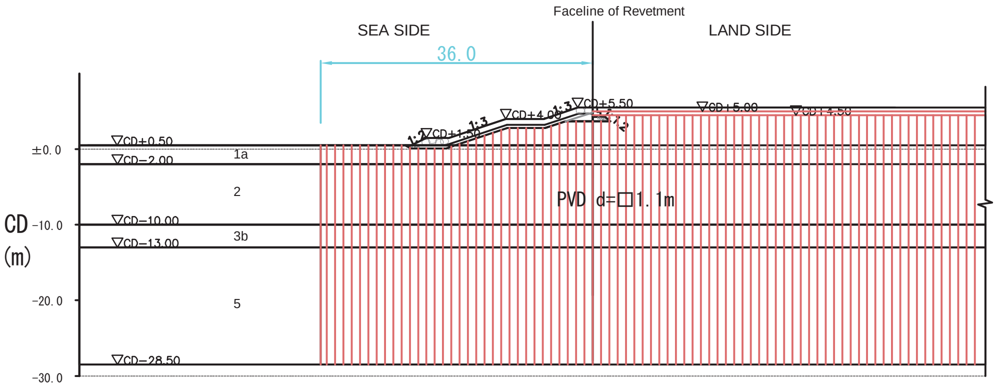
Pavement and Inner Revetment
construction



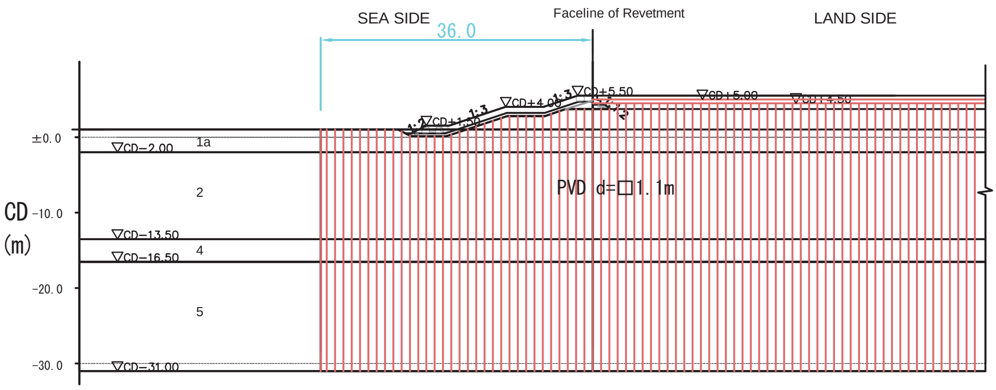
Step 7 (5 years later)

Fill for Port extension area

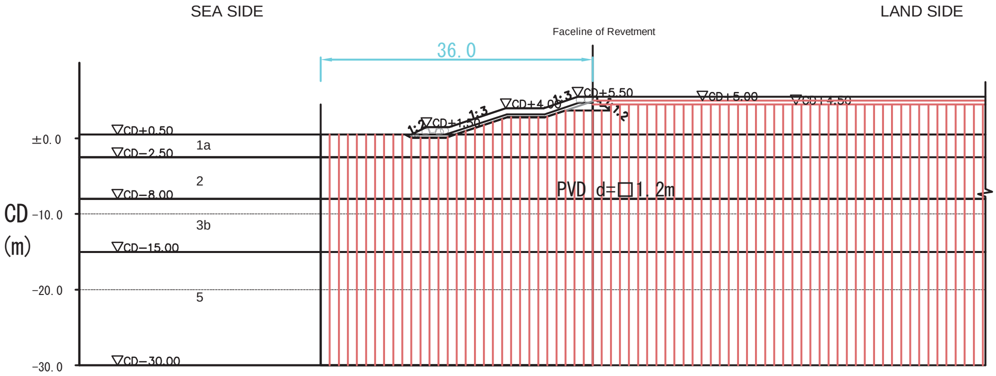
Inner Revetment IR-1



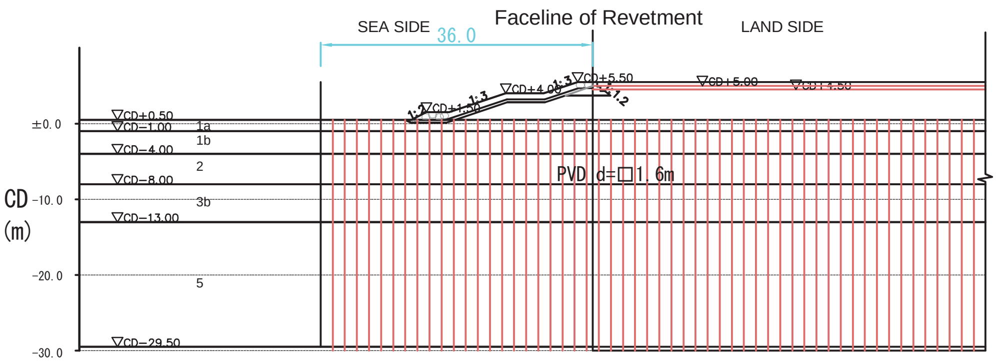
Inner Revetment IR-2



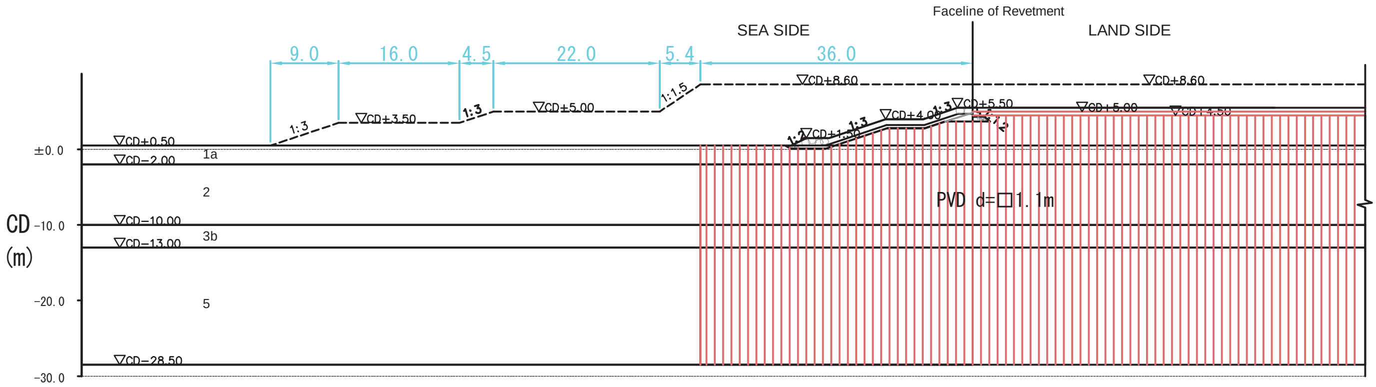
Inner Revetment IR-3



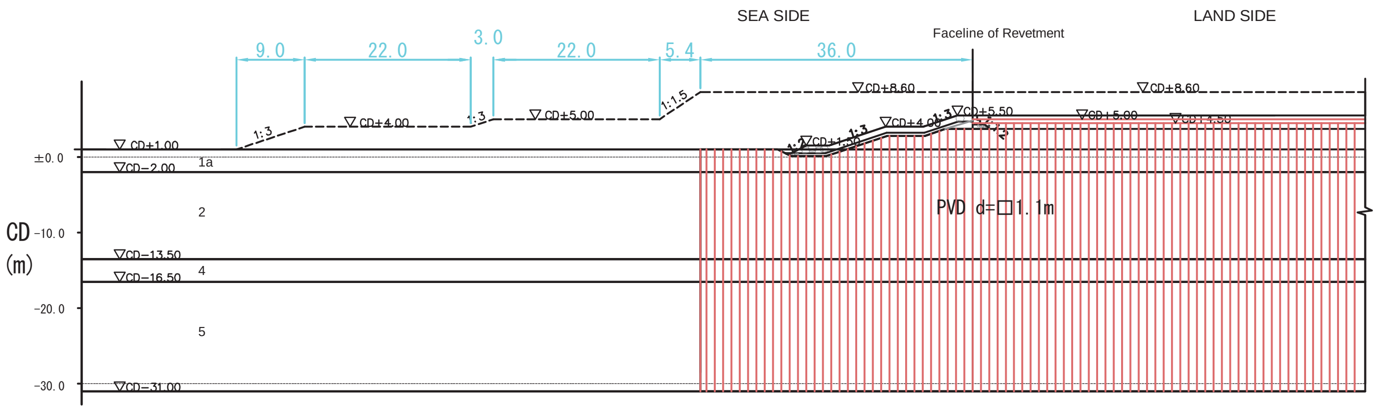
Inner Revetment IR-4



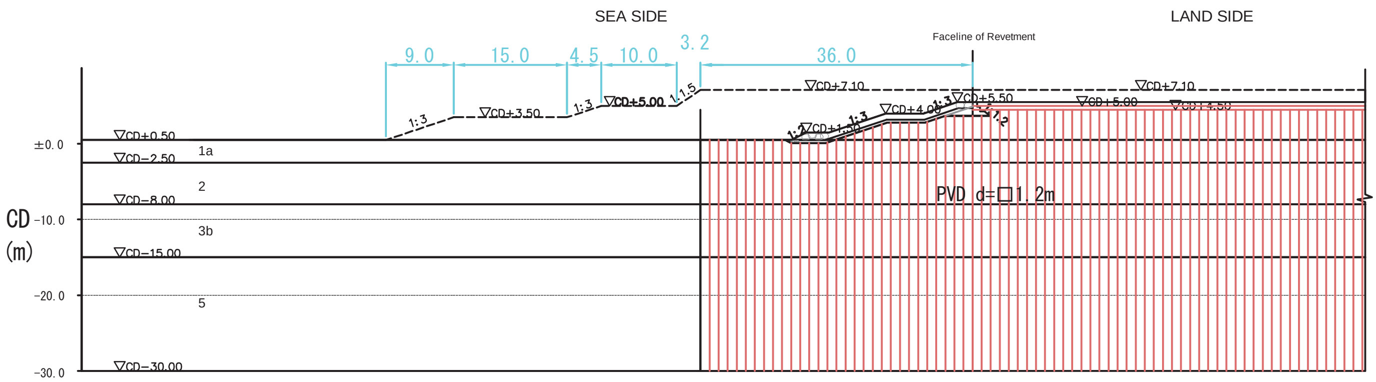
Inner Revetment IR-1



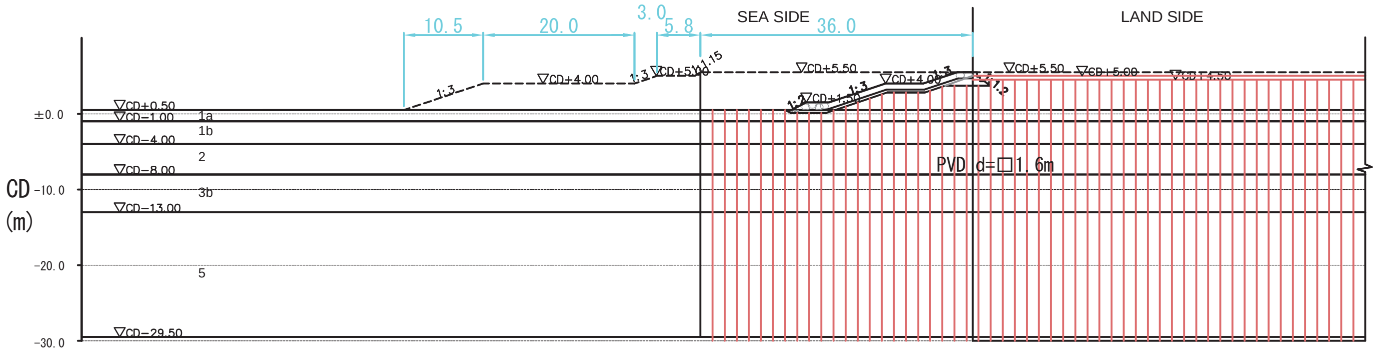
Inner Revetment IR-2



Inner Revetment IR-3



Inner Revetment IR-4



5) Economical Comparison between PVD+Preload Method and Sand Replacement Method for Outer Revetment A

Economical Comparison between PVD+Preload and Sand Replacement Method for Outer Revetment A

Outer Revetment A PVD(□1.6m)

per 1m

Item	Spec.	Unit	Quantity	Unit Price (VND)	Price (VND)	Remarks
Fill	CD+5.00	m3	450.0	171,756	77,290,200	
Preload	CD+8.00 (H=3.00m)	m3	150.2	191,271	28,728,904	
Removal of Preload		m3	562.0	36,632	20,587,184	
Installation of PVD	d□=1.6m	m	375.0	8,994	3,372,750	32m/point
Total					129,979,038	

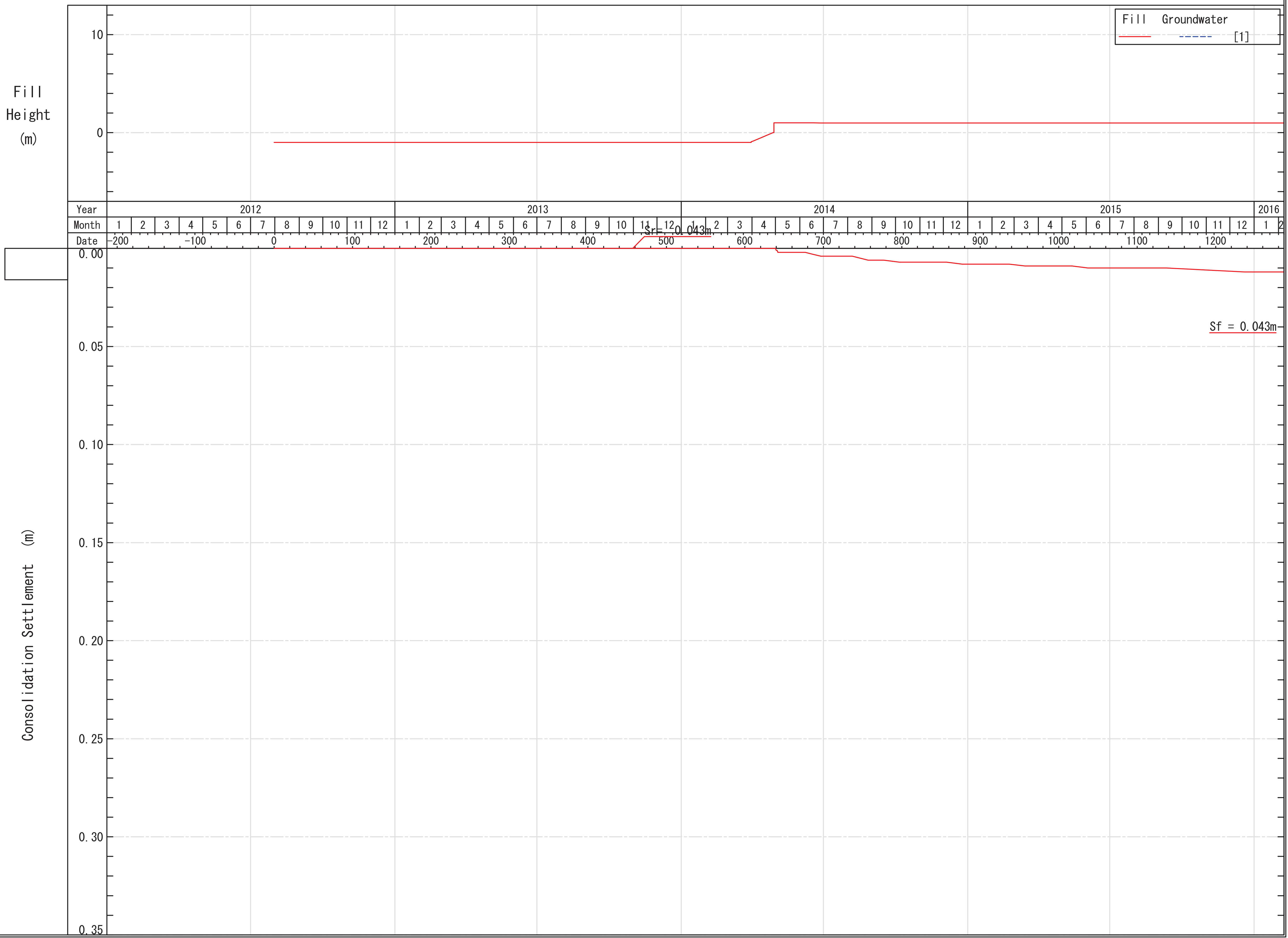
Outer Revetment A Sand Replacement

per 1m

Item	Spec.	Unit	Quantity	Unit Price (VND)	Price (VND)	Remarks
Sand replacement	Excavation and Fill	m3	691.2	196,948	136,130,458	
Total					136,130,458	

6) Slope Stability Analysis Result and Settlement-Time Curves with Sand Replacement Method for Outer Revetment A

Settlement - Time Curve   Outer Revetment A improved by by Sand Replacement Method



Type	Scale
Date	0.200mm/d
Fill	2.500mm/m
Settlement	500.000mm/m

File Name 1:[14-置換(護岸法線).Ptw]

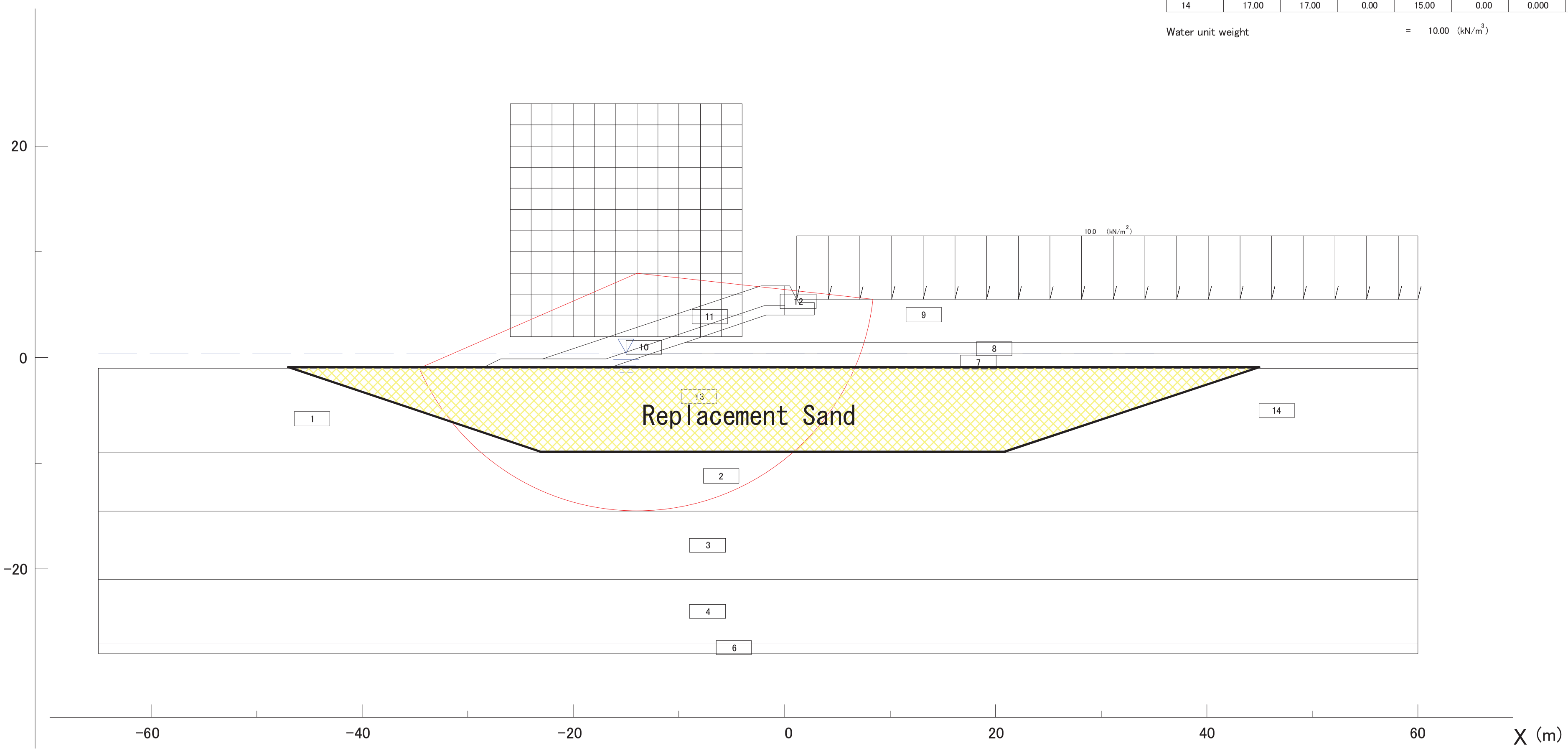
Outer Revetment A (Sand Replacement Method)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.080	
Center of arc	X	=	−14.00	(m)
	Y	=	8.00	(m)
Radius	R	=	22.50	(m)
Resisting moment	M_R	=	28018.1	(kNm)
Sliding moment	M_D	=	25950.2	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	17.50	17.50	0.00	40.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	16.50	11.50	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	17.00	17.00	0.00	15.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)

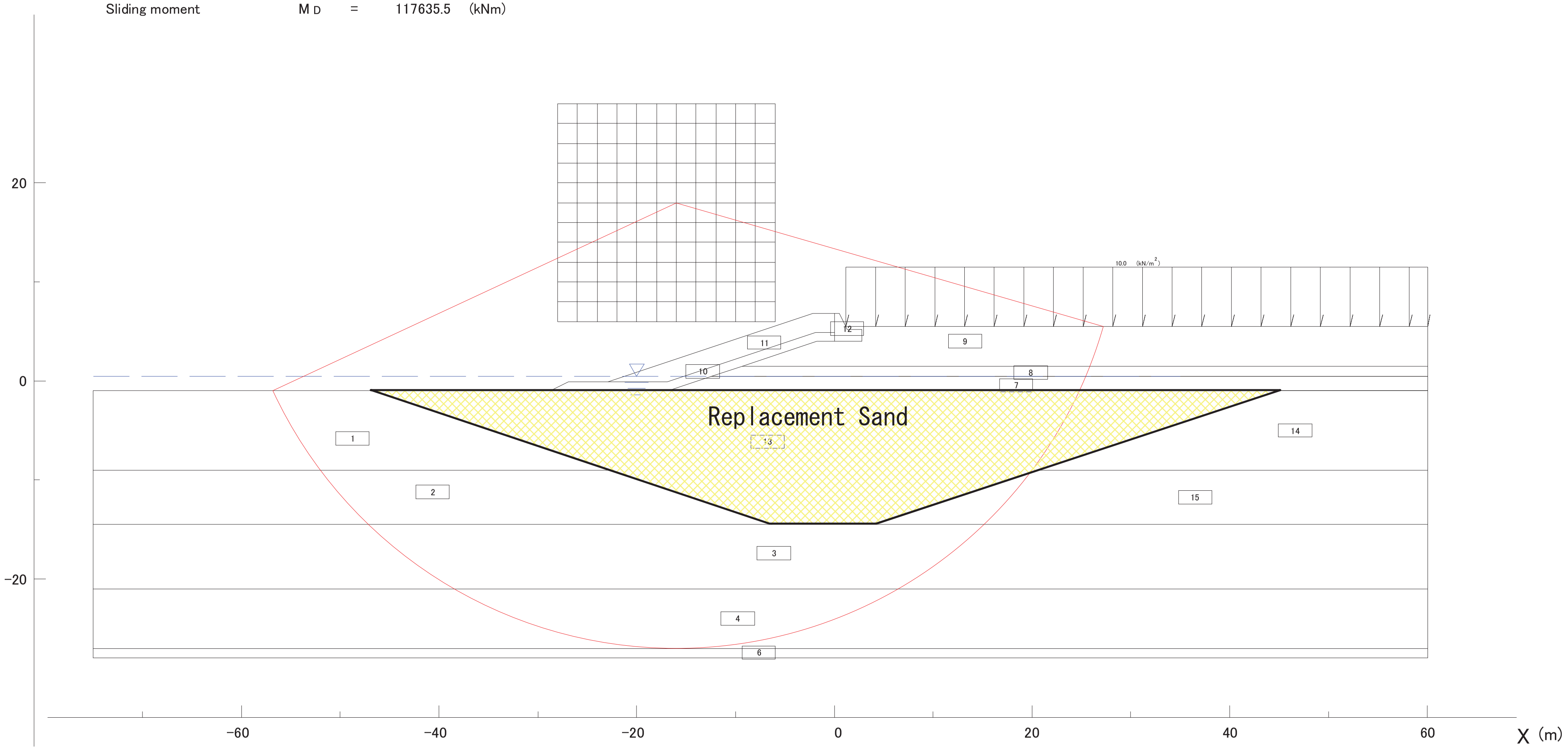


Safety Factor (Ordinary Condition)

Outer Revetment A (Sand Replacement Method)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.345	
Center of arc	X	=	−16.00	(m)
	Y	=	18.00	(m)
Radius	R	=	45.00	(m)
Resisting moment	M_R	=	158245.5	(kNm)
Sliding moment	M_D	=	117635.5	(kNm)



Safety Factor (Ordinary Condition)

7) Slope Stability Analysis Result for Outer Revetment A

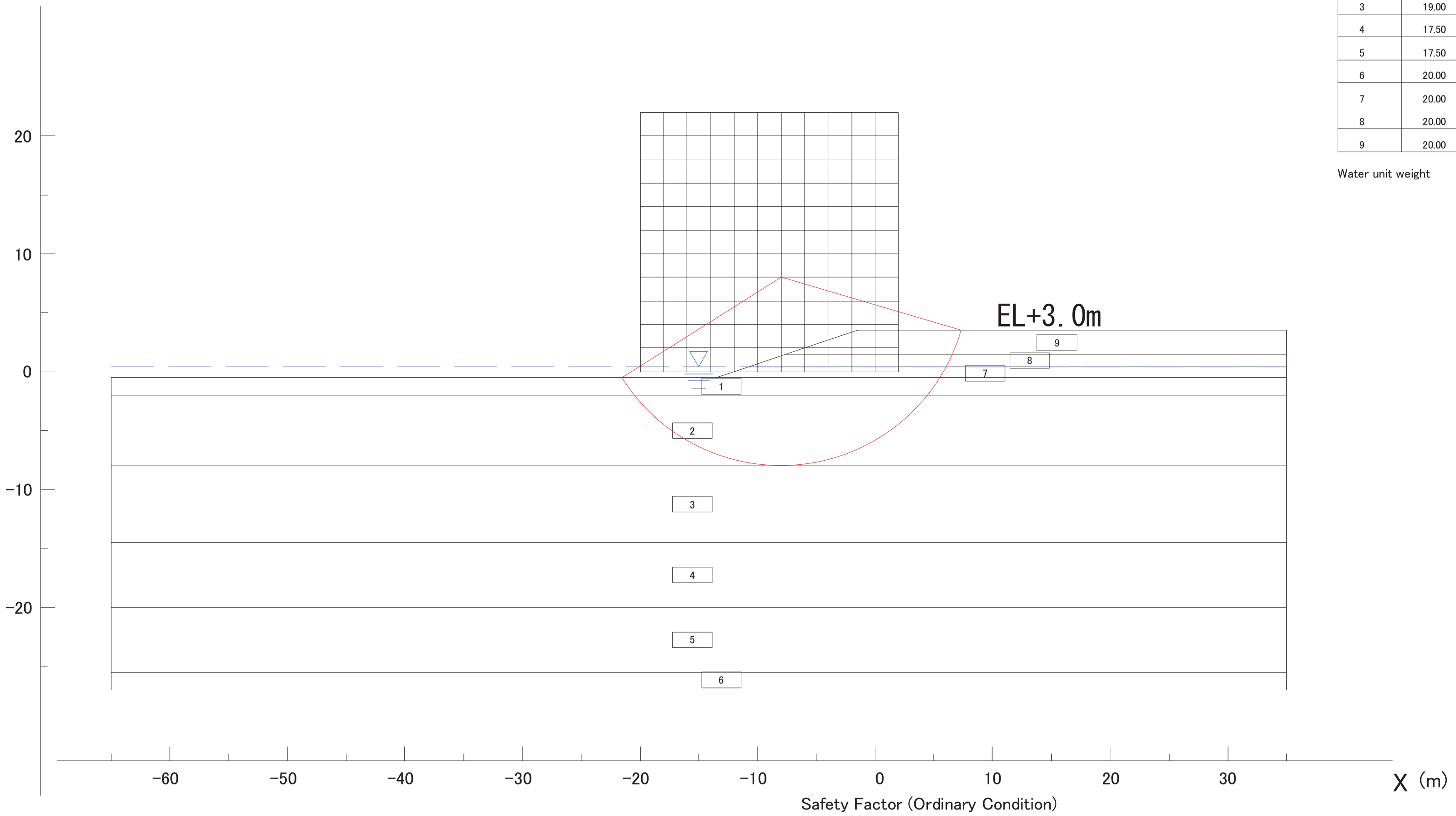
ラックフェン港−外側護岸−1 1段目:+5.0m(小段 h=3.8m L=16m)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.191	
Center of arc	X	=	−8.00	(m)
	Y	=	8.00	(m)
Radius	R	=	16.00	(m)
Resisting moment	M R	=	8066.0	(kNm)
Sliding moment	M D	=	6770.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



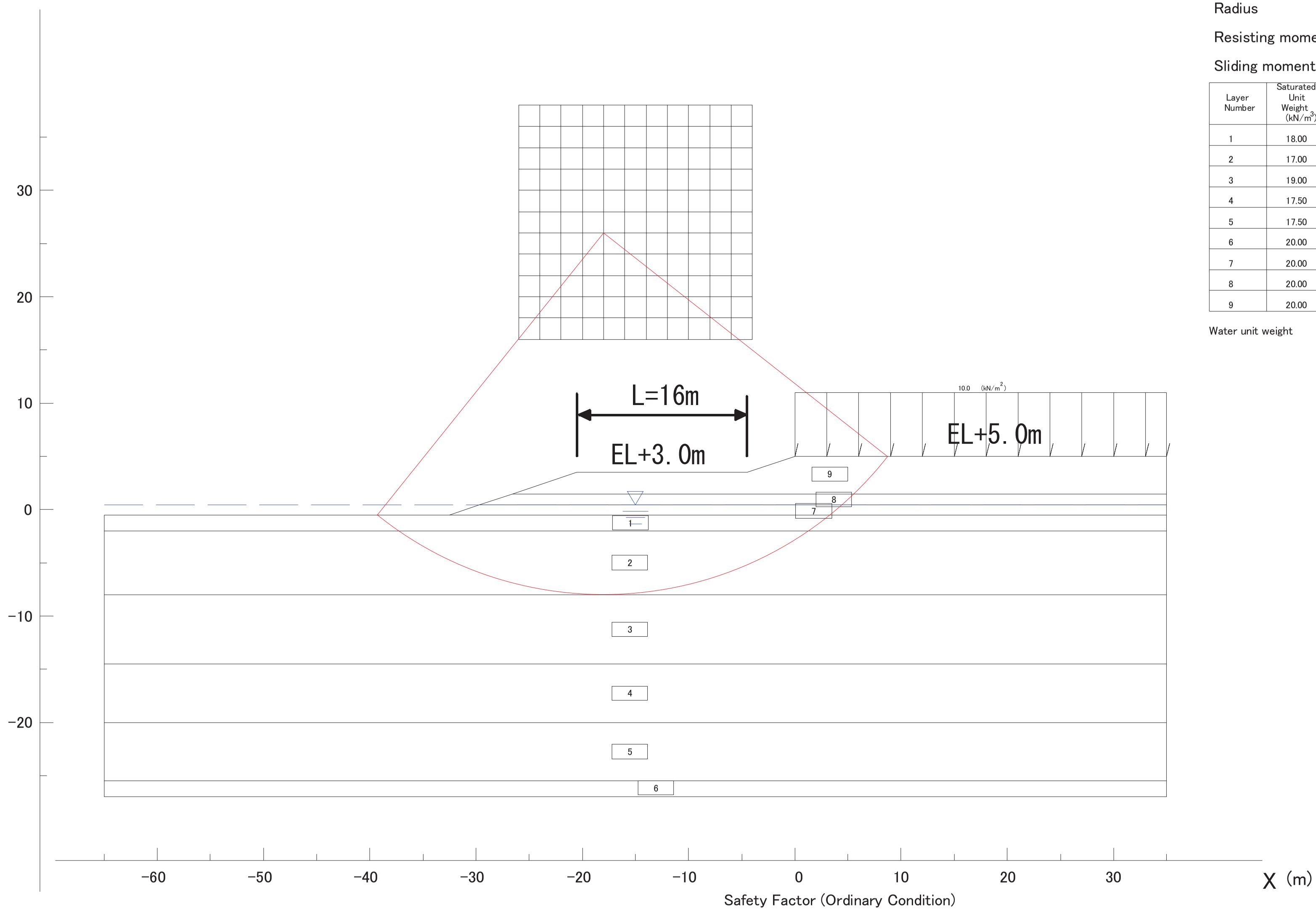
ラックフェン港−外側護岸−1 1段目:+5.0m(小段 h=3.8m L=16m)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.149	
Center of arc	X	=	−18.00	(m)
	Y	=	26.00	(m)
Radius	R	=	34.00	(m)
Resisting moment	M R	=	27615.8	(kNm)
Sliding moment	M D	=	24027.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



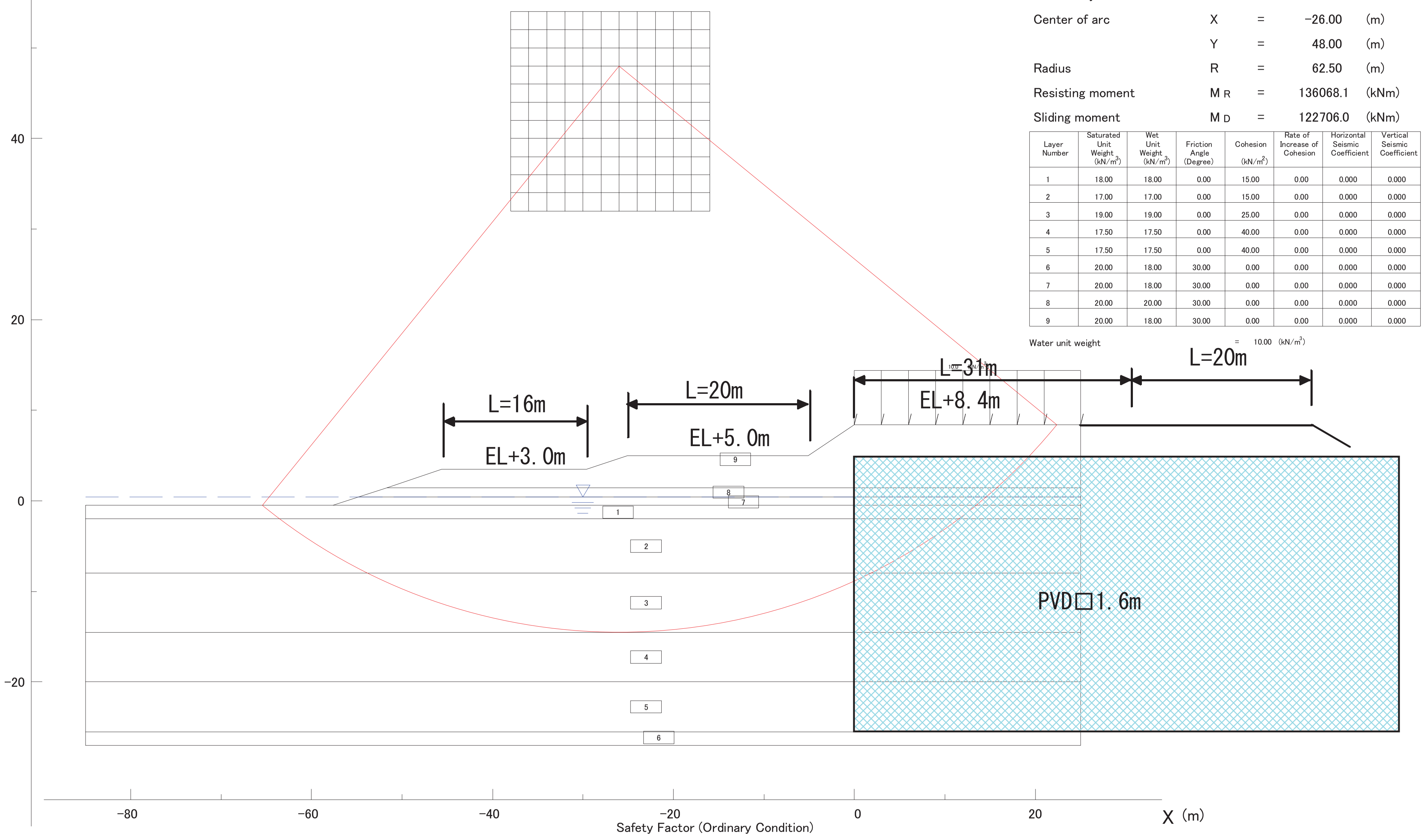
ラックフェン港−外側護岸−1 2段目:+8.4m(小段 h=5.0m L=20m)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.109	
Center of arc	X	=	−26.00	(m)
	Y	=	48.00	(m)
Radius	R	=	62.50	(m)
Resisting moment	M R	=	136068.1	(kNm)
Sliding moment	M D	=	122706.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

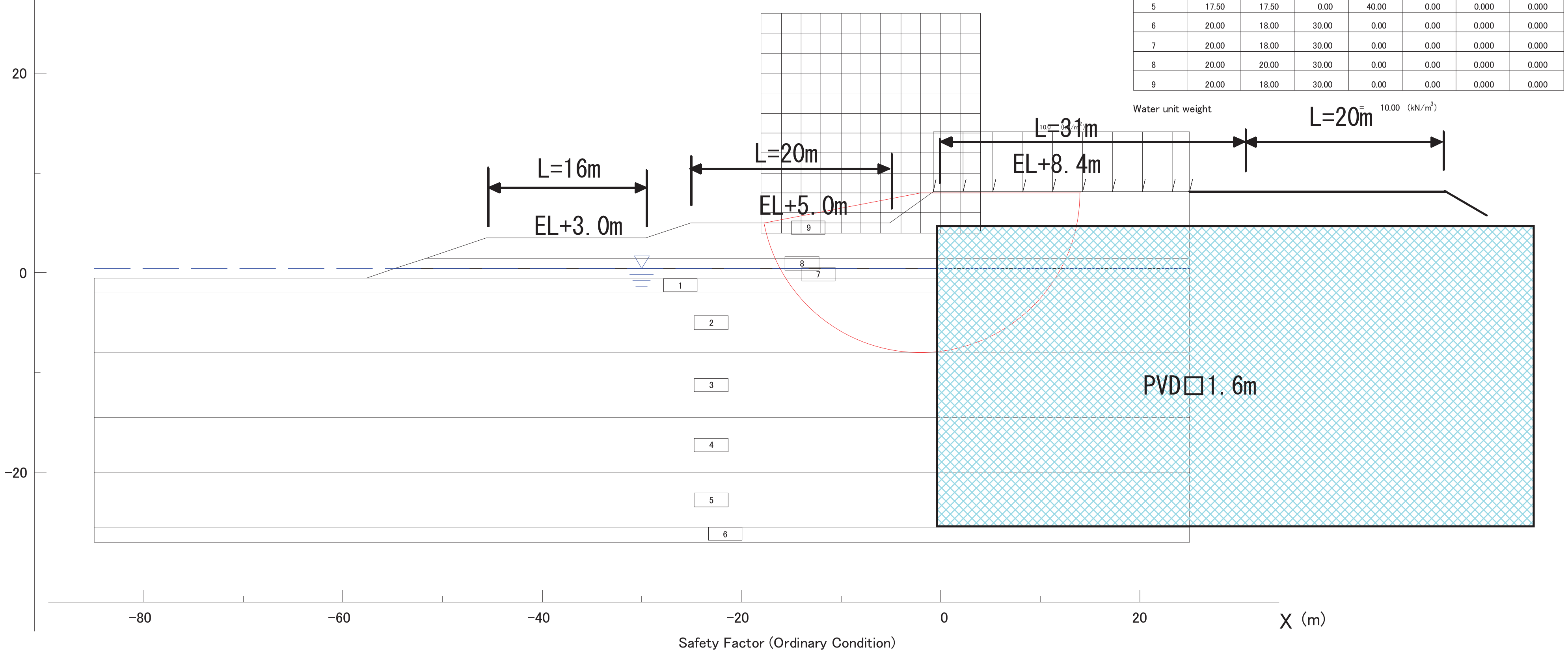
ラックフェン港-外側護岸-1 2段目:+8.4m(小段 h=5.0m L=20m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.102	
Center of arc	X	=	-2.00	(m)
	Y	=	8.00	(m)
Radius	R	=	16.00	(m)
Resisting moment	M_R	=	9230.2	(kNm)
Sliding moment	M_D	=	8378.8	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



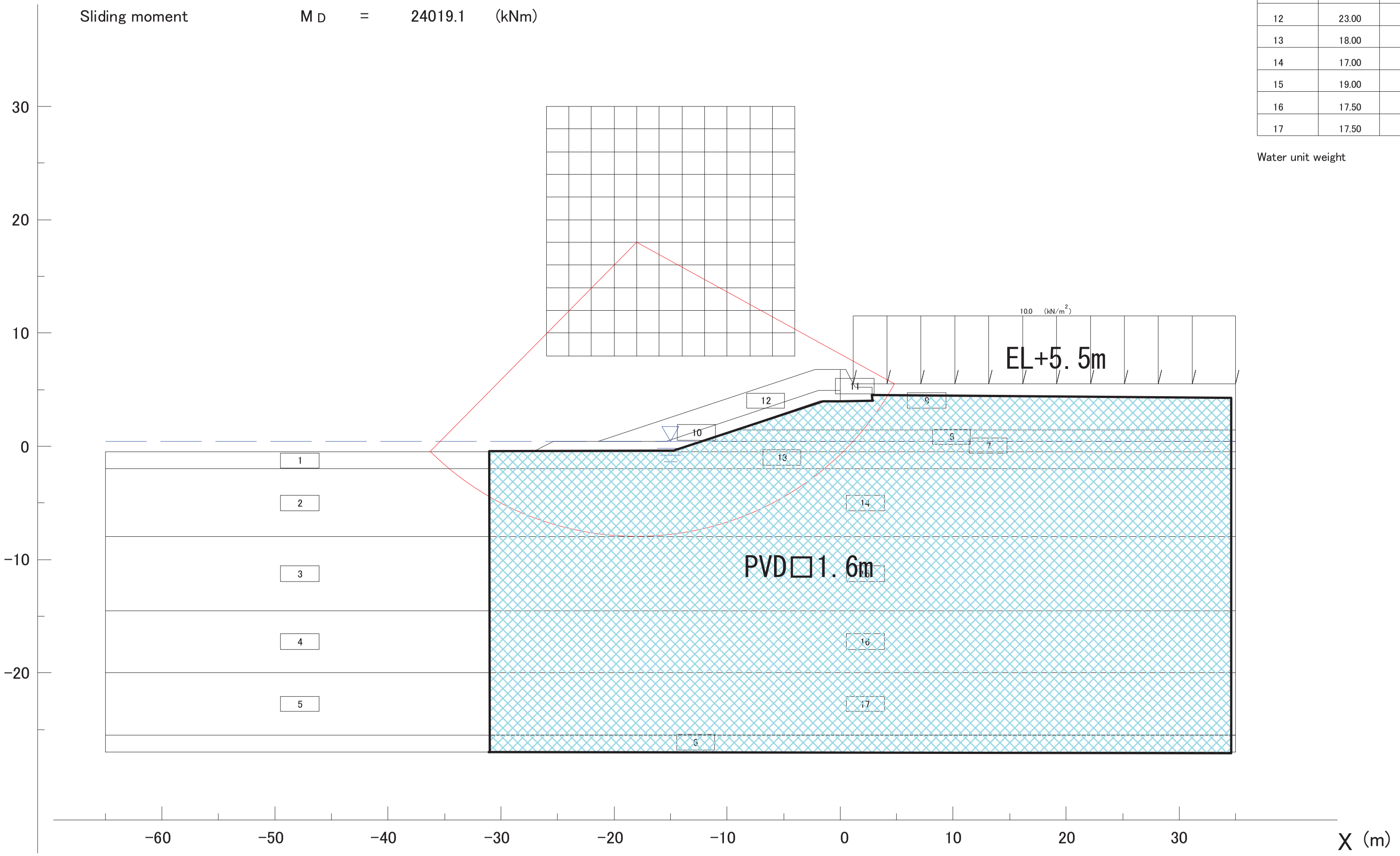
ラックフェン港−外側護岸−1 完成形(改良幅=31m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.303	
Center of arc	X	=	−18.00	(m)
	Y	=	18.00	(m)
Radius	R	=	26.00	(m)
Resisting moment	M_R	=	31286.9	(kNm)
Sliding moment	M_D	=	24019.1	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	16.50	11.50	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	18.00	18.00	0.00	27.02	0.00	0.000	0.000
14	17.00	17.00	0.00	29.99	0.00	0.000	0.000
15	19.00	19.00	0.00	37.85	0.00	0.000	0.000
16	17.50	17.50	0.00	47.38	0.00	0.000	0.000
17	17.50	17.50	0.00	46.81	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

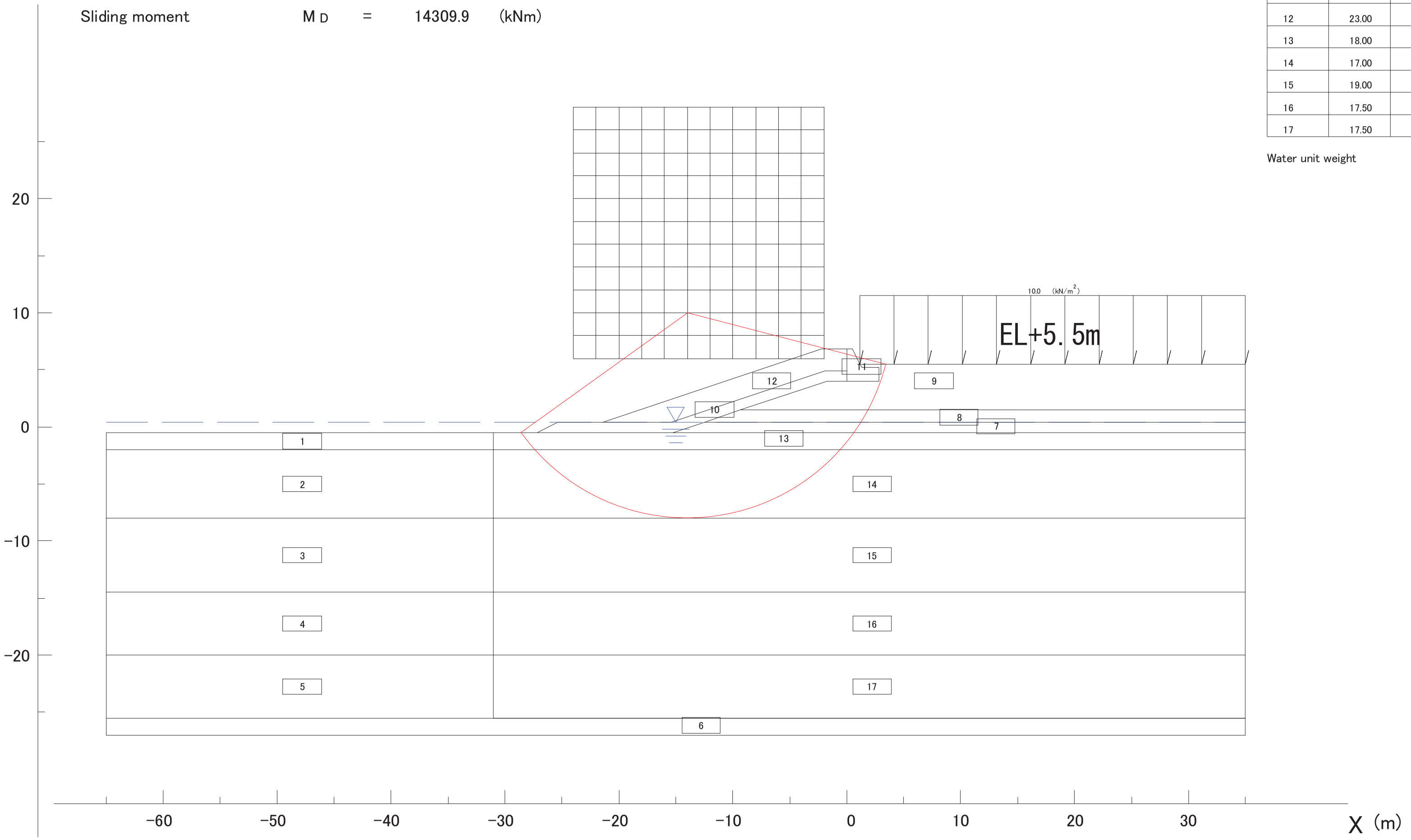
ラックフェン港-外側護岸-1 完成形(無処理)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	0.701	
Center of arc	X	=	-14.00	(m)
	Y	=	10.00	(m)
Radius	R	=	18.00	(m)
Resisting moment	M_R	=	10031.0	(kNm)
Sliding moment	M_D	=	14309.9	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	25.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	16.50	11.50	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	18.00	18.00	0.00	15.00	0.00	0.000	0.000
14	17.00	17.00	0.00	15.00	0.00	0.000	0.000
15	19.00	19.00	0.00	25.00	0.00	0.000	0.000
16	17.50	17.50	0.00	40.00	0.00	0.000	0.000
17	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



Safety Factor (Ordinary Condition)

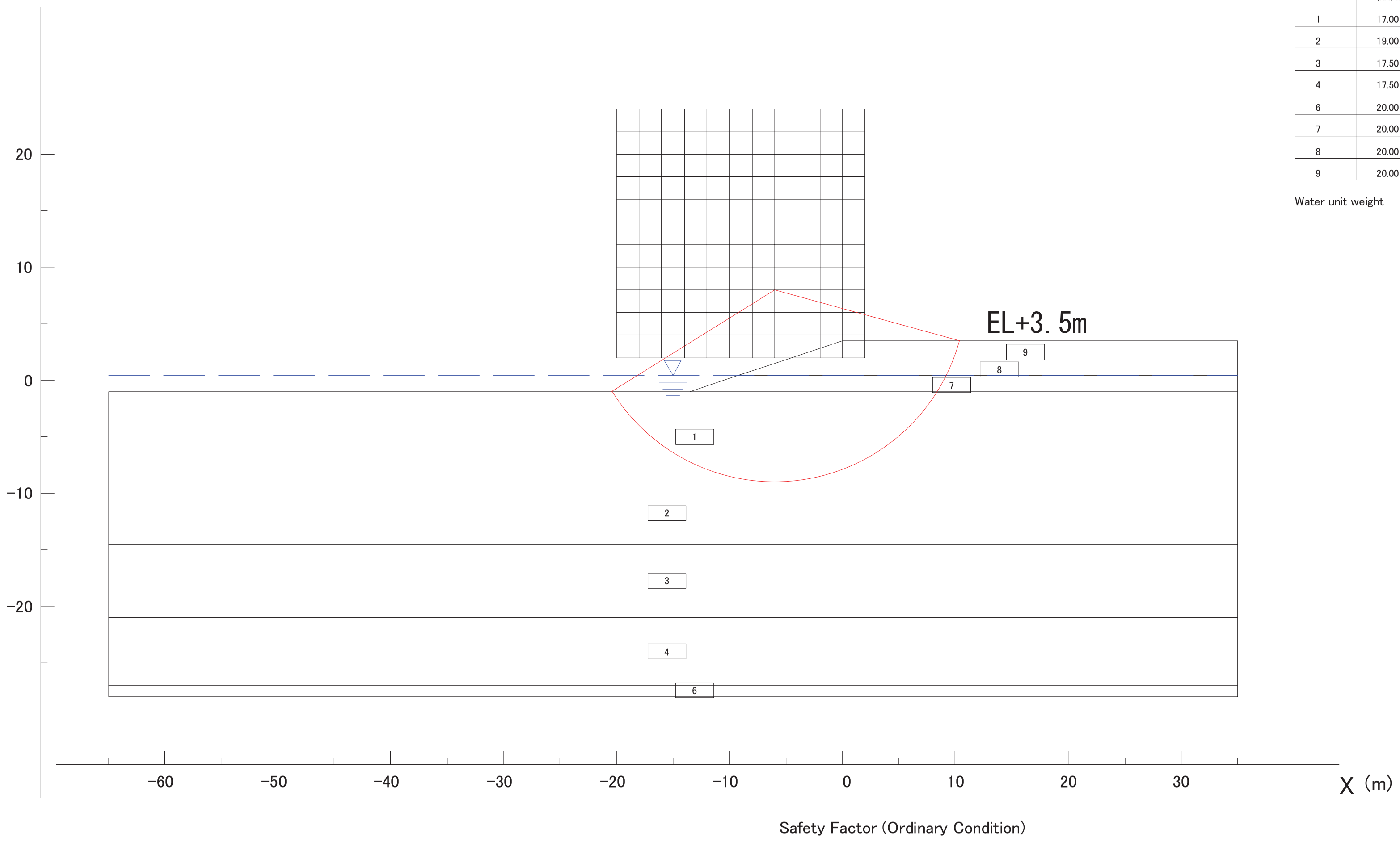
ラックフェン港-外側護岸-2 1段目:限界盛土H=+3.5m

Scale ; 1/ 600

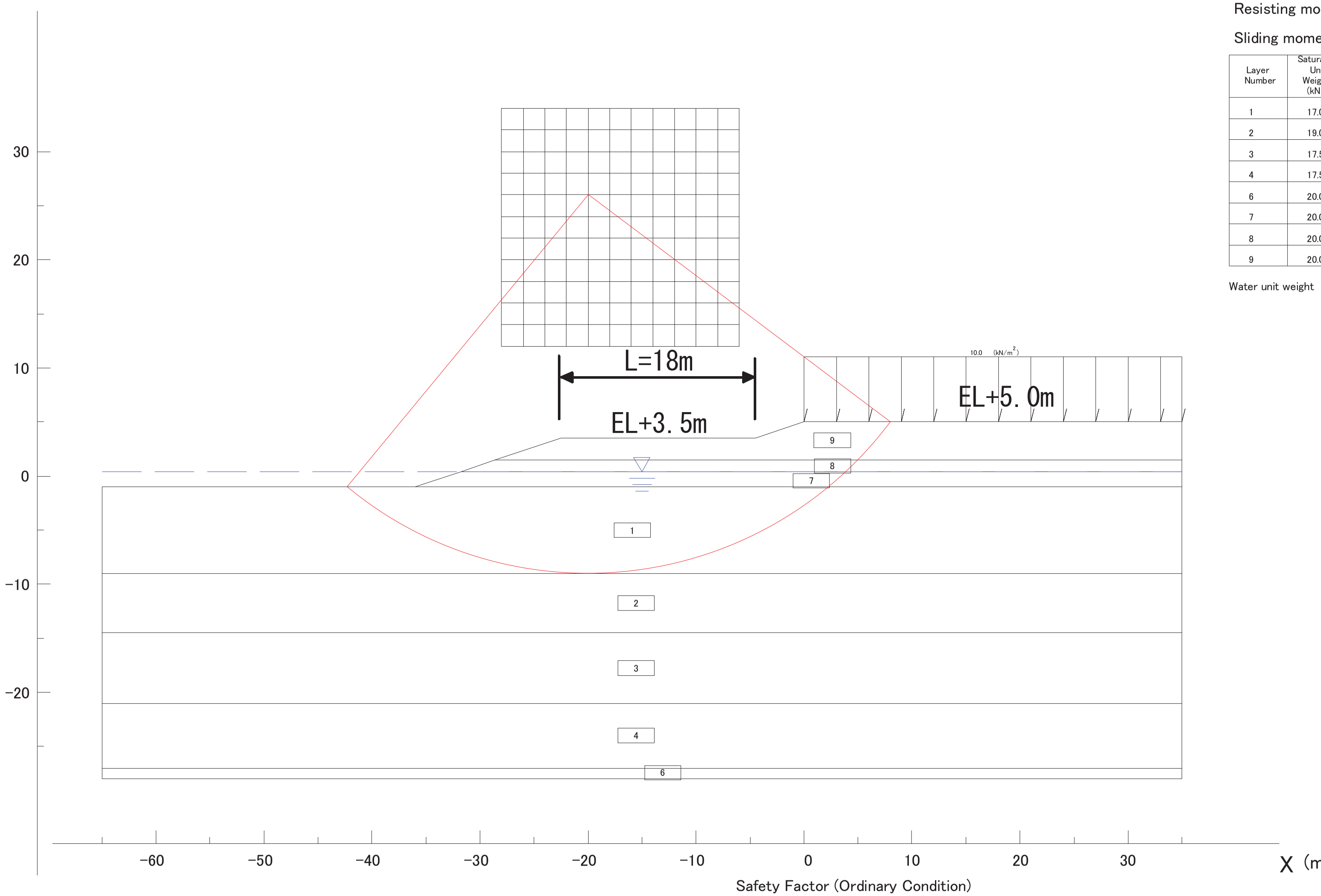
Min. safety factor	$F_{S\,MIN}$	=	1.103	
Center of arc	X	=	−6.00	(m)
	Y	=	8.00	(m)
Radius	R	=	17.00	(m)
Resisting moment	M_R	=	9167.9	(kNm)
Sliding moment	M_D	=	8310.2	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	17.50	17.50	0.00	40.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



ラックフェン港-外側護岸-2 1段目:+5.0m(小段+3.5m L=18m)



Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.115	
Center of arc	X	=	-20.00	(m)
	Y	=	26.00	(m)
Radius	R	=	35.00	(m)
Resisting moment	M R	=	30116.9	(kNm)
Sliding moment	M D	=	27009.7	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	17.50	17.50	0.00	40.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)

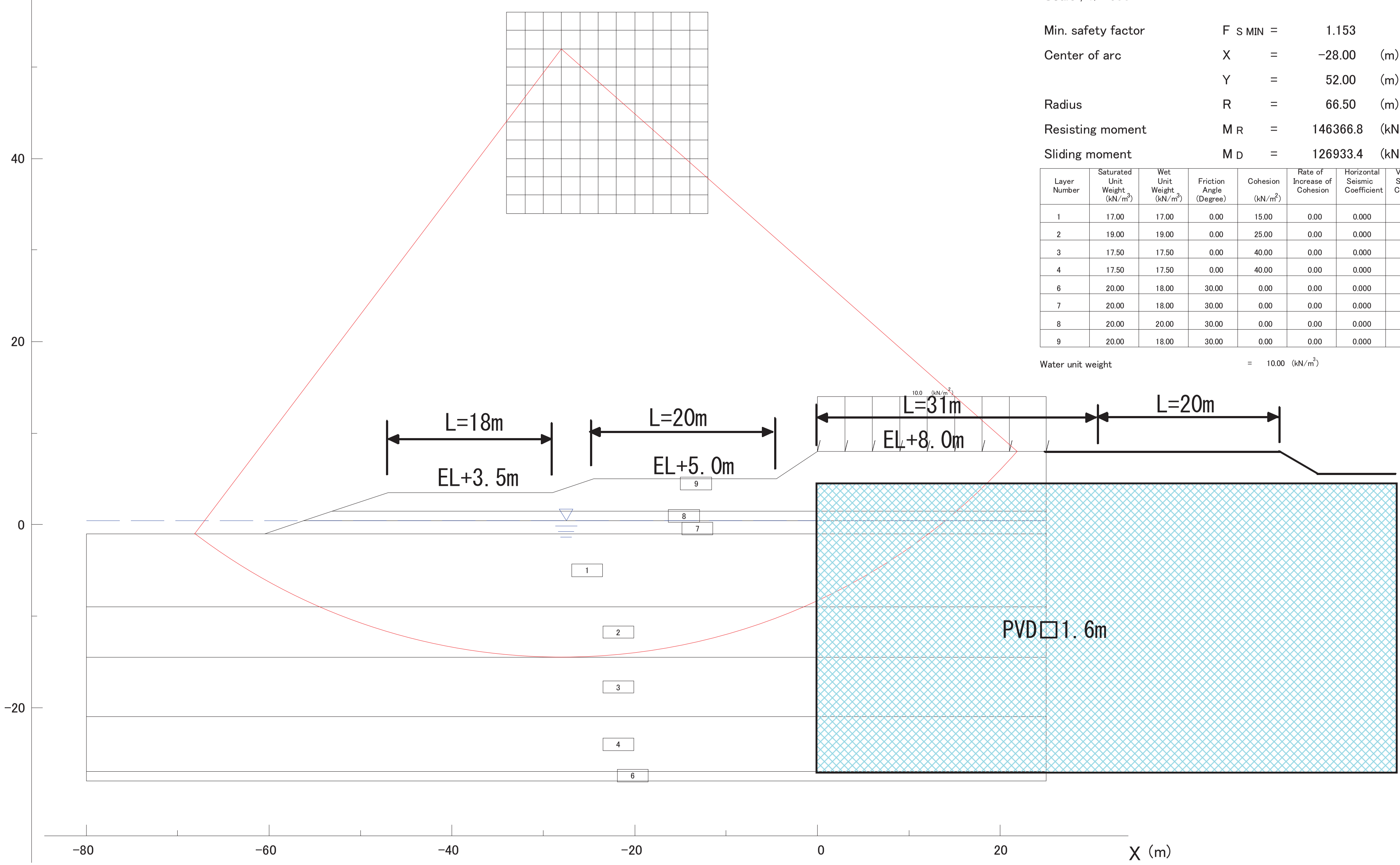
ラックフェン港-外側護岸-2 2段目:+8.0m(小段+5.0m L=18m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.153	
Center of arc	X	=	-28.00	(m)
	Y	=	52.00	(m)
Radius	R	=	66.50	(m)
Resisting moment	M_R	=	146366.8	(kNm)
Sliding moment	M_D	=	126933.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	17.50	17.50	0.00	40.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

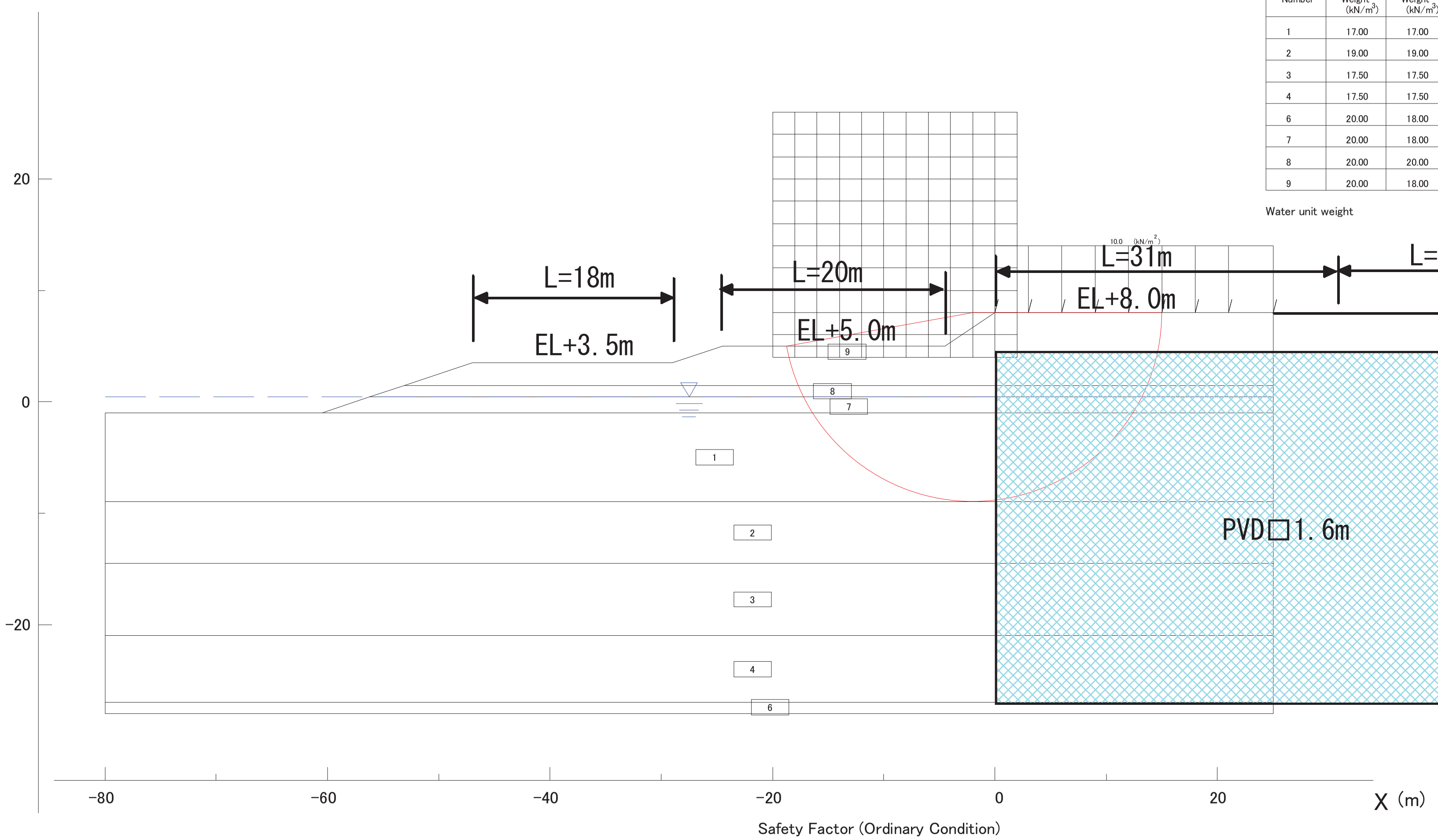
ラックフェン港-外側護岸-2 2段目:+8.0m(小段+5.0m L=18m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$ =	1.154	
Center of arc	X =	-2.00	(m)
	Y =	8.00	(m)
Radius	R =	17.00	(m)
Resisting moment	M_R =	10497.3	(kNm)
Sliding moment	M_D =	9098.7	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	17.50	17.50	0.00	40.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



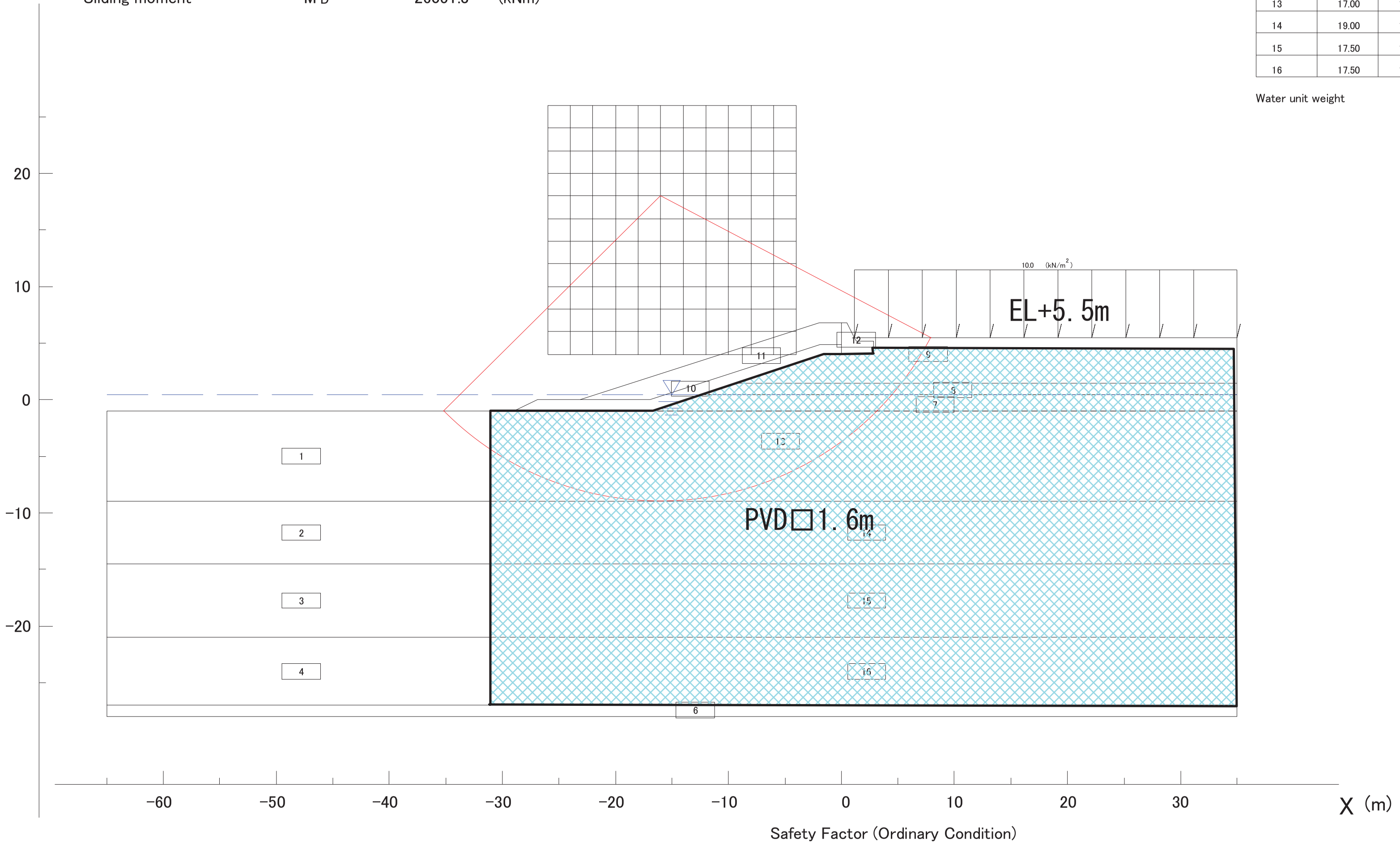
ラックフェン港-外側護岸-2 完成形(改良幅=30m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.315	
Center of arc	X	=	−16.00	(m)
	Y	=	18.00	(m)
Radius	R	=	27.00	(m)
Resisting moment	M_R	=	34252.3	(kNm)
Sliding moment	M_D	=	26051.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	17.50	17.50	0.00	40.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	16.50	11.50	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	17.00	17.00	0.00	28.92	0.00	0.000	0.000
14	19.00	19.00	0.00	37.74	0.00	0.000	0.000
15	17.50	17.50	0.00	47.36	0.00	0.000	0.000
16	17.50	17.50	0.00	46.75	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



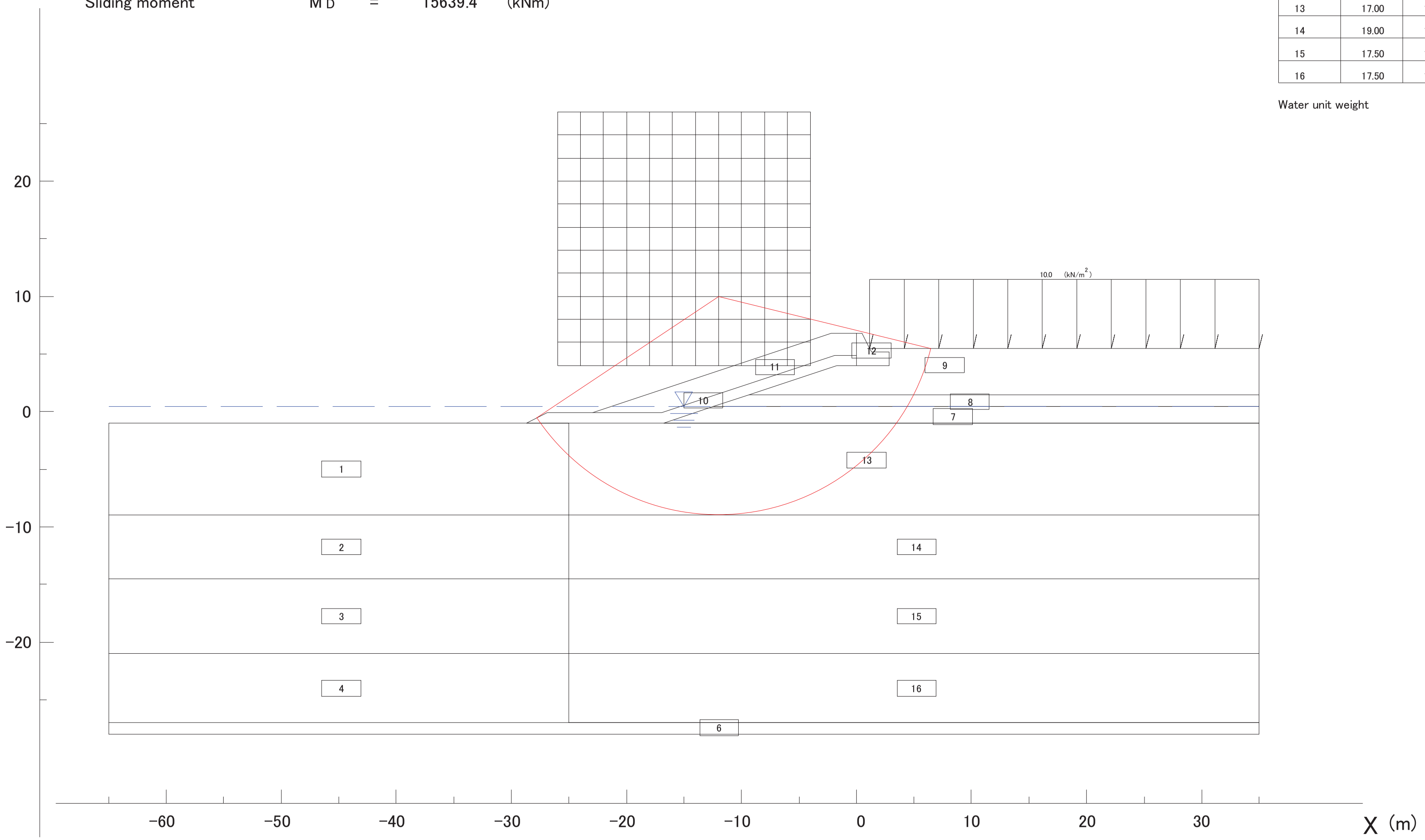
ラックフェン港-外側護岸-2 1段目:+5.0m(小段+3.5m L=18m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	0.728	
Center of arc	X	=	-12.00	(m)
	Y	=	10.00	(m)
Radius	R	=	19.00	(m)
Resisting moment	M_R	=	11385.6	(kNm)
Sliding moment	M_D	=	15639.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	17.50	17.50	0.00	40.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	40.00	0.00	0.00	0.000	0.000
11	16.50	11.50	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	17.00	17.00	0.00	15.00	0.00	0.000	0.000
14	19.00	19.00	0.00	25.00	0.00	0.000	0.000
15	17.50	17.50	0.00	40.00	0.00	0.000	0.000
16	17.50	17.50	0.00	40.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



Safety Factor (Ordinary Condition)

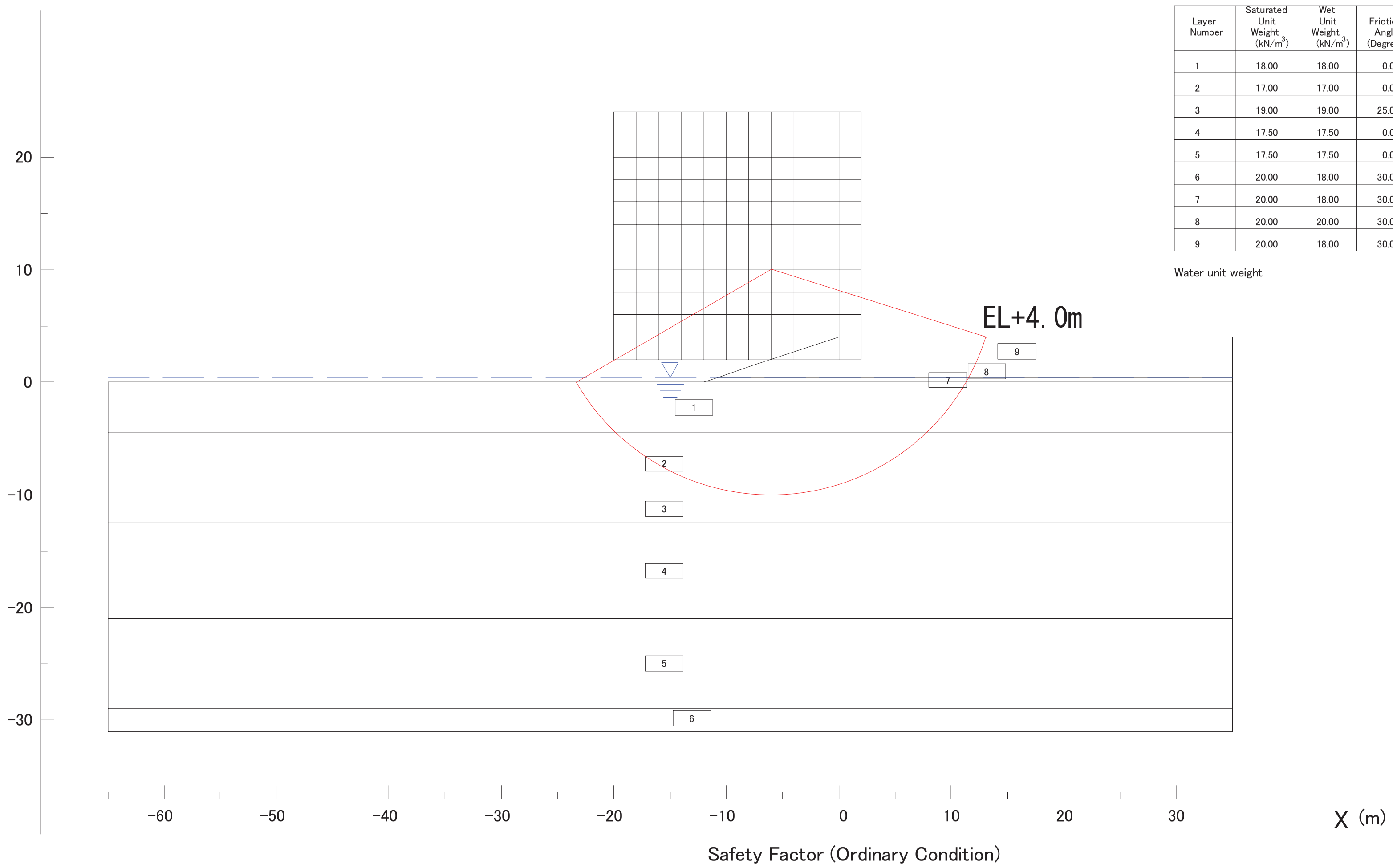
ラックフェン港-外側護岸-3 1段目:限界盛土H=+4.10m

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.127	
Center of arc	X	=	-6.00	(m)
	Y	=	10.00	(m)
Radius	R	=	20.00	(m)
Resisting moment	M_R	=	12921.4	(kNm)
Sliding moment	M_D	=	11460.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



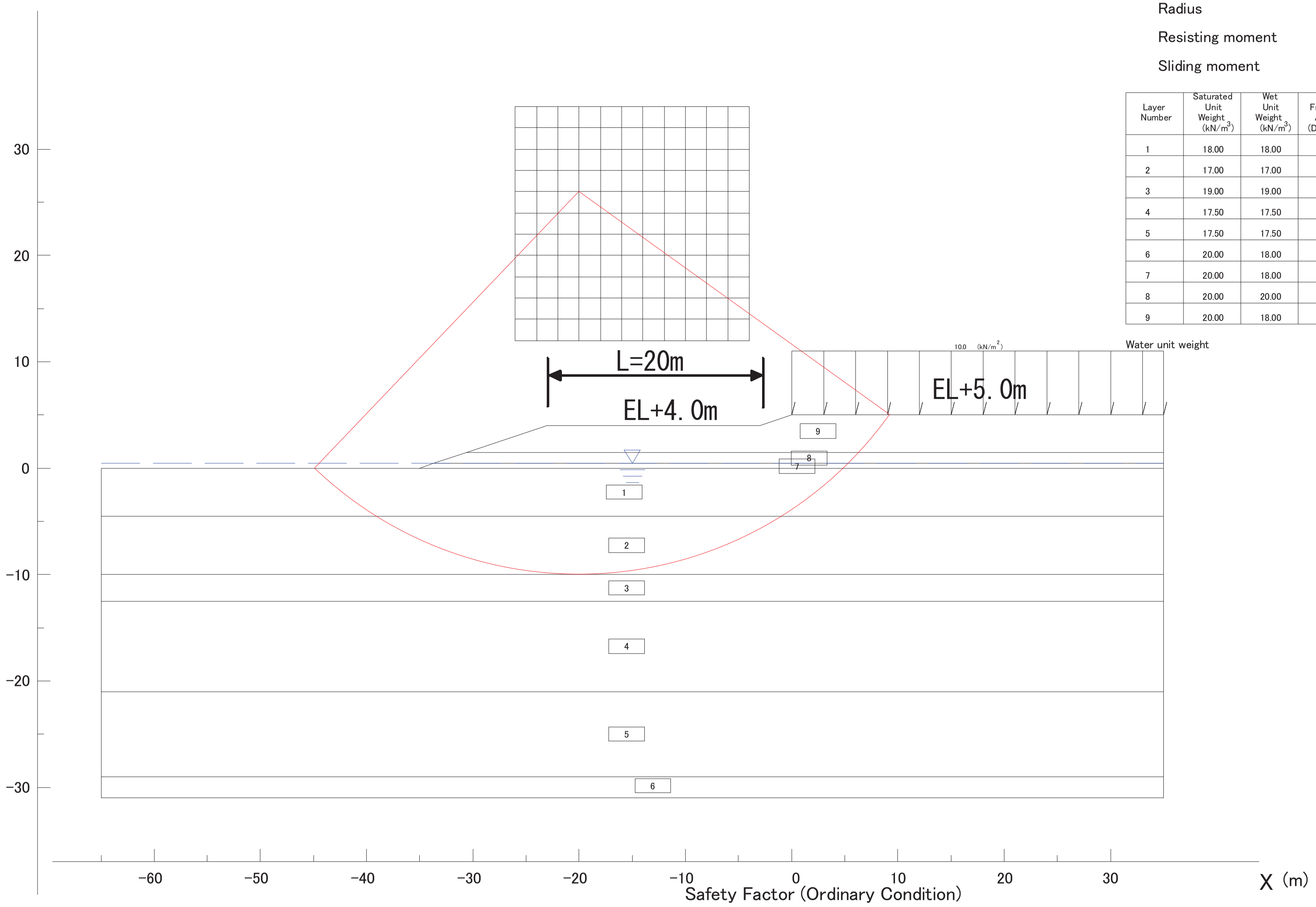
ラックフェン港-外側護岸-3 1段目:+5.00m(小段h=4.1m L=20m)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.125	
Center of arc	X	=	-20.00	(m)
	Y	=	26.00	(m)
Radius	R	=	36.00	(m)
Resisting moment	M R	=	32637.8	(kNm)
Sliding moment	M D	=	29021.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



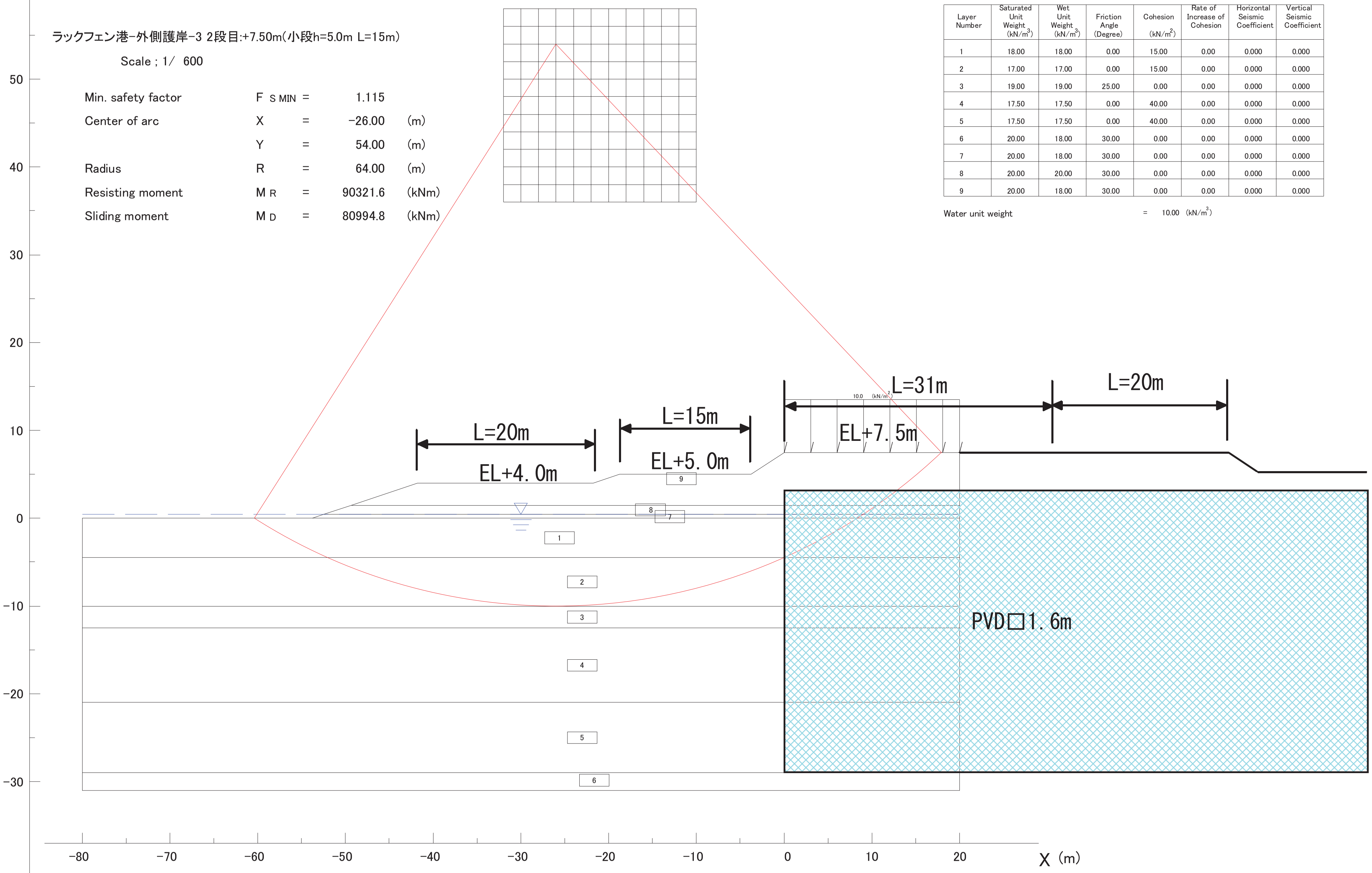
ラックフェン港−外側護岸−3 2段目:+7.50m(小段h=5.0m L=15m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.115	
Center of arc	X	=	−26.00	(m)
	Y	=	54.00	(m)
Radius	R	=	64.00	(m)
Resisting moment	M_R	=	90321.6	(kNm)
Sliding moment	M_D	=	80994.8	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

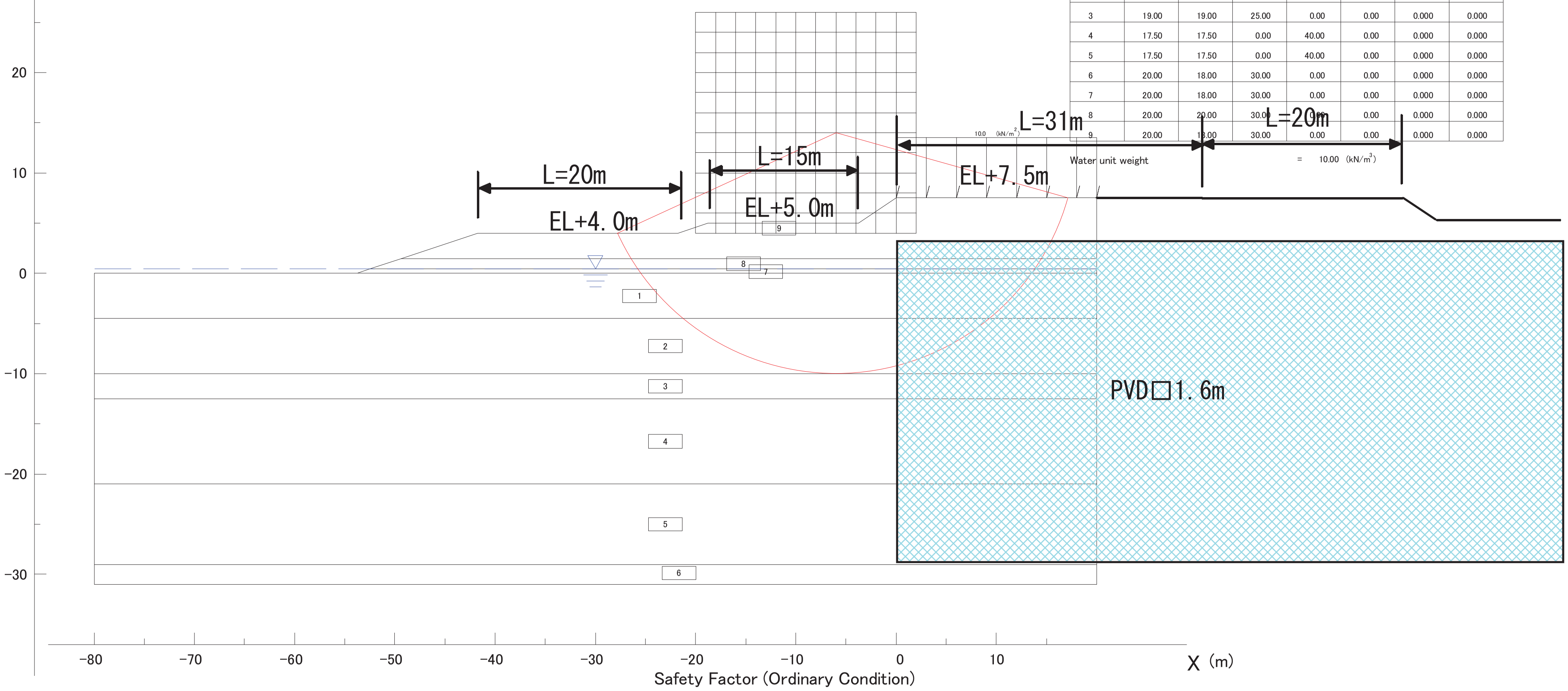
ラックフェン港-外側護岸-3 2段目:+7.50m(小段h=5.0m L=15m)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.170	
Center of arc	X	=	-6.00	(m)
	Y	=	14.00	(m)
Radius	R	=	24.00	(m)
Resisting moment	M R	=	18968.1	(kNm)
Sliding moment	M D	=	16211.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



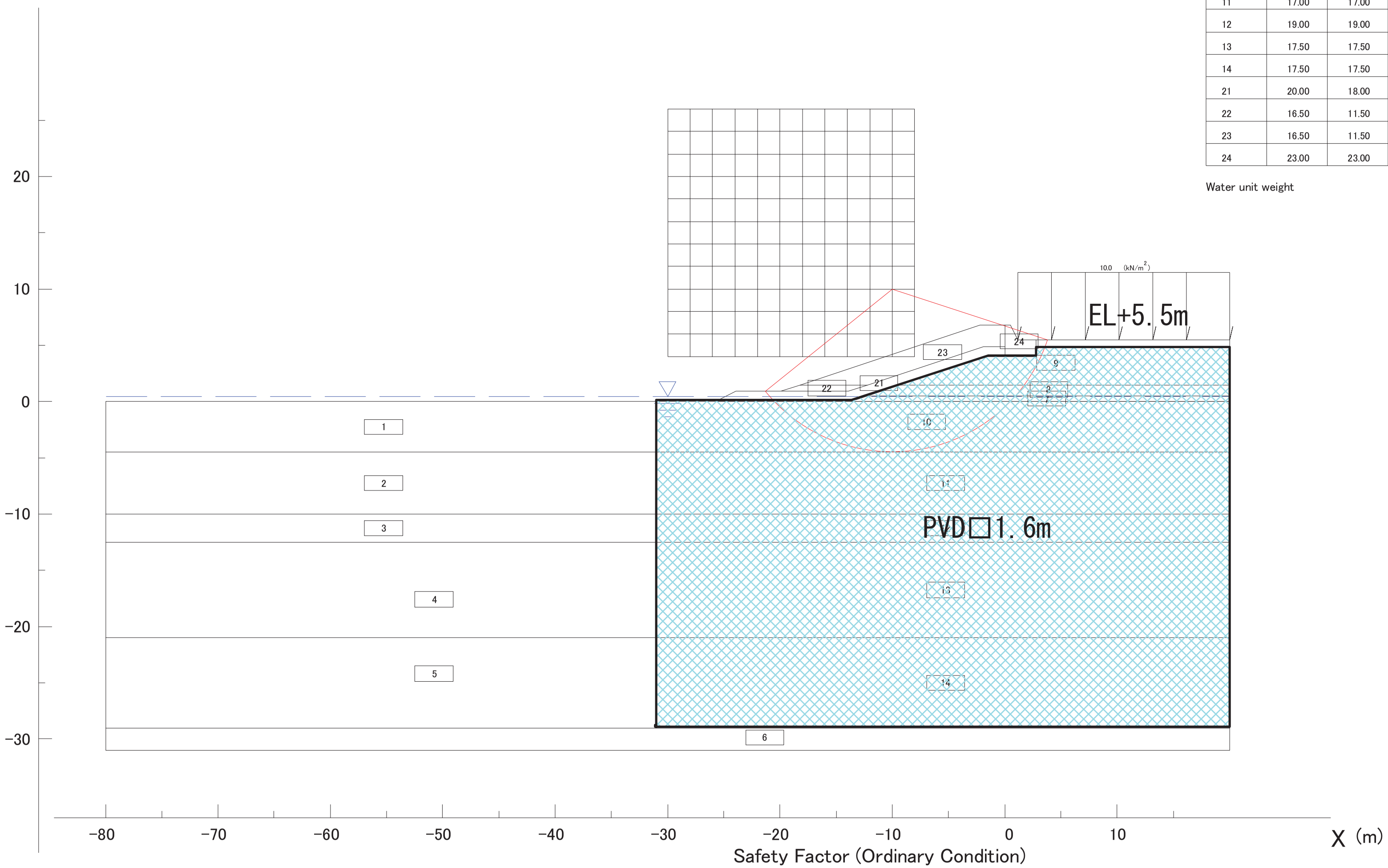
ラックフェン港-外側護岸-3 完成形(改良幅=25m)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.331	
Center of arc	X	=	-10.00	(m)
	Y	=	10.00	(m)
Radius	R	=	14.50	(m)
Resisting moment	M R	=	9418.1	(kNm)
Sliding moment	M D	=	7076.9	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	18.00	18.00	0.00	24.37	0.00	0.000	0.000
11	17.00	17.00	0.00	29.87	0.00	0.000	0.000
12	19.00	19.00	25.00	0.00	0.00	0.000	0.000
13	17.50	17.50	0.00	44.31	0.00	0.000	0.000
14	17.50	17.50	0.00	43.55	0.00	0.000	0.000
21	20.00	18.00	40.00	0.00	0.00	0.000	0.000
22	16.50	11.50	40.00	0.00	0.00	0.000	0.000
23	16.50	11.50	40.00	0.00	0.00	0.000	0.000
24	23.00	23.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



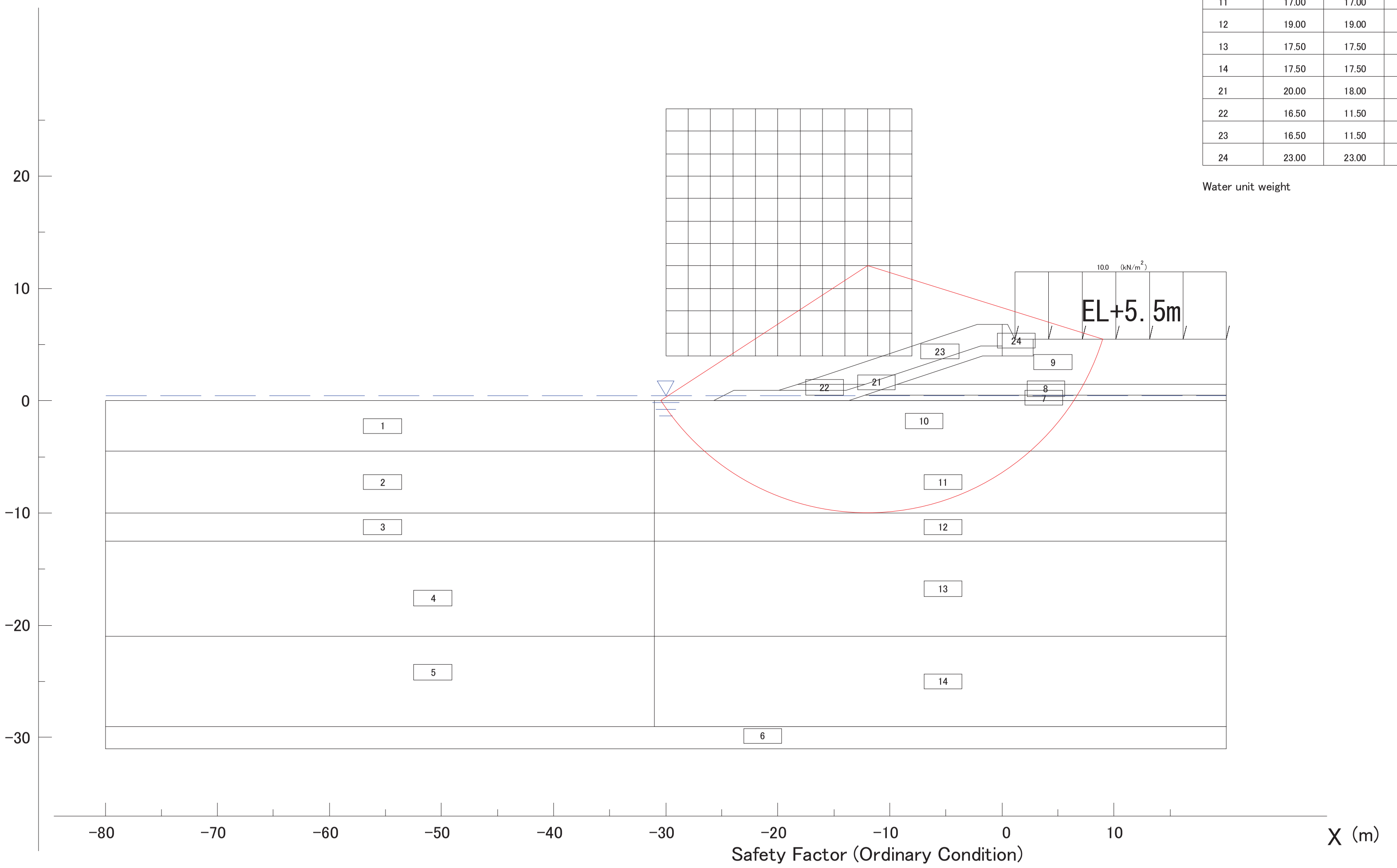
ラックフェン港-外側護岸-3 完成形(改良幅=25m)

Scale ; 1/ 600

Min. safety factor	$F_{S MIN}$	=	0.774	
Center of arc	X	=	−12.00	(m)
	Y	=	12.00	(m)
Radius	R	=	22.00	(m)
Resisting moment	M_R	=	15290.1	(kNm)
Sliding moment	M_D	=	19760.7	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	0.00	15.00	0.00	0.000	0.000
2	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	25.00	0.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
5	17.50	17.50	0.00	40.00	0.00	0.000	0.000
6	20.00	18.00	30.00	0.00	0.00	0.000	0.000
7	20.00	18.00	30.00	0.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	18.00	18.00	0.00	15.00	0.00	0.000	0.000
11	17.00	17.00	0.00	15.00	0.00	0.000	0.000
12	19.00	19.00	25.00	0.00	0.00	0.000	0.000
13	17.50	17.50	0.00	40.00	0.00	0.000	0.000
14	17.50	17.50	0.00	40.00	0.00	0.000	0.000
21	20.00	18.00	40.00	0.00	0.00	0.000	0.000
22	16.50	11.50	40.00	0.00	0.00	0.000	0.000
23	16.50	11.50	40.00	0.00	0.00	0.000	0.000
24	23.00	23.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



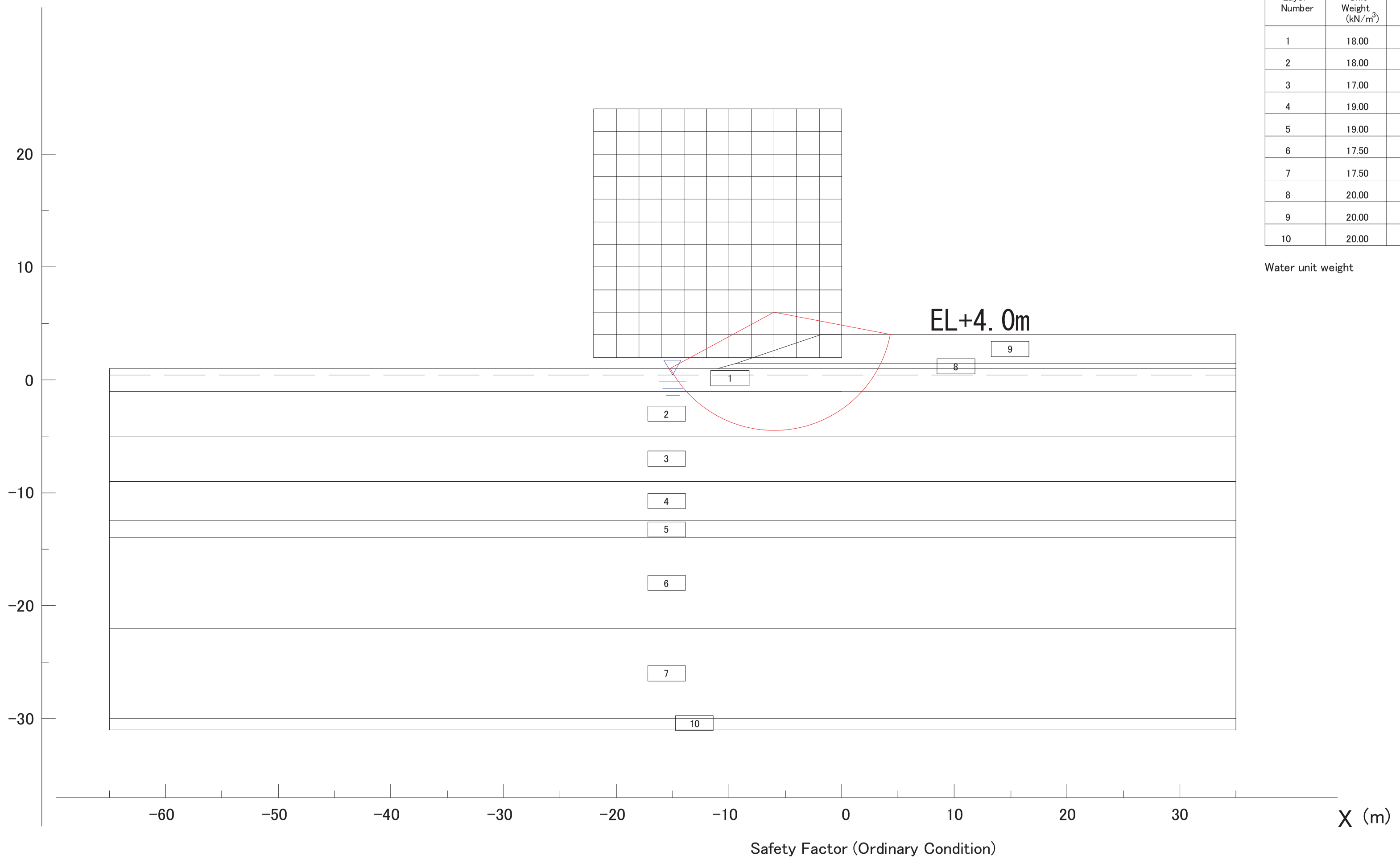
ラックフェン港-外側護岸-4 1段目:+5.00m(小段　h=4.6m L=15m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$ =	1.294	
Center of arc	X =	−6.00	(m)
	Y =	6.00	(m)
Radius	R =	10.50	(m)
Resisting moment	M_R =	3194.8	(kNm)
Sliding moment	M_D =	2469.5	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	19.00	19.00	0.00	50.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	17.50	17.50	0.00	40.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



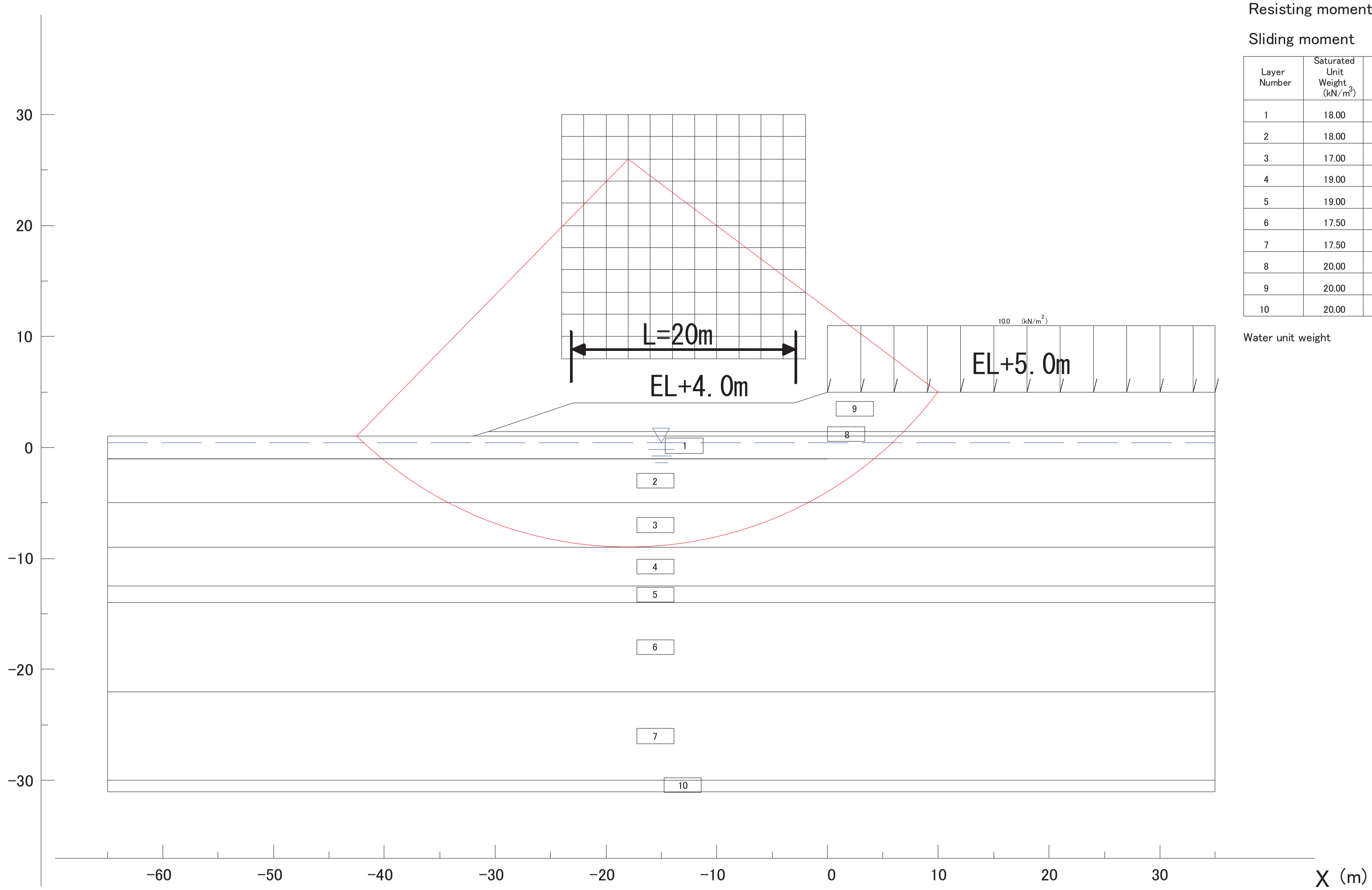
ラックフェン港−外側護岸−4 1段目:+5.00m(小段 h=4.6m L=15m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.331	
Center of arc	X	=	−18.00	(m)
	Y	=	26.00	(m)
Radius	R	=	35.00	(m)
Resisting moment	M_R	=	29852.0	(kNm)
Sliding moment	M_D	=	22433.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	19.00	19.00	0.00	50.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	17.50	17.50	0.00	40.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m³)



Safety Factor (Ordinary Condition)

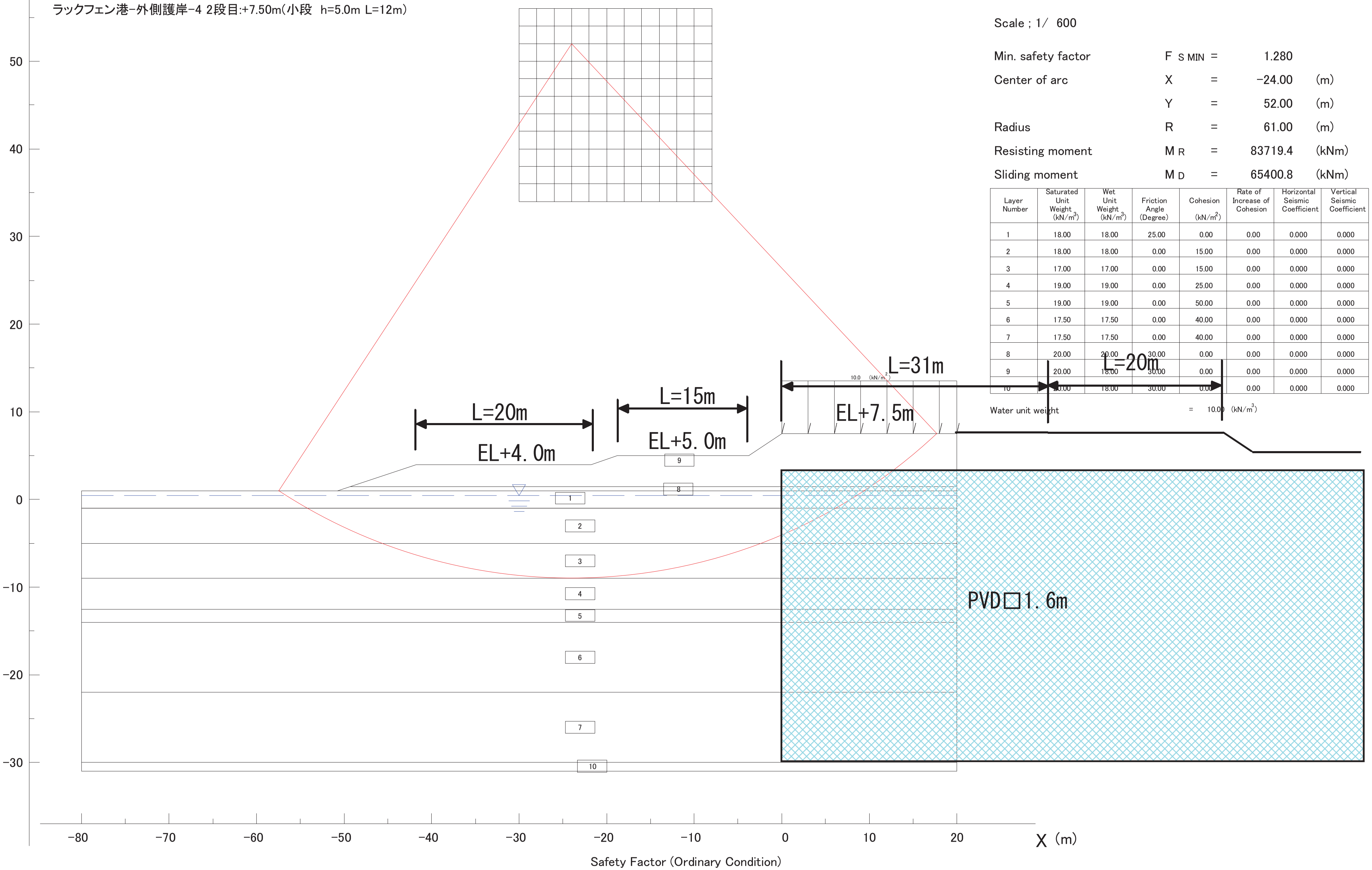
ラックフェン港−外側護岸−4 2段目:+7.50m(小段　h=5.0m L=12m)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.280	
Center of arc	X	=	−24.00	(m)
	Y	=	52.00	(m)
Radius	R	=	61.00	(m)
Resisting moment	M R	=	83719.4	(kNm)
Sliding moment	M D	=	65400.8	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	19.00	19.00	0.00	50.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	17.50	17.50	0.00	40.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



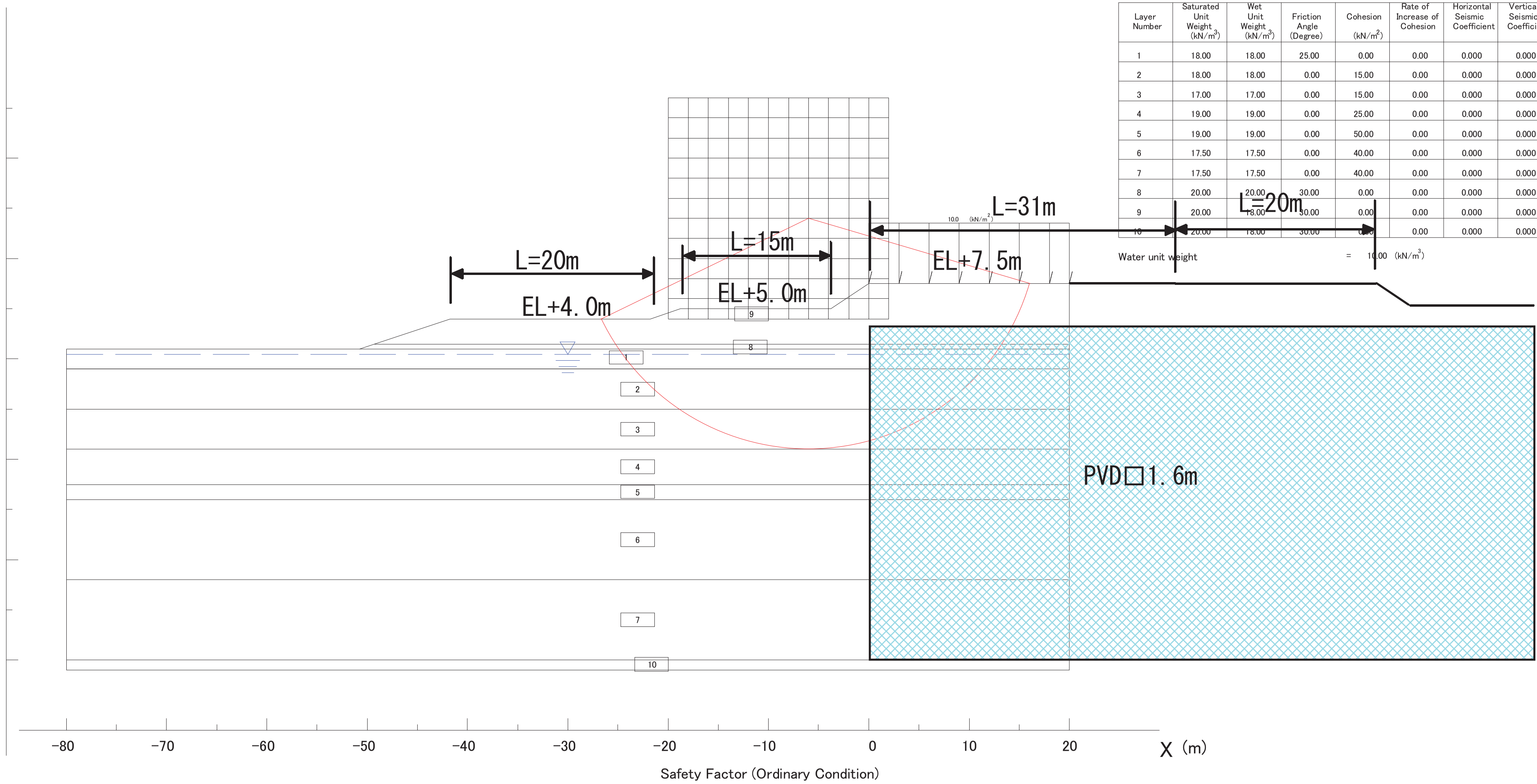
ラックフェン港−外側護岸−4 2段目:+7.50m(小段　h=5.0m L=12m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	1.195	
Center of arc	X	=	−6.00	(m)
	Y	=	14.00	(m)
Radius	R	=	23.00	(m)
Resisting moment	M_R	=	17327.8	(kNm)
Sliding moment	M_D	=	14495.9	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	19.00	19.00	0.00	50.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	17.50	17.50	0.00	40.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



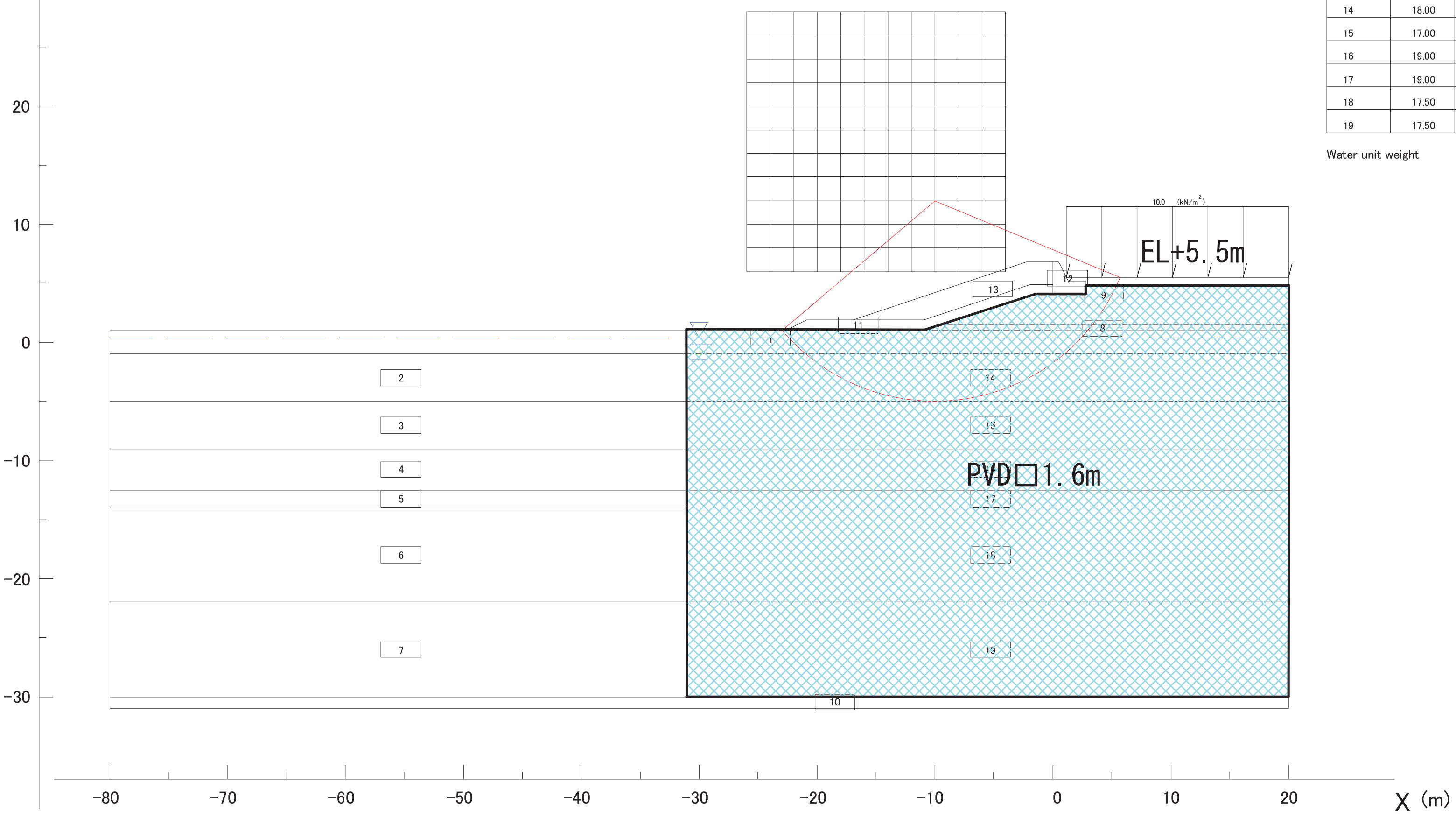
ラックフェン港-外側護岸-4 完成形(改良幅=18m)

Scale ; 1/ 600

Min. safety factor	F S MIN	=	1.420	
Center of arc	X	=	−10.00	(m)
	Y	=	12.00	(m)
Radius	R	=	17.00	(m)
Resisting moment	M R	=	11944.2	(kNm)
Sliding moment	M D	=	8412.2	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	19.00	19.00	0.00	50.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	17.50	17.50	0.00	40.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	30.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	16.50	11.50	40.00	0.00	0.00	0.000	0.000
14	18.00	18.00	0.00	24.38	0.00	0.000	0.000
15	17.00	17.00	0.00	29.14	0.00	0.000	0.000
16	19.00	19.00	0.00	32.63	0.00	0.000	0.000
17	19.00	19.00	0.00	50.00	0.00	0.000	0.000
18	17.50	17.50	0.00	42.22	0.00	0.000	0.000
19	17.50	17.50	0.00	41.46	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

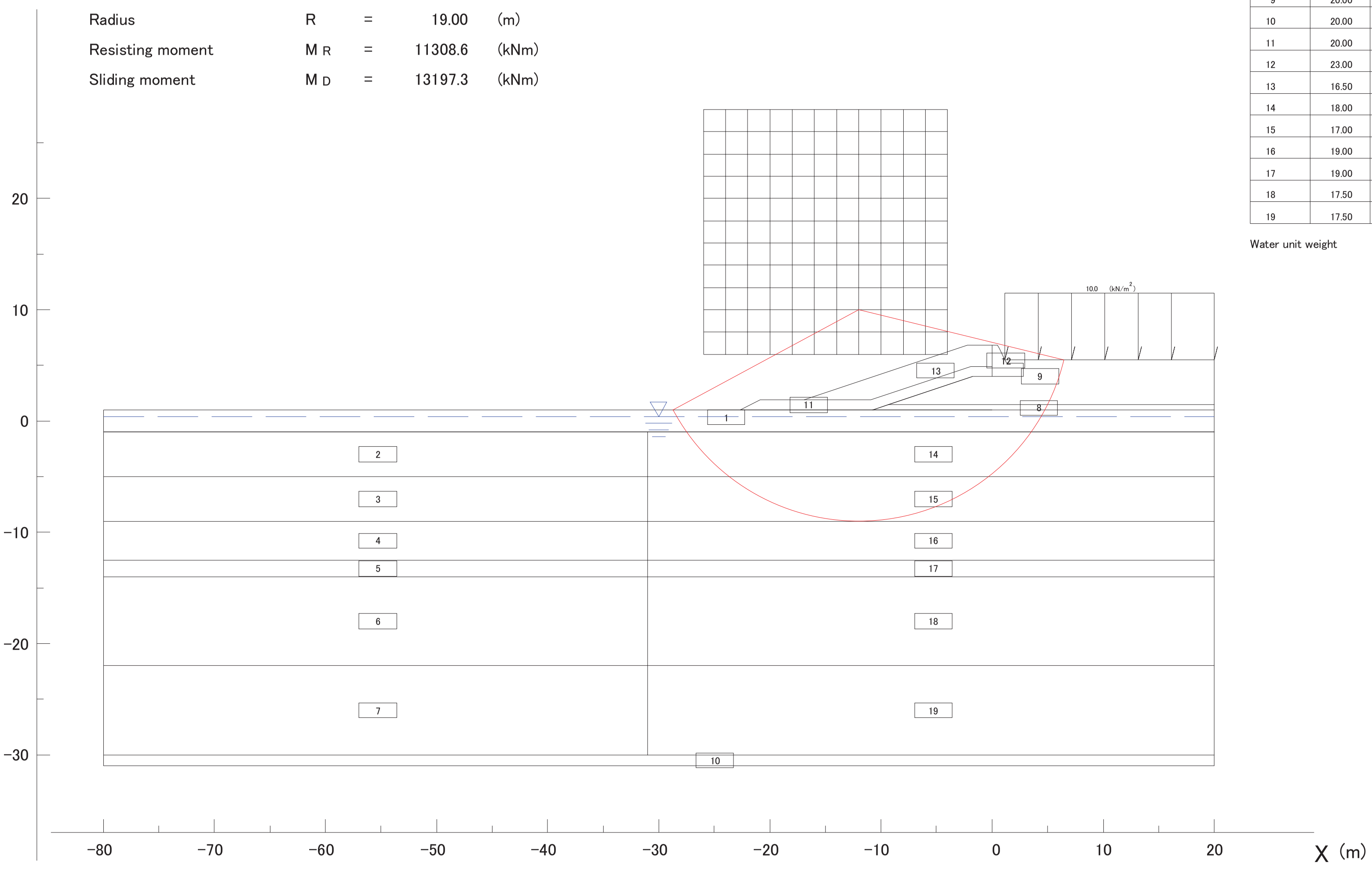
ラックフェン港-外側護岸-4 完成形(改良幅=18m)

Scale ; 1/ 600

Min. safety factor	$F_{S\,MIN}$	=	0.857	
Center of arc	X	=	−12.00	(m)
	Y	=	10.00	(m)
Radius	R	=	19.00	(m)
Resisting moment	M_R	=	11308.6	(kNm)
Sliding moment	M_D	=	13197.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	25.00	0.00	0.00	0.000	0.000
2	18.00	18.00	0.00	15.00	0.00	0.000	0.000
3	17.00	17.00	0.00	15.00	0.00	0.000	0.000
4	19.00	19.00	0.00	25.00	0.00	0.000	0.000
5	19.00	19.00	0.00	50.00	0.00	0.000	0.000
6	17.50	17.50	0.00	40.00	0.00	0.000	0.000
7	17.50	17.50	0.00	40.00	0.00	0.000	0.000
8	20.00	20.00	30.00	0.00	0.00	0.000	0.000
9	20.00	18.00	30.00	0.00	0.00	0.000	0.000
10	20.00	18.00	30.00	0.00	0.00	0.000	0.000
11	20.00	18.00	40.00	0.00	0.00	0.000	0.000
12	23.00	23.00	40.00	0.00	0.00	0.000	0.000
13	16.50	11.50	40.00	0.00	0.00	0.000	0.000
14	18.00	18.00	0.00	15.00	0.00	0.000	0.000
15	17.00	17.00	0.00	15.00	0.00	0.000	0.000
16	19.00	19.00	0.00	25.00	0.00	0.000	0.000
17	19.00	19.00	0.00	50.00	0.00	0.000	0.000
18	17.50	17.50	0.00	40.00	0.00	0.000	0.000
19	17.50	17.50	0.00	40.00	0.00	0.000	0.000

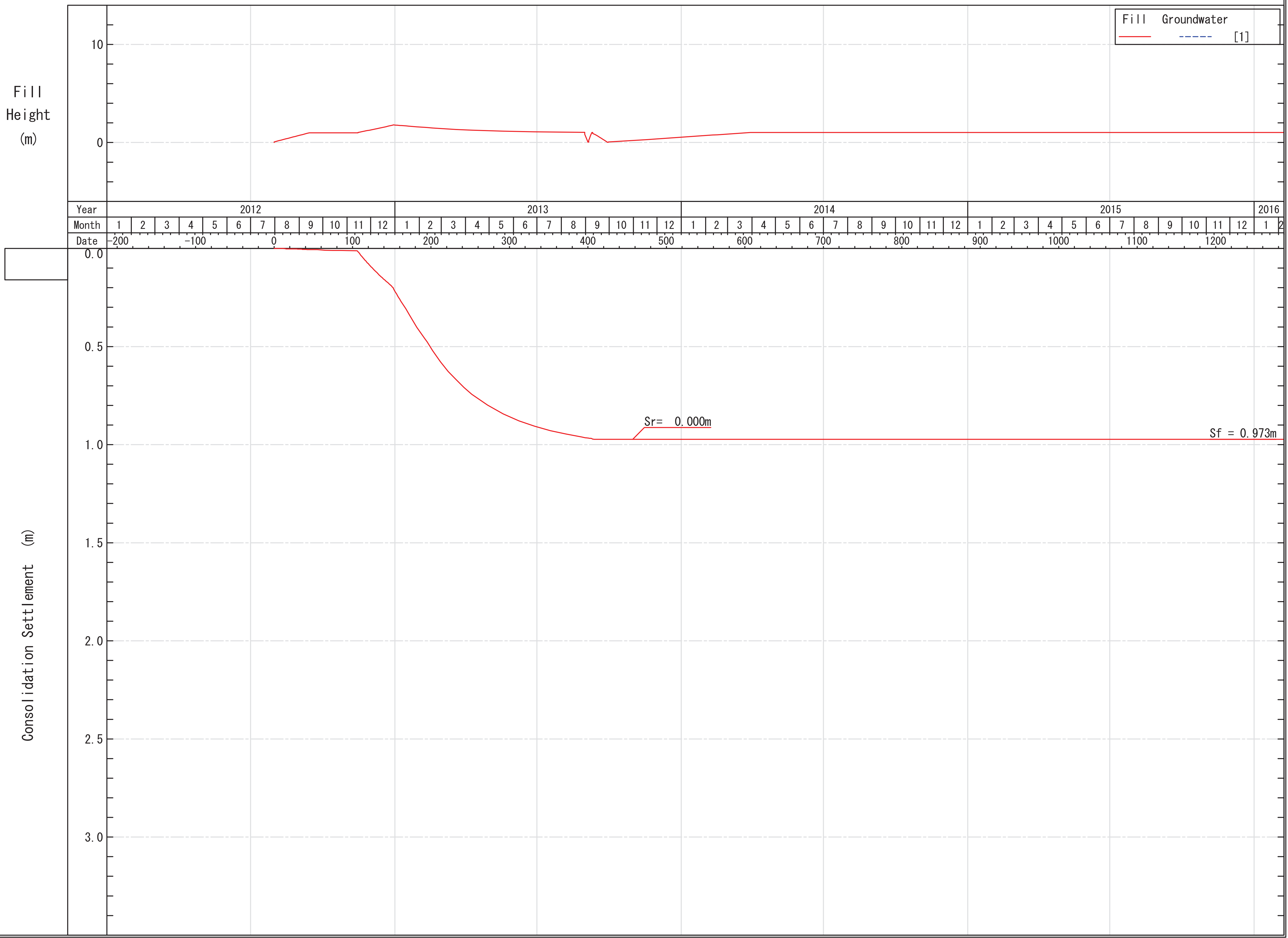
Water unit weight = 10.00 (kN/m^3)



Safety Factor (Ordinary Condition)

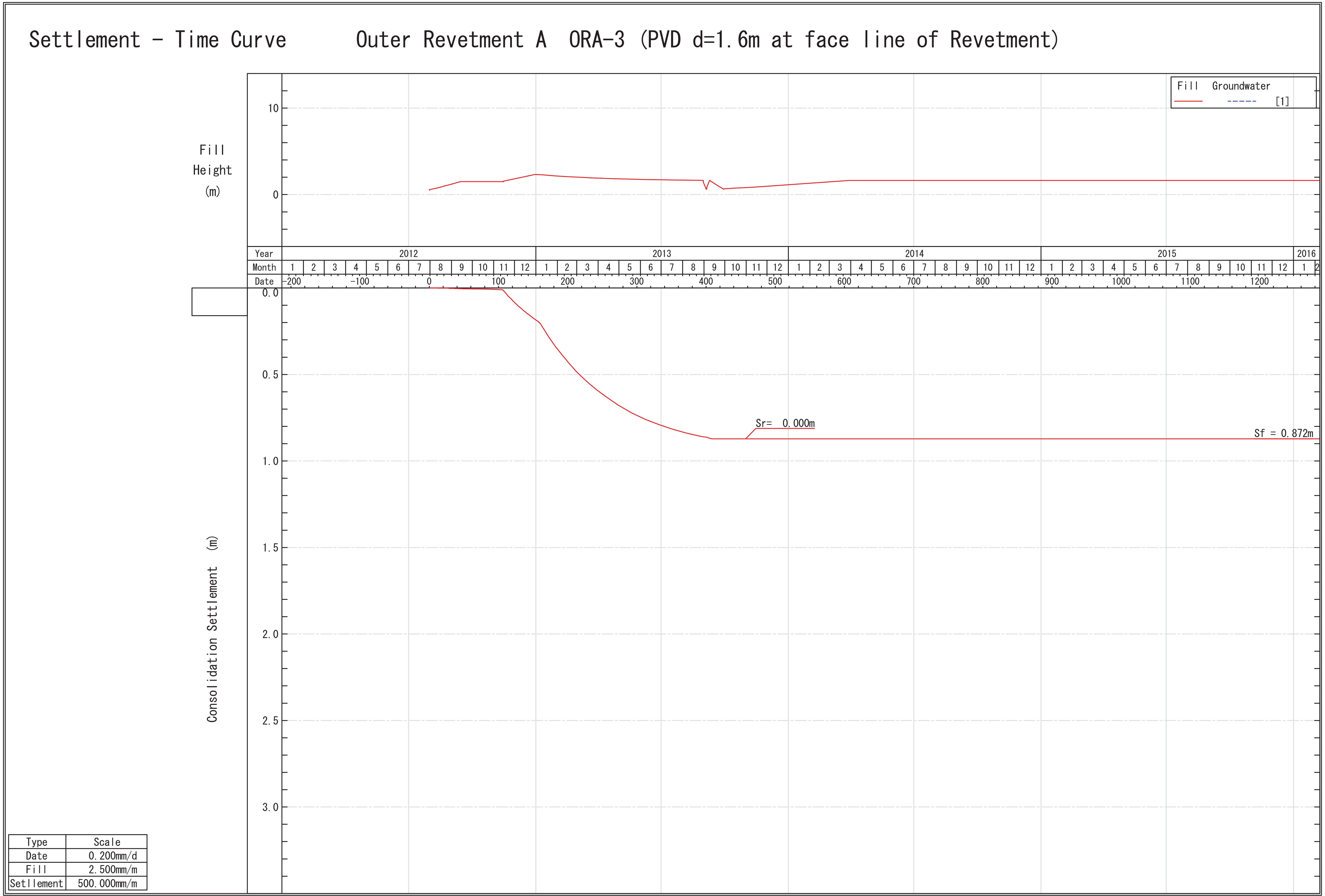
8) Settlement-Time Curves with PVD for Outer Revetment A

Settlement - Time Curve   Outer Revetment A ORA-1 (PVD d=1.6m at face line of Revetment)



Type	Scale
Date	0.200mm/d
Fill	2.500mm/m
Settlement	500.000mm/m

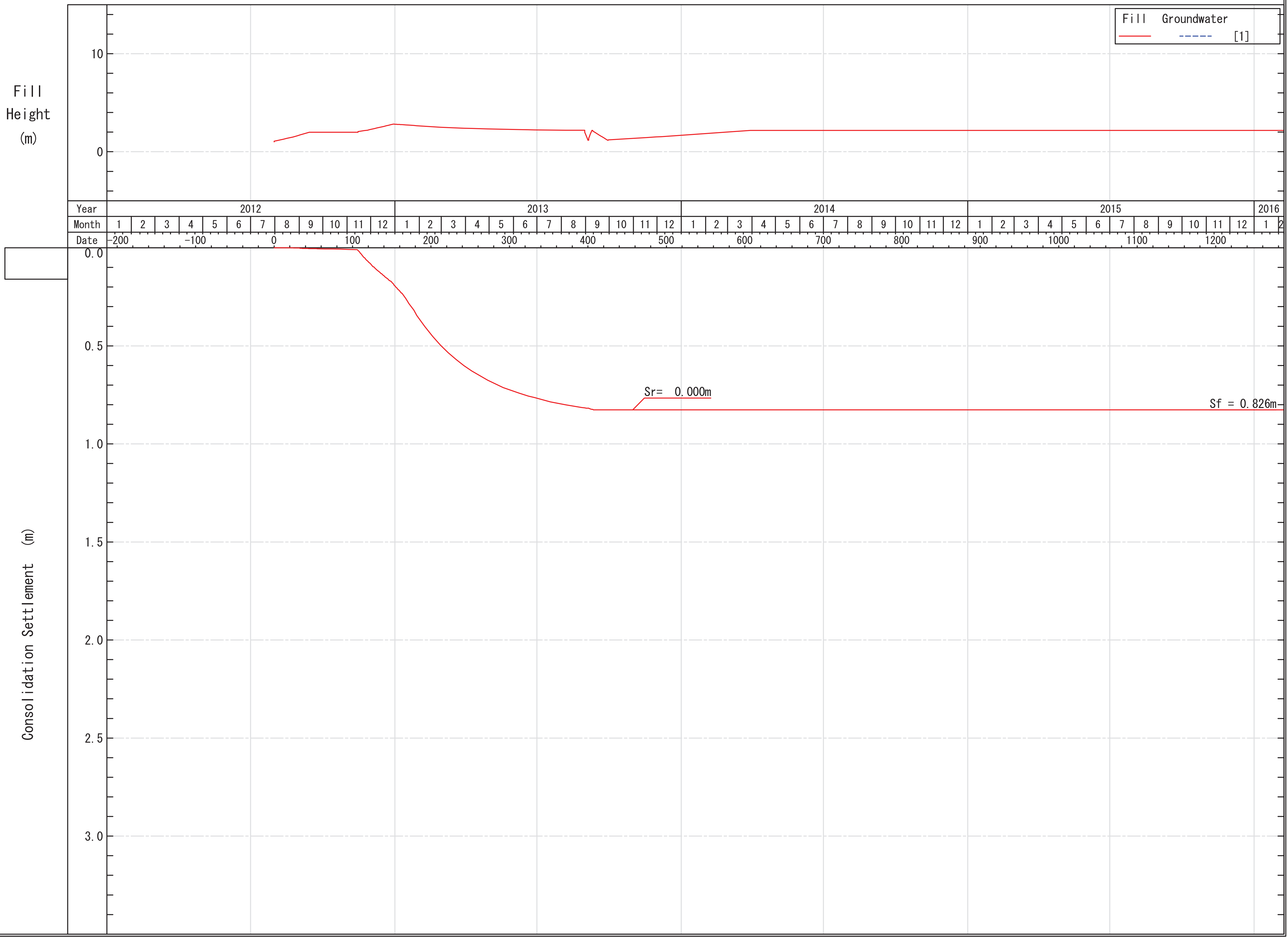
ファイル名 1:[13-ｄ口=1.6m-(護岸法線).Ptw]



Type	Scale
Date	0.200mm/d
Fill	2.500mm/m
Settlement	500.000mm/m

ファイル名 1:[15-ｄ口=1.6m-(護岸法線).Ptw]

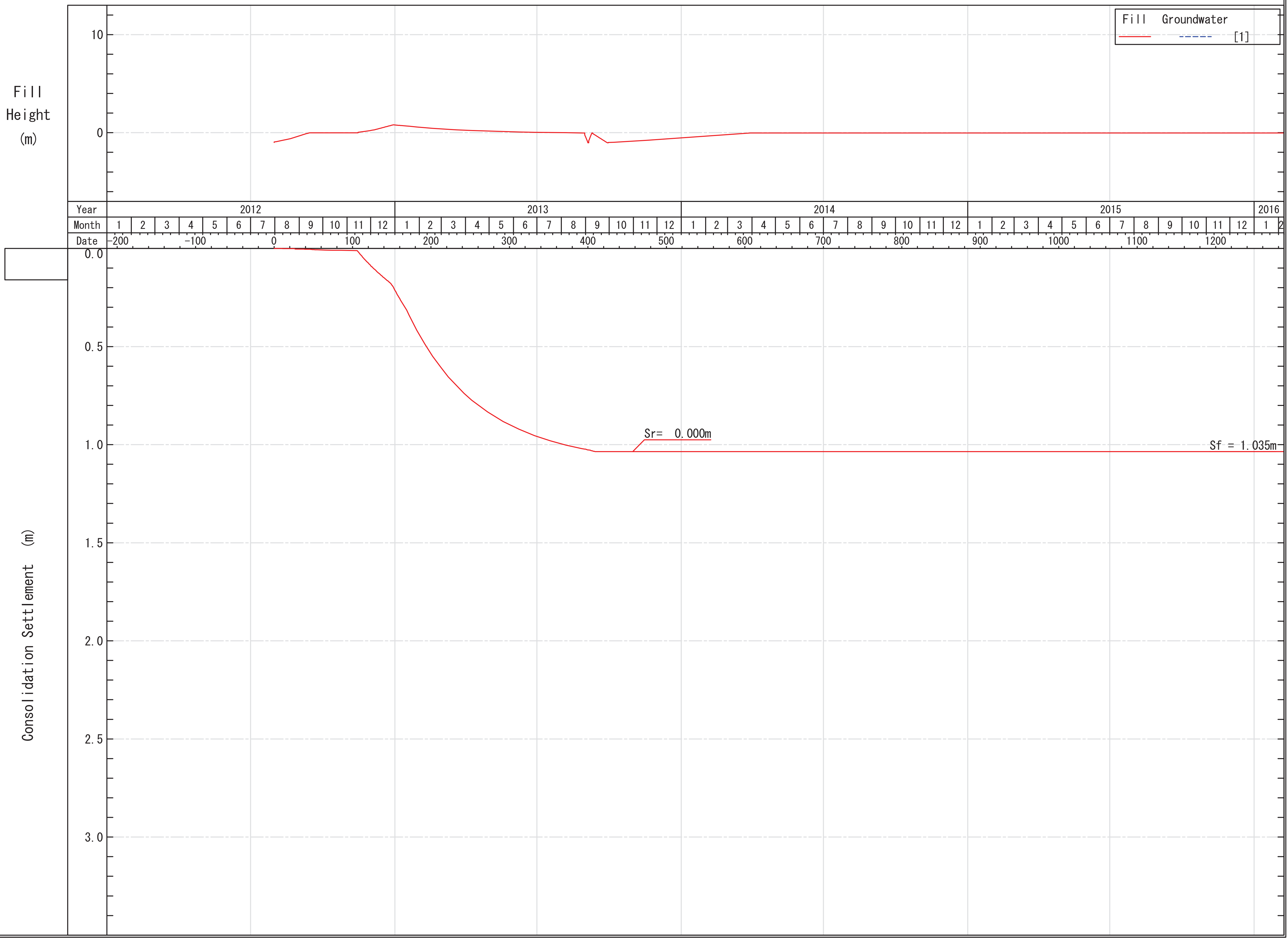
Settlement - Time Curve   Outer Revetment A ORA-4 (PVD d=1.6m at face line of Revetment)



Type	Scale
Date	0.200mm/d
Fill	2.500mm/m
Settlement	500.000mm/m

ファイル名 1:[16-ｄ□=1.6m-(護岸法線).Ptw]

Settlement - Time Curve Outer Revetment A ORA-2 (PVD d=1.6m at face line of Revetment)

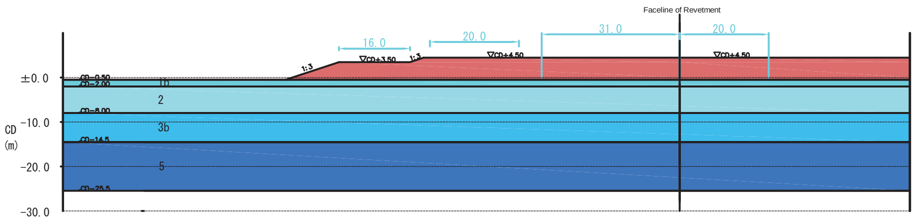


Type	Scale
Date	0.200mm/d
Fill	2.500mm/m
Settlement	500.000mm/m

ファイル名 1:[14-ｄ口=1.6m-(護岸法線).Ptw]

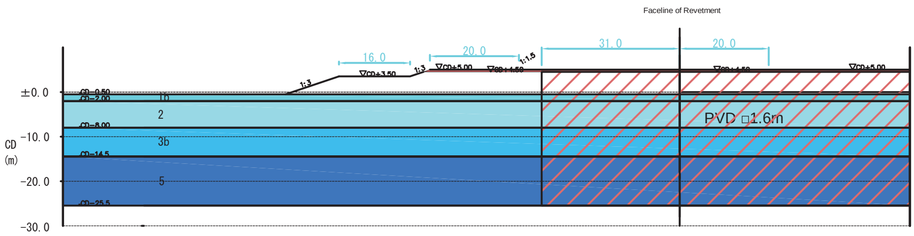
9) Subsoil Improvement Procedure with PVD and Preload Method for Outer Revetment A

Outer Revetment ORA-1



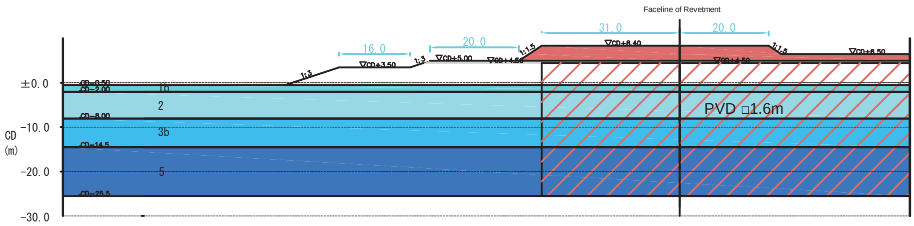
Step 1 (1.5 month)

Fill
(Including Sand Mat. (+4.0 ~ +4.5m))



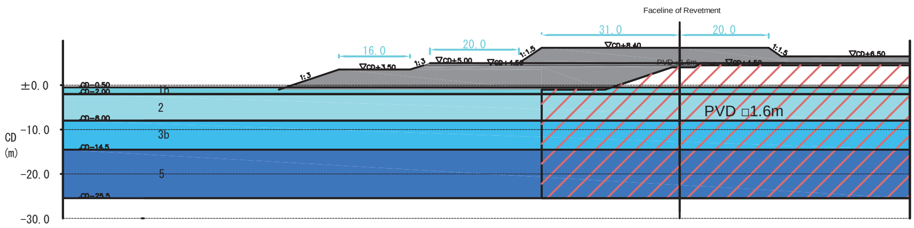
Step 2 (2.0 months)

Soil Improvement (PVD d=□1.6m)
Cover sand (+4.5 ~ +5.0m)



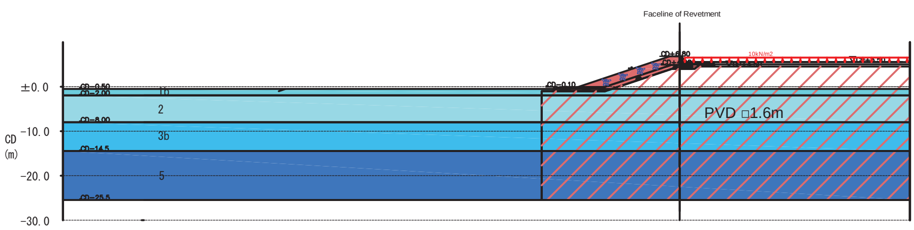
Step 3 (1.5 months)

Preload (+8.4m): Outer Revetment
Preload (+6.5): Access Road Area
Retaining period (8 months)



Step 4 (1 month)

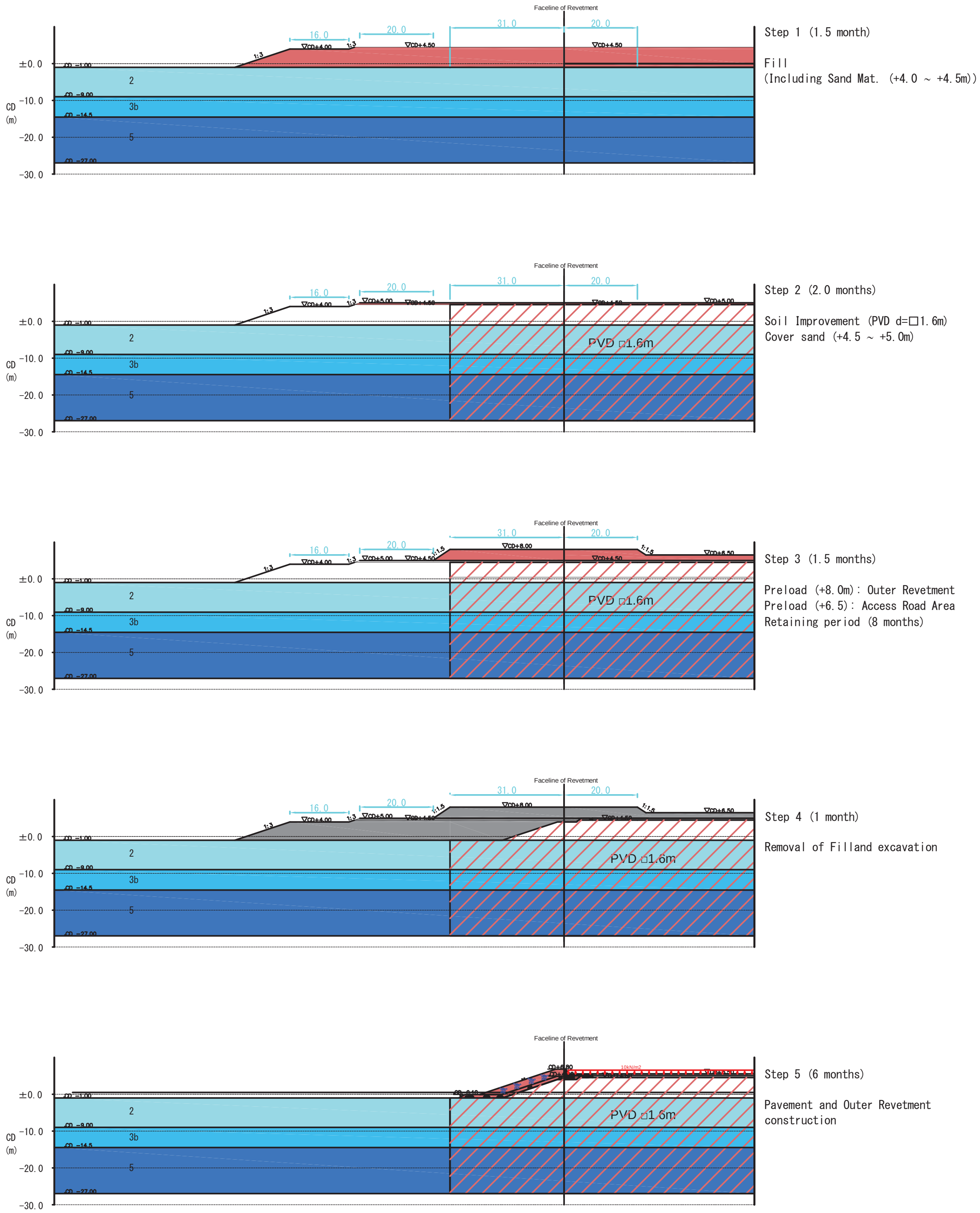
Removal of Filland excavation



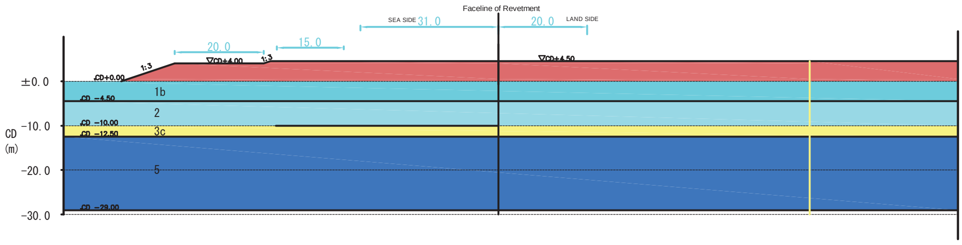
Step 5 (6 months)

Pavement and Outer Revetment
construction

Outer Revetment ORA-2

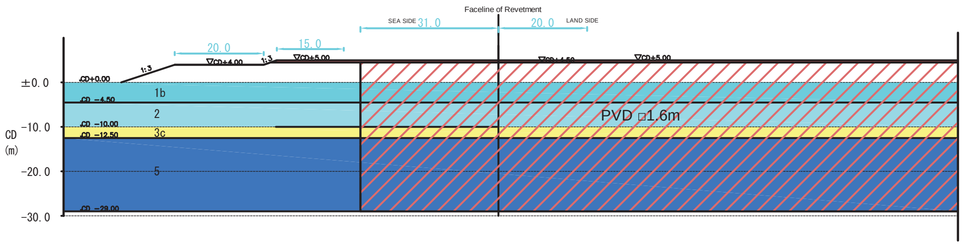


Outer Revetment ORA-3



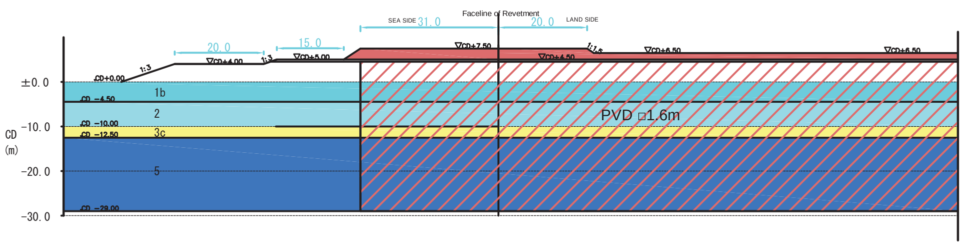
Step 1 (1.5 month)

Fill
(Including Sand Mat. (+4.0 ~ +4.5m))



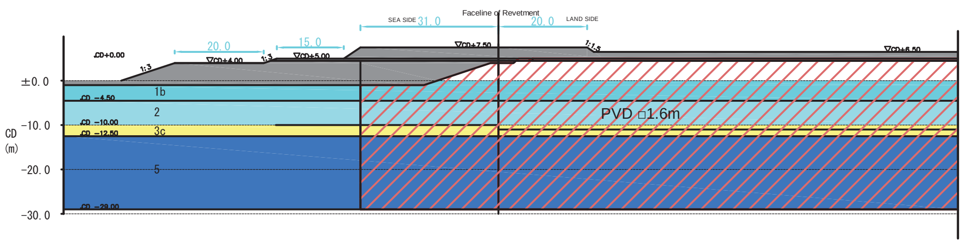
Step 2 (2.0 months)

Soil Improvement (PVD d=□1.6m)
Cover sand (+4.5 ~ +5.0m)



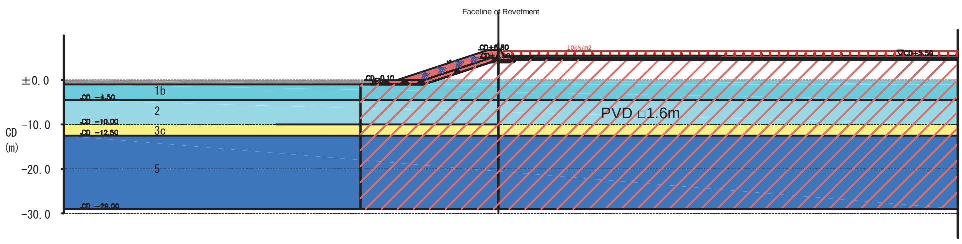
Step 3 (1.5 months)

Preload (+7.5m): Outer Revetment
Preload (+6.5): Access Road Area
Retaining period (8 months)



Step 4 (1 month)

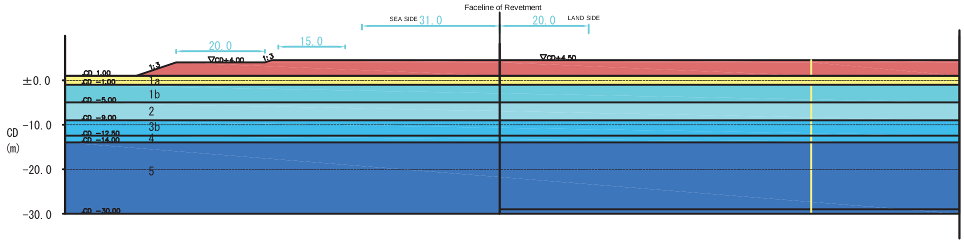
Removal of Filland excavation



Step 5 (6 months)

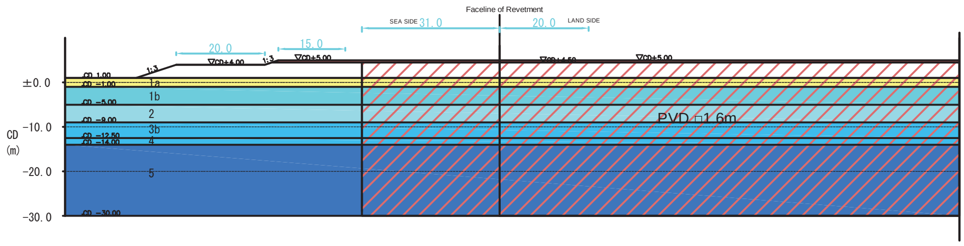
Pavement and Outer Revetment construction

Outer Revetment ORA-4



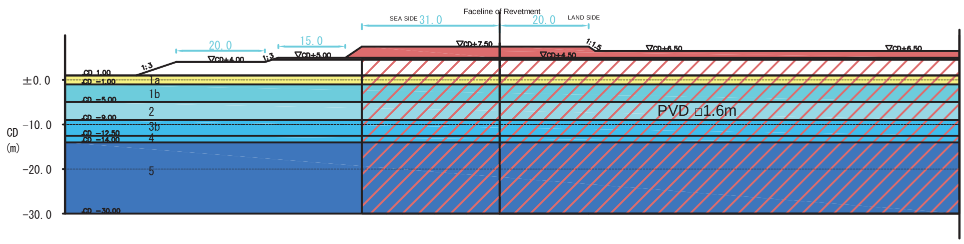
Step 1 (1.5 month)

Fill
(Including Sand Mat. (+4.0 ~ +4.5m))



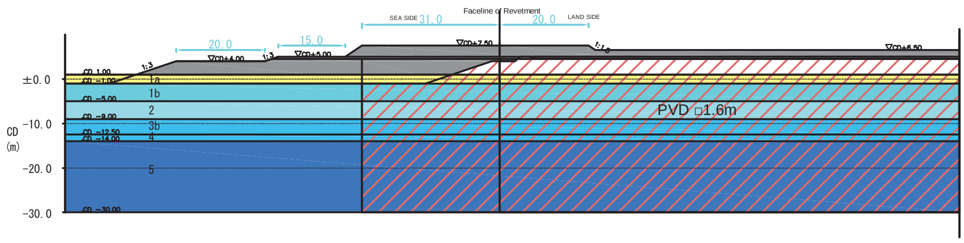
Step 2 (2.0 months)

Soil Improvement (PVD d=□1.6m)
Cover sand (+4.5 ~ +5.0m)



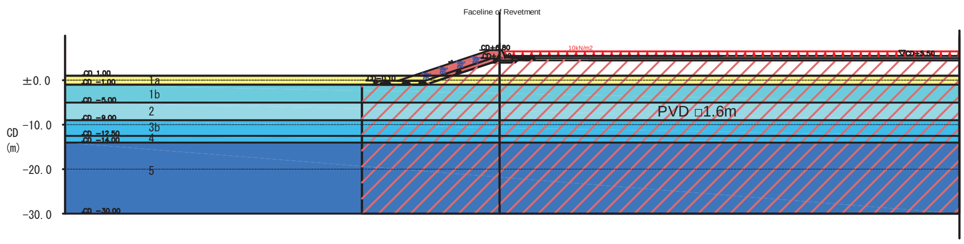
Step 3 (1.5 months)

Preload (+7.5m): Outer Revetment
Preload (+6.5): Access Road Area
Retaining period (8 months)



Step 4 (1 month)

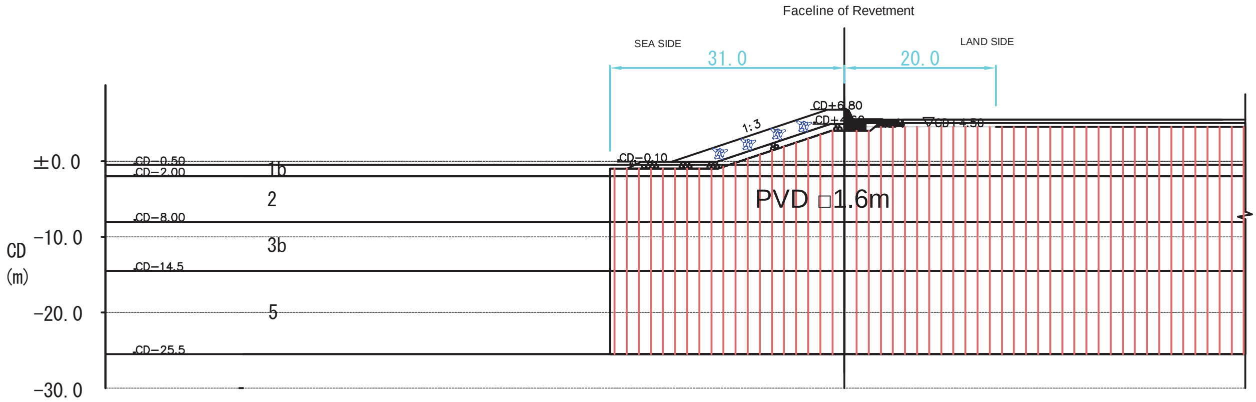
Removal of Filland excavation



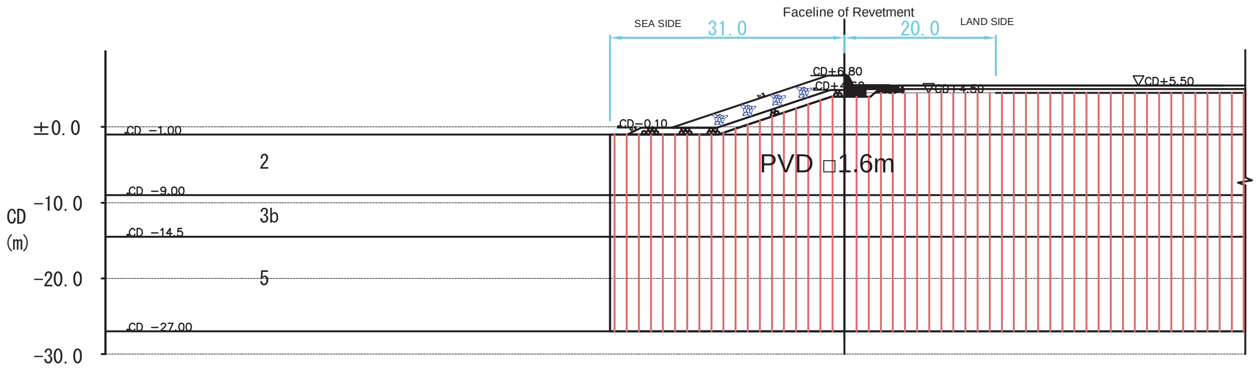
Step 5 (6 months)

Pavement and Outer Revetment
construction

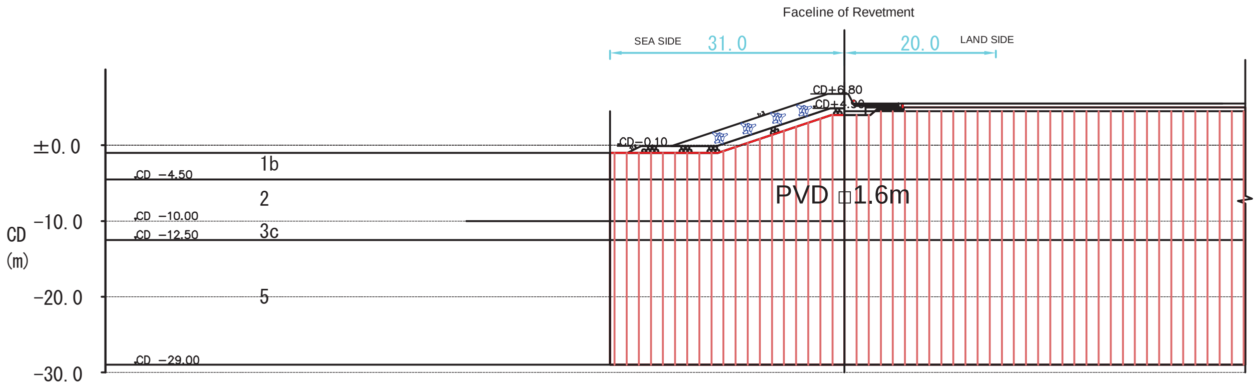
Outer Revetment ORA-1



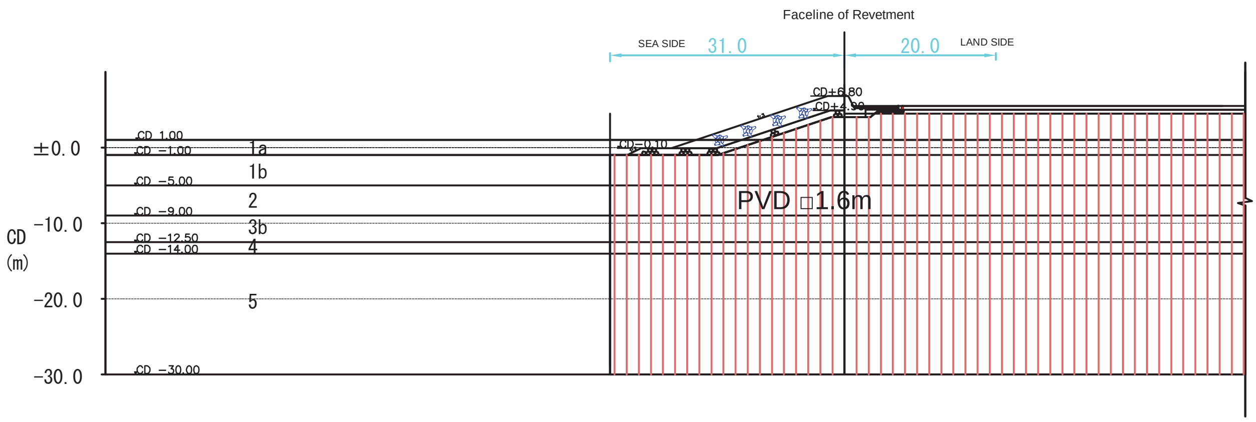
Outer Revetment ORA-2



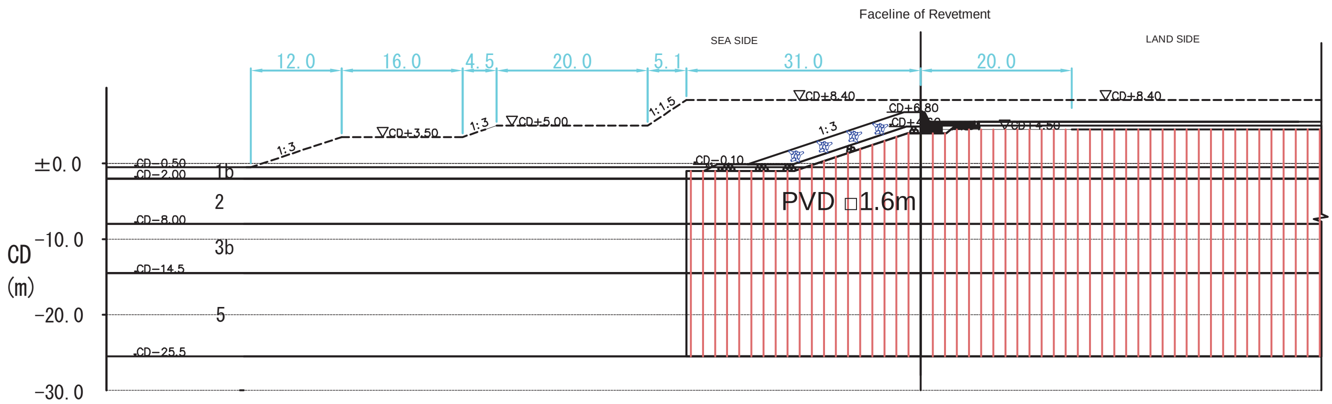
Outer Revetment ORA-3



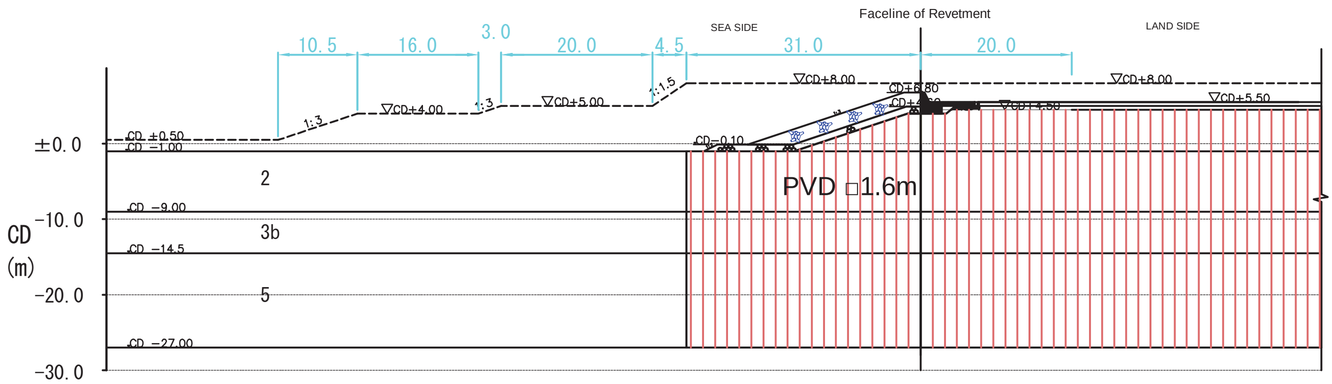
Outer Revetment ORA-4



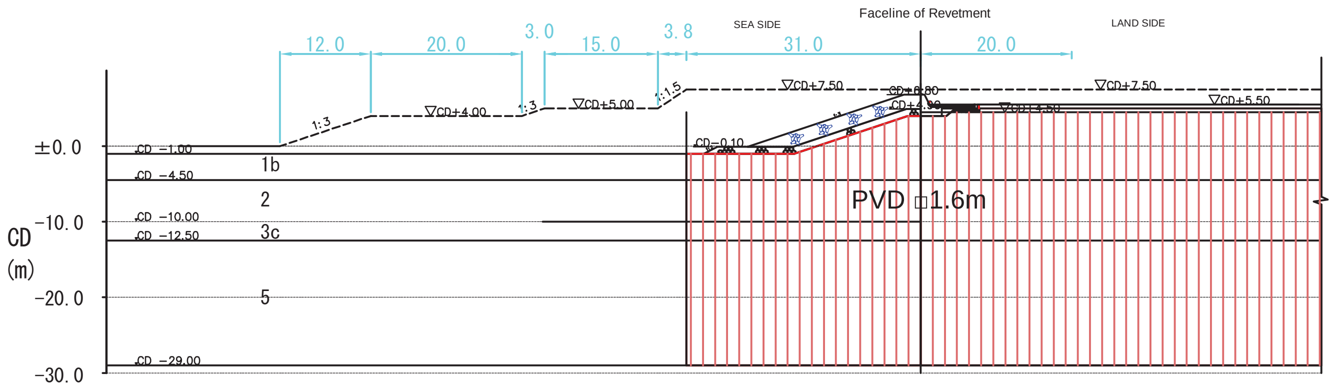
Outer Revetment ORA-1



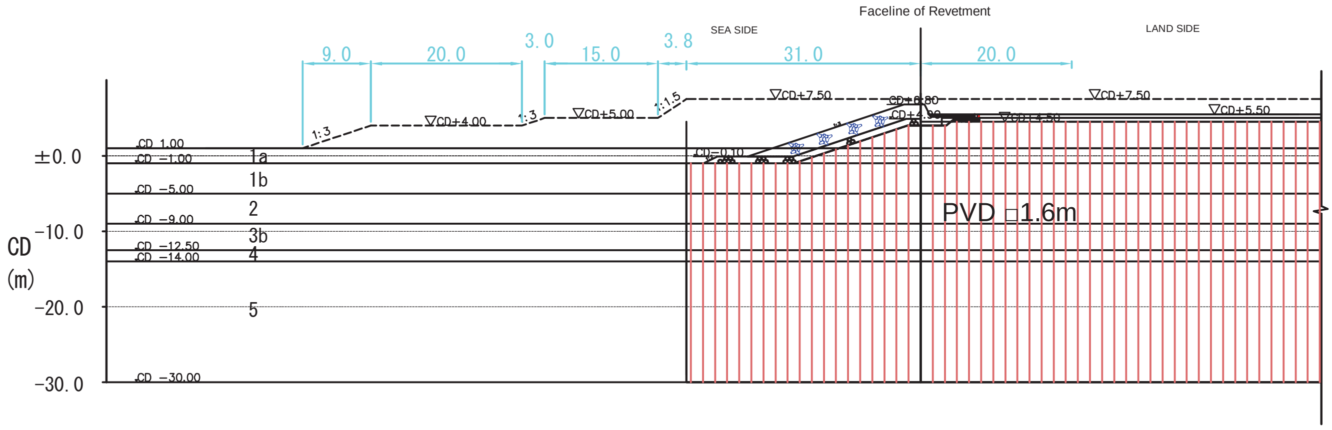
Outer Revetment ORA-2



Outer Revetment ORA-3



Outer Revetment ORA-4



Phụ lục 7-3

Tính toán ổn định chống trượt và chống lật (phía sau tường chắn đất)

Examination for sliding Model: Block-①

1．Calculation condition

（1） General condition

・Water level

Active side : D.L. 3.55 (m)

Passive side : D.L. 0.43 (m)

・Unit weight of wate : γ_w= 10.00 (kN/m^3)

・Surcharge

Active side w_1= 79.2 (kN/m^2) (Preload)

（2） Condition of bearing layer

Internal friction angle : ϕ_B= 35 (°) (μ =tanϕ_B= 0.700)

Cohesion : c_B= 0.0 (kN/m^2)

（3） Specification of improved column

Width : B= 38.1 (m)

Depth of upper end : -2.00 (m)

Depth of lower end : -26.00 (m)

Improvement rate 51.7 (%)

Design strength : q_u 600.0 (kN/m^2)

（4） Soil parameters of calculation

・Soil parameters of active side

Soil layer	Lower end of layer D.L. (m)	γ_t (kN/m^3)	γ' (kN/m^3)	γ_{sat} (kN/m^3)	c (kN/m^2)	ϕ (°)	δ (°)
	4.50						
Fill					0.00		
	3.55	18.00	10.00	20.00	0.00	30	15
Fill					0.00		
	-2.00	18.00	10.00	20.00	0.00	30	15
Layer-2					15.00		
	-8.00	17.00	7.00	17.00	15.00	0	0
Layer-3b					25.00		
	-10.00	19.00	9.00	19.00	25.00	0	0
Layer-4					50.00		
	-15.00	19.00	9.00	19.00	50.00	0	0
Layer-5					40.00		
	-26.00	17.50	7.50	17.50	40.00	0	0

2．Examination for sliding
(1)Calculation earth pressure

・Active earth pressure

Number	Calculated depth (m)	K_A	$\Sigma \gamma h+w_1$ (kN/m^2)	p_a (kN/m^2)	p_{ah} (kN/m^2)	p_{av} (kN/m^2)
1	4.50 (down)	0.301	79.20	23.87	23.06	6.18
2	3.55 (up)	0.301	96.30	29.03	28.04	7.51
3	3.55 (down)	0.301	96.30	29.03	28.04	7.51
4	-2.00 (up)	0.301	151.80	45.76	44.20	11.84
5	-2.00 (down)		151.80	121.80	121.80	0.00
6	-8.00 (up)		193.80	163.80	163.80	0.00
7	-8.00 (down)		193.80	143.80	143.80	0.00
8	-10.00 (up)		211.80	161.80	161.80	0.00
9	-10.00 (down)		211.80	111.80	111.80	0.00
10	-15.00 (up)		256.80	156.80	156.80	0.00
11	-15.00 (down)		256.80	176.80	176.80	0.00
12	-26.00 (up)		339.30	259.30	259.30	0.00

	P_{AH}		y_A	$P_{AH} \cdot y_A$	P_{AV}		B	$P_{AV} \cdot B$
	Calculation	(kN/m)	(m)	(kN/m·m)	Calculation	(kN/m)	(m)	(kN/m·m)
PA1	23.06 × 0.95 × 1／2	10.95	30.18	330.60	6.18 × 0.95 × 1／2	2.93	38.10	111.82
PA2	28.04 × 0.95 × 1／2	13.32	29.87	397.76	7.51 × 0.95 × 1／2	3.57	38.10	135.96
PA3	28.04 × 5.55 × 1／2	77.80	27.70	2,155.16	7.51 × 5.55 × 1／2	20.85	38.10	794.29
PA4	44.20 × 5.55 × 1／2	122.64	25.85	3,170.34	11.84 × 5.55 × 1／2	32.86	38.10	1,252.05
PA5	121.80 × 6.00 × 1／2	365.40	22.00	8,038.80	0.00 × 6.00 × 1／2	0.00	38.10	0.00
PA6	163.80 × 6.00 × 1／2	491.40	20.00	9,828.00	0.00 × 6.00 × 1／2	0.00	38.10	0.00
PA7	143.80 × 2.00 × 1／2	143.80	17.33	2,492.53	0.00 × 2.00 × 1／2	0.00	38.10	0.00
PA8	161.80 × 2.00 × 1／2	161.80	16.67	2,696.67	0.00 × 2.00 × 1／2	0.00	38.10	0.00
PA9	111.80 × 5.00 × 1／2	279.50	14.33	4,006.17	0.00 × 5.00 × 1／2	0.00	38.10	0.00
PA10	156.80 × 5.00 × 1／2	392.00	12.67	4,965.33	0.00 × 5.00 × 1／2	0.00	38.10	0.00
PA11	176.80 × 11.00 × 1／2	972.40	7.33	7,130.93	0.00 × 11.00 × 1／2	0.00	38.10	0.00
PA12	259.30 × 11.00 × 1／2	1,426.15	3.67	5,229.22	0.00 × 11.00 × 1／2	0.00	38.10	0.00
Total		4,457.17		50,441.51		60.21		2,294.12

・Residual Water Pressure

	P_W		y_W	$P_W \cdot y_W$
	Calculation	(kN/m)	(m)	(kN/m·m)
Pw1	31.20 × 3.12 × 1／2	48.67	27.47	1,337.02
Pw2	31.20 × 26.43	824.62	13.22	10,897.30
Total		873.29		12,234.32

(2)Calculation of weight

Block	Base (m)	Height (m)	Unit weight (kN/m^3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
q 1	0.00	0.00	0.0	0.00		0.00	0
W E 1	38.10	0.95	18.0	651.51		19.05	0.0
W E 2	38.10	5.55	10.0	2114.55		19.05	0.0

Block	Base (m)	Height (m)	Unit weight (kN/m3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
W1	38.1	6.00	7.0	1600.20		19.05	0.0
W2	38.1	2.00	9.0	685.80		19.05	0.0
W3	38.1	5.00	9.0	1714.50		19.05	0.0
W4	38.1	11.00	7.5	3143.25		19.05	0.0

・Weight on top of improved part

Block	W (kN/m)	x (m)	W・x (kN/m・m)
q 1	0.00	0.00	0.00
WE1	651.51	19.05	12411.27
WE2	2114.55	19.05	40282.18
ΣWE	2766.06		52693.44

・Weight of improved part

Block	W (kN/m)	x (m)	W・x (kN/m・m)
ΣWE	2766.06		52693.44
W1	1600.20	19.05	30483.81
W2	685.80	19.05	13064.49
W3	1714.50	19.05	32661.23
W4	3143.25	19.05	59878.91
ΣW	9909.81		188781.88

(3)Result of external force

Part			Normal situation
Resultant force of weight	: ΣW	(kN/m)	9909.81
Horizontal component of active earth pressure	: ΣP_A	(kN/m)	4,457.17
Vertical component of passive earth pressure	: ΣP_{AV}	(kN/m)	60.21
Residual Water Pressure	: ΣP_w	(kN/m)	873.29
Horizontal component of active earth pressure	: ΣP_P	(kN/m)	0.00
Vertical component of active earth pressure	: ΣP_{PV}	(kN/m)	0.00
Moment by effective weight	: $\Sigma W \cdot x$	(kN/m・m)	188,781.88
Moment by horizontal component of active earth pressure	: $\Sigma P_A \cdot y_A$	(kN/m・m)	50,441.51
Moment by vertical component of active earth pressure	: $\Sigma P_v \cdot x_v$	(kN/m・m)	2,294.12
Moment by Residual Water Pressure	: $\Sigma P_w \cdot y_w$	(kN/m・m)	12,234.32

(4)Result of examination for sliding

(Safety factor : $Fs \geqq 1.10$)

$F_{R1} = (\Sigma W + PV) \cdot \mu$

$= 6981.09$ (kN/m)

$F_{R2} = \tau \cdot B = (1/2 \cdot q_{uck} \cdot a_p) \cdot B$

$= 5909.31$ (kN/m)

$F_R = F_{R2}$

$= 5909.31$ (kN/m)

$Fs = F_R / (\Sigma P_{AH} + \Sigma P_w)$

$= 1.109 > 1.1$ ……… OK

(5)Result of examination

(Safety factor : $Fs \geqq 1.20$)

$\Sigma M_R = \Sigma W \cdot x + \Sigma P_{AV} \cdot B + \Sigma P_{PH} \cdot y_P$

$= 191{,}076.00$ (kN・m/m)

$\Sigma M_A = \Sigma P_W \cdot y_W + \Sigma P_{AH} \cdot y_A$

$= 62{,}675.83$ (kN・m/m)

$Fs = \Sigma M_R / \Sigma M_A$

$= 3.049 > 1.1$ ……… OK

Examination for sliding　　　　Model:　　Block-a

1. Calculation condition

(1) General condition

・Water level

Active side	:	D.L.	3.55	(m)
Passive side	:	D.L.	0.43	(m)

・Unit weight of wate　:　γ_w =　10.00 (kN/m^3)

・Surcharge

Active side　w_1 =　79.2 (kN/m^2)

(2) Condition of bearing layer

Internal friction angle : ϕ_B =　35　(°)　(μ = tan ϕ_B =　0.700)

Cohesion　: c_B =　0.0　(kN/m^2)

(3) Specification of improved column

Width : B=	33.9	(m)
Depth of upper end :	-2.00	(m)
Depth of lower end :	-25.00	(m)
Improvement rate	51.7	(%)
Design strength : q_u	600.0	(kN/m^2)

(4) Soil parameters of calculation

・Soil parameters of active side

Soil layer	Lower end of layer D.L. (m)	γ_t (kN/m^3)	γ' (kN/m^3)	γ_{sat} (kN/m^3)	c (kN/m^2)	ϕ (°)	δ (°)
	4.50						
Fill					0.00		
	3.55	17.00	7.00	17.00	0.00	30	15
Fill					0.00		
	-2.00	19.00	9.00	19.00	0.00	30	15
Layer-2					15.00		
	-7.50	17.00	7.00	17.00	15.00	0	0
Layer-4					50.00		
	-14.50	19.00	9.00	19.00	50.00	0	0
Layer-5					40.00		
	-25.00	17.50	7.50	17.50	40.00	0	0

２．Examination for sliding

(１)Calculation earth pressure

・Active earth pressure

Number	Calculated depth (m)	K_A	$\Sigma\gamma h+w_1$ (kN/m^2)	p_a (kN/m^2)	p_{ah} (kN/m^2)	p_{av} (kN/m^2)
1	4.50 (down)	0.301	79.20	23.87	23.06	6.18
2	3.55 (up)	0.301	95.35	28.74	27.76	7.44
3	3.55 (down)	0.301	95.35	28.74	27.76	7.44
4	-2.00 (up)	0.301	145.30	43.80	42.30	11.34
5	-2.00 (down)		145.30	115.30	115.30	0.00
6	-7.50 (up)		183.80	153.80	153.80	0.00
7	-7.50 (down)		183.80	83.80	83.80	0.00
8	-14.50 (up)		246.80	146.80	146.80	0.00
9	-14.50 (down)		246.80	166.80	166.80	0.00
10	-25.00 (up)		325.55	245.55	245.55	0.00

	P_{AH}		y_A	$P_{AH}\cdot y_A$	P_{AV}		B	$P_{AV}\cdot B$
	Calculation	(kN/m)	(m)	(kN/m·m)	Calculation	(kN/m)	(m)	(kN/m·m)
PA1	23.06 × 0.95 × 1／2	10.95	29.18	319.64	6.18 × 0.95 × 1／2	2.93	33.90	99.49
PA2	27.76 × 0.95 × 1／2	13.19	28.87	380.65	7.44 × 0.95 × 1／2	3.53	33.90	119.78
PA3	27.76 × 5.55 × 1／2	77.04	26.70	2,056.87	7.44 × 5.55 × 1／2	20.64	33.90	699.76
PA4	42.30 × 5.55 × 1／2	117.39	24.85	2,917.20	11.34 × 5.55 × 1／2	31.46	33.90	1,066.33
PA5	115.30 × 5.50 × 1／2	317.08	21.17	6,711.42	0.00 × 5.50 × 1／2	0.00	33.90	0.00
PA6	153.80 × 5.50 × 1／2	422.95	19.33	8,177.03	0.00 × 5.50 × 1／2	0.00	33.90	0.00
PA7	83.80 × 7.00 × 1／2	293.30	15.17	4,448.38	0.00 × 7.00 × 1／2	0.00	33.90	0.00
PA8	146.80 × 7.00 × 1／2	513.80	12.83	6,593.77	0.00 × 7.00 × 1／2	0.00	33.90	0.00
PA9	166.80 × 10.50 × 1／2	875.70	7.00	6,129.90	0.00 × 10.50 × 1／2	0.00	33.90	0.00
PA10	245.55 × 10.50 × 1／2	1,289.14	3.50	4,511.98	0.00 × 10.50 × 1／2	0.00	33.90	0.00
Total		3,930.53		42,246.84		58.57		1,985.36

・Residual Water Pressure

	P_W		y_W	$P_W\cdot y_W$
	Calculation	(kN/m)	(m)	(kN/m·m)
Pw1	31.20 × 3.12 × 1／2	48.67	26.47	1,288.35
Pw2	31.20 × 25.43	793.42	12.72	10,088.28
Total		842.09		11,376.63

(2)Calculation of weight

Block	Base (m)	Height (m)	Unit weight (kN/m^3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
q 1	0.00	0.00	0.0	0.00		0.00	0
W E 1	33.90	0.95	18.0	579.69		16.95	0.0
W E 2	33.90	5.55	10.0	1881.45		16.95	0.0

Block	Base (m)	Height (m)	Unit weight (kN/m^3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
W1	33.9	5.50	7.0	1305.15		16.95	0.0
W2	33.9	7.00	9.0	2135.70		16.95	0.0
W3	33.9	10.50	7.5	2669.63		16.95	0.0

・Weight on top of improved part

Block	W (kN/m)	x (m)	W・x (kN/m・m)
q 1	0.00	0.00	0.00
WE1	579.69	16.95	9825.75
WE2	1881.45	16.95	31890.58
ΣWE	2461.14		41716.32

・Weight of improved part

Block	W (kN/m)	x (m)	W・x (kN/m・m)
ΣWE	2461.14		41716.32
W1	1305.15	16.95	22122.29
W2	2135.70	16.95	36200.12
W3	2669.63	16.95	45250.14
ΣW	8571.62		145288.87

(3)Result of external force

Part			Normal situation
Resultant force of weight	: ΣW	(kN/m)	8571.62
Horizontal component of active earth pressure	: ΣP_A	(kN/m)	3,930.53
Vertical component of passive earth pressure	: ΣP_{AV}	(kN/m)	58.57
Residual Water Pressure	: ΣP_w	(kN/m)	842.09
Horizontal component of active earth pressure	: ΣP_P	(kN/m)	0.00
Vertical component of active earth pressure	: ΣP_{PV}	(kN/m)	0.00
Moment by effective weight	: $\Sigma W \cdot x$	(kN/m·m)	145,288.87
Moment by horizontal component of active earth pressure	: $\Sigma P_A \cdot y_A$	(kN/m·m)	42,246.84
Moment by vertical component of active earth pressure	: $\Sigma P_v \cdot x_v$	(kN/m·m)	1,985.36
Moment by Residual Water Pressure	: $\Sigma P_w \cdot y_w$	(kN/m·m)	11,376.63

(4)Result of examination for sliding

(Safety factor : $Fs \geqq 1.10$)

$F_{R1} = (\Sigma W + PV) \cdot \mu$

$= 6042.92$ (kN/m)

$F_{R2} = \tau \cdot B = (1/2 \cdot q_{uck} . a_p) \cdot B$

$= 5257.89$ (kN/m)

$F_R = F_{R2}$

$= 5257.89$ (kN/m)

$Fs = F_R / (\Sigma P_{AH} + \Sigma P_w)$

$= 1.102 > 1.1$ ……… OK

(5)Result of examination

(Safety factor : $Fs \geqq 1.20$)

$\Sigma M_R = \Sigma W \cdot x + \Sigma P_{AV} \cdot B + \Sigma P_{PH} \cdot y_P$

$= 147,274.23$ (kN·m/m)

$\Sigma M_A = \Sigma P_W \cdot y_W + \Sigma P_{AH} \cdot y_A$

$= 53,623.47$ (kN·m/m)

$Fs = \Sigma M_R / \Sigma M_A$

$= 2.746 > 1.1$ ……… OK

Examination for sliding Model: Block-b

1. Calculation condition

(1) General condition

・Water level

Active side	: D.L.	3.55	(m)
Passive side	: D.L.	0.43	(m)

・Unit weight of wate : γ_w= 10.00 (kN/m^3)

・Surcharge

Active side w_1= 70.2 (kN/m^2)

(2) Condition of bearing layer

Internal friction angle : ϕ_B= 35 (°) (μ =tanϕ_B= 0.700)

Cohesion : c_B= 0.0 (kN/m^2)

(3) Specification of improved column

Width : B=	36.0	(m)
Depth of upper end :	-2.00	(m)
Depth of lower end :	-25.00	(m)
Improvement rate	51.7	(%)
Design strength : q_u	600.0	(kN/m^2)

(4) Soil parameters of calculation

・Soil parameters of active side

Soil layer	Lower end of layer D.L. (m)	γ_t (kN/m^3)	γ' (kN/m^3)	γ_{sat} (kN/m^3)	c (kN/m^2)	ϕ (°)	δ (°)
	4.50						
Fill					0.00		
	3.55	18.00	10.00	20.00	0.00	30	15
Fill					0.00		
	-2.00	18.00	10.00	20.00	0.00	30	15
Layer-1b					15.00		
	-2.50	18.00	8.00	18.00	15.00	0	0
Layer-2					15.00		
	-9.00	17.00	7.00	17.00	15.00	0	0
Layer-3b					25.00		
	-13.00	19.00	9.00	19.00	25.00	0	0
Layer-4					50.00		
	-16.00	19.00	9.00	19.00	50.00	0	
Layer-5					40.00		
	-25.00	17.50	7.50	17.50	40.00	0	

2. Examination for sliding

(1) Calculation earth pressure

・Active earth pressure

Number	Calculated depth (m)	K_A	$\Sigma\gamma h+w_1$ (kN/m^2)	p_a (kN/m^2)	p_{ah} (kN/m^2)	p_{av} (kN/m^2)
1	4.50 (down)	0.301	70.20	21.16	20.44	5.48
2	3.55 (up)	0.301	87.30	26.31	25.42	6.81
3	3.55 (down)	0.301	87.30	26.31	25.42	6.81
4	-2.00 (up)	0.301	142.80	43.04	41.58	11.14
5	-2.00 (down)		142.80	112.80	112.80	0.00
6	-2.50 (up)		146.80	116.80	116.80	0.00
7	-2.50 (down)		146.80	116.80	116.80	0.00
8	-9.00 (up)		192.30	162.30	162.30	0.00
9	-9.00 (down)		192.30	142.30	142.30	0.00
10	-13.00 (up)		228.30	178.30	178.30	0.00
11	-13.00 (down)		228.30	128.30	128.30	0.00
12	-16.00 (up)		255.30	155.30	155.30	0.00
13	-16.00 (down)		255.30	175.30	175.30	0.00
14	-25.00 (up)		345.30	265.30	265.30	0.00

	P_{AH}		y_A	$P_{AH}\cdot y_A$	P_{AV}		B	$P_{AV}\cdot B$
	Calculation	(kN/m)	(m)	(kN/m·m)	Calculation	(kN/m)	(m)	(kN/m·m)
PA1	20.44 × 0.95 × 1/2	9.71	29.18	283.32	5.48 × 0.95 × 1/2	2.60	36.00	93.65
PA2	25.42 × 0.95 × 1/2	12.07	28.87	348.51	6.81 × 0.95 × 1/2	3.23	36.00	116.46
PA3	25.42 × 5.55 × 1/2	70.53	26.70	1,883.21	6.81 × 5.55 × 1/2	18.90	36.00	680.37
PA4	41.58 × 5.55 × 1/2	115.37	24.85	2,867.01	11.14 × 5.55 × 1/2	30.91	36.00	1,112.90
PA5	112.80 × 0.50 × 1/2	28.20	22.83	643.90	0.00 × 0.50 × 1/2	0.00	36.00	0.00
PA6	116.80 × 0.50 × 1/2	29.20	22.67	661.87	0.00 × 0.50 × 1/2	0.00	36.00	0.00
PA7	116.80 × 6.50 × 1/2	379.60	20.33	7,718.53	0.00 × 6.50 × 1/2	0.00	36.00	0.00
PA8	162.30 × 6.50 × 1/2	527.48	18.17	9,582.46	0.00 × 6.50 × 1/2	0.00	36.00	0.00
PA9	142.30 × 4.00 × 1/2	284.60	14.67	4,174.13	0.00 × 4.00 × 1/2	0.00	36.00	0.00
PA10	178.30 × 4.00 × 1/2	356.60	13.33	4,754.67	0.00 × 4.00 × 1/2	0.00	36.00	0.00
PA11	128.30 × 3.00 × 1/2	192.45	11.00	2,116.95	0.00 × 3.00 × 1/2	0.00	36.00	0.00
PA12	155.30 × 3.00 × 1/2	232.95	10.00	2,329.50	0.00 × 3.00 × 1/2	0.00	36.00	0.00
PA13	175.30 × 9.00 × 1/2	788.85	6.00	4,733.10	0.00 × 9.00 × 1/2	0.00	36.00	0.00
PA14	265.30 × 9.00 × 1/2	1,193.85	4.00	4,775.40	0.00 × 9.00 × 1/2	0.00	36.00	0.00
Total		4,221.46		46,872.56		55.65		2,003.38

・Residual Water Pressure

	P_W		y_W	$P_W\cdot y_W$
	Calculation	(kN/m)	(m)	(kN/m·m)
Pw1	31.20 × 3.12 × 1/2	48.67	26.47	1,288.35
Pw2	31.20 × 25.43	793.42	12.72	10,088.28
Total		842.09		11,376.63

(2)Calculation of weight

Block	Base (m)	Height (m)	Unit weight (kN/m^3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
q 1	0.00	0.00	0.0	0.00		0.00	0
W E 1	36.00	0.95	18.0	615.60		18.00	0.0
W E 2	36.00	5.55	10.0	1998.00		18.00	0.0

Block	Base (m)	Height (m)	Unit weight (kN/m^3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
W1	36.0	0.50	8.0	144.00		18.00	0.0
W2	36.0	6.50	7.0	1638.00		18.00	0.0
W3	36.0	4.00	9.0	1296.00		18.00	0.0
W4	36.0	3.00	9.0	972.00		18.00	0.0
W5	36.0	9.00	7.5	2430.00		18.00	0.0

・Weight on top of improved part

Block	W (kN/m)	x (m)	W・x (kN/m・m)
q 1	0.00	0.00	0.00
WE1	615.60	18.00	11080.80
WE2	1998.00	18.00	35964.00
ΣWE	2613.60		47044.80

・Weight of improved part

Block	W (kN/m)	x (m)	W・x (kN/m・m)
ΣWE	2613.60		47044.80
W1	144.00	18.00	2592.00
W2	1638.00	18.00	29484.00
W3	1296.00	18.00	23328.00
W4	972.00	18.00	17496.00
W5	2430.00	18.00	43740.00
ΣW	9093.60		163684.80

(3)Result of external force

Part			Normal situation
Resultant force of weight	: ΣW	(kN/m)	9093.60
Horizontal component of active earth pressure	: ΣP_A	(kN/m)	4,221.46
Vertical component of passive earth pressure	: ΣP_{AV}	(kN/m)	55.65
Residual Water Pressure	: ΣP_w	(kN/m)	842.09
Horizontal component of active earth pressure	: ΣP_P	(kN/m)	0.00
Vertical component of active earth pressure	: ΣP_{PV}	(kN/m)	0.00
Moment by effective weight	: $\Sigma W \cdot x$	(kN/m·m)	163,684.80
Moment by horizontal component of active earth pressure	: $\Sigma P_A \cdot y_A$	(kN/m·m)	46,872.56
Moment by vertical component of active earth pressure	: $\Sigma P_v \cdot x_v$	(kN/m·m)	2,003.38
Moment by Residual Water Pressure	: $\Sigma P_w \cdot y_w$	(kN/m·m)	11,376.63

(4)Result of examination for sliding

(Safety factor : $Fs \geqq 1.10$)

$F_{R1} = (\Sigma W + PV) \cdot \mu$

$= 6406.37$ (kN/m)

$F_{R2} = \tau \cdot B = (1/2 \cdot q_{uck}.a_p) \cdot B$

$= 5583.60$ (kN/m)

$F_R = F_{R2}$

$= 5583.60$ (kN/m)

$Fs = F_R / (\Sigma P_{AH} + \Sigma P_w)$

$= 1.103 > 1.1$ ……… OK

(5)Result of examination

(Safety factor : $Fs \geqq 1.20$)

$\Sigma M_R = \Sigma W \cdot x + \Sigma P_{AV} \cdot B + \Sigma P_{PH} \cdot y_P$

$= 165,688.18$ (kN·m/m)

$\Sigma M_A = \Sigma P_W \cdot y_W + \Sigma P_{AH} \cdot y_A$

$= 58,249.19$ (kN·m/m)

$Fs = \Sigma M_R / \Sigma M_A$

$= 2.844 > 1.1$ ……… OK

Examination for sliding Model: Block-c

1. Calculation condition

(1) General condition

・Water level

Active side : D.L. 3.55 (m)

Passive side : D.L. 0.43 (m)

・Unit weight of wate : γ_w= 10.00 (kN/m^3)

・Surcharge

Active side w_1= 73.8 (kN/m^2)

(2) Condition of bearing layer

Internal friction angle : ϕ_B= 35 (°) (μ =tanϕ_B= 0.700)

Cohesion : c_B= 0.0 (kN/m^2)

(3) Specification of improved column

Width : B= 38.1 (m)

Depth of upper end : -2.00 (m)

Depth of lower end : -27.00 (m)

Improvement rate 51.7 (%)

Design strength : q_u 600.0 (kN/m^2)

(4) Soil parameters of calculation

・Soil parameters of active side

Soil layer	Lower end of layer D.L. (m)	γ_t (kN/m^3)	γ' (kN/m^3)	γ_{sat} (kN/m^3)	c (kN/m^2)	ϕ (°)	δ (°)
	4.50						
Fill					0.00		
	3.55	18.00	10.00	20.00	0.00	30	15
Fill					0.00		
	-2.00	18.00	10.00	20.00	0.00	30	15
Layer-2					15.00		
	-8.00	17.00	7.00	17.00	15.00	0	0
Layer-3a					0.00		
	-9.50	19.00	9.00	19.00	0.00	25	13
Layer-4					50.00		
	-15.50	19.00	9.00	19.00	50.00	0	0
Layer-5					40.00		
	-27.00	17.50	7.50	17.50	40.00	0	0

2．Examination for sliding

(1)Calculation earth pressure

・Active earth pressure

Number	Calculated depth (m)	K_A	$\Sigma\gamma h+w_1$ (kN/m^2)	p_a (kN/m^2)	p_{ah} (kN/m^2)	p_{av} (kN/m^2)
1	4.50 (down)	0.301	73.80	22.24	21.49	5.76
2	3.55 (up)	0.301	90.90	27.40	26.47	7.09
3	3.55 (down)	0.301	90.90	27.40	26.47	7.09
4	-2.00 (up)	0.301	146.40	44.13	42.62	11.42
5	-2.00 (down)		146.40	116.40	116.40	0.00
6	-8.00 (up)		188.40	158.40	158.40	0.00
7	-8.00 (down)	0.367	188.40	69.21	67.57	14.98
8	-9.50 (up)	0.367	201.90	74.17	72.41	16.05
9	-9.50 (down)		201.90	101.90	101.90	0.00
10	-15.50 (up)		255.90	155.90	155.90	0.00
11	-15.50 (down)		255.90	175.90	175.90	0.00
12	-27.00 (up)		342.15	262.15	262.15	0.00

	P_{AH} Calculation	P_{AH} (kN/m)	y_A (m)	$P_{AH}\cdot y_A$ (kN/m·m)	P_{AV} Calculation	P_{AV} (kN/m)	B (m)	$P_{AV}\cdot B$ (kN/m·m)
PA1	21.49 × 0.95 × 1／2	10.21	31.18	318.26	5.76 × 0.95 × 1／2	2.73	38.10	104.19
PA2	26.47 × 0.95 × 1／2	12.57	30.87	388.02	7.09 × 0.95 × 1／2	3.37	38.10	128.34
PA3	26.47 × 5.55 × 1／2	73.44	28.70	2,107.75	7.09 × 5.55 × 1／2	19.68	38.10	749.75
PA4	42.62 × 5.55 × 1／2	118.28	26.85	3,175.85	11.42 × 5.55 × 1／2	31.69	38.10	1,207.51
PA5	116.40 × 6.00 × 1／2	349.20	23.00	8,031.60	0.00 × 6.00 × 1／2	0.00	38.10	0.00
PA6	158.40 × 6.00 × 1／2	475.20	21.00	9,979.20	0.00 × 6.00 × 1／2	0.00	38.10	0.00
PA7	67.57 × 1.50 × 1／2	50.68	18.50	937.54	14.98 × 1.50 × 1／2	11.24	38.10	428.05
PA8	72.41 × 1.50 × 1／2	54.31	18.00	977.57	16.05 × 1.50 × 1／2	12.04	38.10	458.73
PA9	101.90 × 6.00 × 1／2	305.70	15.50	4,738.35	0.00 × 6.00 × 1／2	0.00	38.10	0.00
PA10	155.90 × 6.00 × 1／2	467.70	13.50	6,313.95	0.00 × 6.00 × 1／2	0.00	38.10	0.00
PA11	175.90 × 11.50 × 1／2	1,011.43	7.67	7,754.26	0.00 × 11.50 × 1／2	0.00	38.10	0.00
PA12	262.15 × 11.50 × 1／2	1,507.36	3.83	5,778.22	0.00 × 11.50 × 1／2	0.00	38.10	0.00
Total		4,436.07		50,500.58		80.75		3,076.57

・Residual Water Pressure

	P_W Calculation	P_W (kN/m)	y_W (m)	$P_W\cdot y_W$ (kN/m·m)
Pw1	31.20 × 3.12 × 1／2	48.67	28.47	1,385.69
Pw2	31.20 × 27.43	855.82	13.72	11,737.52
Total		904.49		13,123.21

(2)Calculation of weight

Block	Base (m)	Height (m)	Unit weight (kN/m^3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
q1	0.00	0.00	0.0	0.00		0.00	0
WE1	38.10	0.95	18.0	651.51		19.05	0.0
WE2	38.10	5.55	10.0	2114.55		19.05	0.0

Block	Base (m)	Height (m)	Unit weight (kN/m^3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
W1	38.1	6.00	7.0	1600.20		19.05	0.0
W2	38.1	1.50	9.0	514.35		19.05	0.0
W3	38.1	6.00	9.0	2057.40		19.05	0.0
W4	38.1	11.50	7.5	3286.13		19.05	0.0

・Weight on top of improved part

Block	W (kN/m)	x (m)	W・x (kN/m・m)
q1	0.00	0.00	0.00
WE1	651.51	19.05	12411.27
WE2	2114.55	19.05	40282.18
ΣWE	2766.06		52693.44

・Weight of improved part

Block	W (kN/m)	x (m)	W・x (kN/m・m)
ΣWE	2766.06		52693.44
W1	1600.20	19.05	30483.81
W2	514.35	19.05	9798.37
W3	2057.40	19.05	39193.47
W4	3286.13	19.05	62600.68
ΣW	10224.14		194769.77

(3)Result of external force

Part			Normal situation
Resultant force of weight	: ΣW	(kN/m)	10224.14
Horizontal component of active earth pressure	: ΣP_A	(kN/m)	4,436.07
Vertical component of passive earth pressure	: ΣP_{AV}	(kN/m)	80.75
Residual Water Pressure	: ΣP_w	(kN/m)	904.49
Horizontal component of active earth pressure	: ΣP_P	(kN/m)	0.00
Vertical component of active earth pressure	: ΣP_{PV}	(kN/m)	0.00
Moment by effective weight	: $\Sigma W \cdot x$	(kN/m·m)	194,769.77
Moment by horizontal component of active earth pressure	: $\Sigma P_A \cdot y_A$	(kN/m·m)	50,500.58
Moment by vertical component of active earth pressure	: $\Sigma P_v \cdot x_v$	(kN/m·m)	3,076.57
Moment by Residual Water Pressure	: $\Sigma P_w \cdot y_w$	(kN/m·m)	13,123.21

(4)Result of examination for sliding

(Safety factor : $Fs \geqq 1.10$)

$F_{R1} = (\Sigma W + PV) \cdot \mu$

$= 7215.56$ (kN/m)

$F_{R2} = \tau \cdot B = (1/2 \cdot q_{uck} \cdot a_p) \cdot B$

$= 5909.31$ (kN/m)

$F_R = F_{R2}$

$= 5909.31$ (kN/m)

$Fs = F_R / (\Sigma P_{AH} + \Sigma P_w)$

$= 1.106 > 1.1$ ……… OK

(5)Result of examination

(Safety factor : $Fs \geqq 1.20$)

$\Sigma M_R = \Sigma W \cdot x + \Sigma P_{AV} \cdot B + \Sigma P_{PH} \cdot y_P$

$= 197,846.35$ (kN·m/m)

$\Sigma M_A = \Sigma P_W \cdot y_W + \Sigma P_{AH} \cdot y_A$

$= 63,623.78$ (kN·m/m)

$Fs = \Sigma M_R / \Sigma M_A$

$= 3.110 > 1.1$ ……… OK

Examination for sliding Model: Block-d

1．Calculation condition

(1) General condition

・Water level

Active side	:	D.L.	3.55	(m)
Passive side	:	D.L.	0.43	(m)

・Unit weight of wate : γ_w= 10.00 (kN/m^3)

・Surcharge

Active side w_1= 73.8 (kN/m^2)

(2) Condition of bearing layer

Internal friction angle : ϕ_B= 35 (°) (μ =tanϕ_B= 0.700)

Cohesion : c_B= 0.0 (kN/m^2)

(3) Specification of improved column

Width : B=	40.2	(m)
Depth of upper end :	-2.00	(m)
Depth of lower end :	-26.50	(m)
Improvement rate	51.7	(%)
Design strength : q_u	600.0	(kN/m^2)

(4) Soil parameters of calculation

・Soil parameters of active side

Soil layer	Lower end of layer D.L. (m)	γ_t (kN/m^3)	γ' (kN/m^3)	γ_{sat} (kN/m^3)	c (kN/m^2)	ϕ (°)	δ (°)
	4.50						
Fill					0.00		
	3.55	18.00	10.00	20.00	0.00	30	15
Fill					0.00		
	-2.00	18.00	10.00	20.00	0.00	30	15
Layer-2					15.00		
	-11.00	17.00	7.00	17.00	15.00	0	0
Layer-3b					25.00		
	-13.50	19.00	9.00	19.00	25.00	0	0
Layer-4					50.00		
	-16.00	19.00	9.00	19.00	50.00	0	0
Layer-5					40.00		
	-26.50	17.50	7.50	17.50	40.00	0	0

2. Examination for sliding

(1)Calculation earth pressure

・Active earth pressure

Number	Calculated depth (m)	K_A	$\Sigma \gamma h + w_1$ (kN/m²)	p_a (kN/m²)	p_{ah} (kN/m²)	p_{av} (kN/m²)
1	4.50 (down)	0.301	73.80	22.24	21.49	5.76
2	3.55 (up)	0.301	90.90	27.40	26.47	7.09
3	3.55 (down)	0.301	90.90	27.40	26.47	7.09
4	-2.00 (up)	0.301	146.40	44.13	42.62	11.42
5	-2.00 (down)		146.40	116.40	116.40	0.00
6	-11.00 (up)		209.40	179.40	179.40	0.00
7	-11.00 (down)		209.40	159.40	159.40	0.00
8	-13.50 (up)		231.90	181.90	181.90	0.00
9	-13.50 (down)		231.90	131.90	131.90	0.00
10	-16.00 (up)		254.40	154.40	154.40	0.00
11	-16.00 (down)		254.40	174.40	174.40	0.00
12	-26.50 (up)		333.15	253.15	253.15	0.00

	P_{AH}		y_A	$P_{AH} \cdot y_A$	P_{AV}		B	$P_{AV} \cdot B$
	Calculation	(kN/m)	(m)	(kN/m·m)	Calculation	(kN/m)	(m)	(kN/m·m)
PA1	21.49 × 0.95 × 1/2	10.21	30.68	313.16	5.76 × 0.95 × 1/2	2.73	40.20	109.94
PA2	26.47 × 0.95 × 1/2	12.57	30.37	381.74	7.09 × 0.95 × 1/2	3.37	40.20	135.41
PA3	26.47 × 5.55 × 1/2	73.44	28.20	2,071.03	7.09 × 5.55 × 1/2	19.68	40.20	791.07
PA4	42.62 × 5.55 × 1/2	118.28	26.35	3,116.70	11.42 × 5.55 × 1/2	31.69	40.20	1,274.07
PA5	116.40 × 9.00 × 1/2	523.80	21.50	11,261.70	0.00 × 9.00 × 1/2	0.00	40.20	0.00
PA6	179.40 × 9.00 × 1/2	807.30	18.50	14,935.05	0.00 × 9.00 × 1/2	0.00	40.20	0.00
PA7	159.40 × 2.50 × 1/2	199.25	14.67	2,922.33	0.00 × 2.50 × 1/2	0.00	40.20	0.00
PA8	181.90 × 2.50 × 1/2	227.38	13.83	3,145.35	0.00 × 2.50 × 1/2	0.00	40.20	0.00
PA9	131.90 × 2.50 × 1/2	164.88	12.17	2,005.98	0.00 × 2.50 × 1/2	0.00	40.20	0.00
PA10	154.40 × 2.50 × 1/2	193.00	11.33	2,187.33	0.00 × 2.50 × 1/2	0.00	40.20	0.00
PA11	174.40 × 10.50 × 1/2	915.60	7.00	6,409.20	0.00 × 10.50 × 1/2	0.00	40.20	0.00
PA12	253.15 × 10.50 × 1/2	1,329.04	3.50	4,651.63	0.00 × 10.50 × 1/2	0.00	40.20	0.00
Total		4,574.74		53,401.22		57.47		2,310.49

・Residual Water Pressure

	P_W		y_W	$P_W \cdot y_W$
	Calculation	(kN/m)	(m)	(kN/m·m)
Pw1	31.20 × 3.12 × 1/2	48.67	27.97	1,361.36
Pw2	31.20 × 26.93	840.22	13.47	11,313.51
Total		888.89		12,674.86

(2)Calculation of weight

Block	Base (m)	Height (m)	Unit weight (kN/m^3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
q1	0.00	0.00	0.0	0.00		0.00	0
WE1	40.20	0.95	18.0	687.42		20.10	0.0
WE2	40.20	5.55	10.0	2231.10		20.10	0.0

Block	Base (m)	Height (m)	Unit weight (kN/m^3)	Weight (kN/m)	□OR△ △＝1	x (m)	y (m)
W1	40.2	9.00	7.0	2532.60		20.10	0.0
W2	40.2	2.50	9.0	904.50		20.10	0.0
W3	40.2	2.50	9.0	904.50		20.10	0.0
W4	40.2	10.50	7.5	3165.75		20.10	0.0

・Weight on top of improved part

Block	W (kN/m)	x (m)	W・x (kN/m·m)
q1	0.00	0.00	0.00
WE1	687.42	20.10	13817.14
WE2	2231.10	20.10	44845.11
ΣWE	2918.52		58662.25

・Weight of improved part

Block	W (kN/m)	x (m)	W・x (kN/m·m)
ΣWE	2918.52		58662.25
W1	2532.60	20.10	50905.26
W2	904.50	20.10	18180.45
W3	904.50	20.10	18180.45
W4	3165.75	20.10	63631.58
ΣW	10425.87		209559.99

(3)Result of external force

Part			Normal situation
Resultant force of weight	: ΣW	(kN/m)	10425.87
Horizontal component of active earth pressure	: ΣP_A	(kN/m)	4,574.74
Vertical component of passive earth pressure	: ΣP_{AV}	(kN/m)	57.47
Residual Water Pressure	: ΣP_w	(kN/m)	888.89
Horizontal component of active earth pressure	: ΣP_P	(kN/m)	0.00
Vertical component of active earth pressure	: ΣP_{PV}	(kN/m)	0.00
Moment by effective weight	: $\Sigma W \cdot x$	(kN/m·m)	209,559.99
Moment by horizontal component of active earth pressure	: $\Sigma P_A \cdot y_A$	(kN/m·m)	53,401.22
Moment by vertical component of active earth pressure	: $\Sigma P_v \cdot x_v$	(kN/m·m)	2,310.49
Moment by Residual Water Pressure	: $\Sigma P_w \cdot y_w$	(kN/m·m)	12,674.86

(4)Result of examination for sliding

(Safety factor : $Fs \geqq 1.10$)

$F_{R1} = (\Sigma W + PV) \cdot \mu$

$= 7340.52$ (kN/m)

$F_{R2} = \tau \cdot B = (1/2 \cdot q_{uck} \cdot a_p) \cdot B$

$= 6235.02$ (kN/m)

$F_R = F_{R2}$

$= 6235.02$ (kN/m)

$Fs = F_R / (\Sigma P_{AH} + \Sigma P_w)$

$= 1.141 > 1.1$ ……… OK

(5)Result of examination

(Safety factor : $Fs \geqq 1.20$)

$\Sigma M_R = \Sigma W \cdot x + \Sigma P_{AV} \cdot B + \Sigma P_{PH} \cdot y_P$

$= 211,870.48$ (kN·m/m)

$\Sigma M_A = \Sigma P_W \cdot y_W + \Sigma P_{AH} \cdot y_A$

$= 66,076.08$ (kN·m/m)

$Fs = \Sigma M_R / \Sigma M_A$

$= 3.206 > 1.1$ ……… OK

Phụ lục 7-4

Tính toán ổn định mái dốc

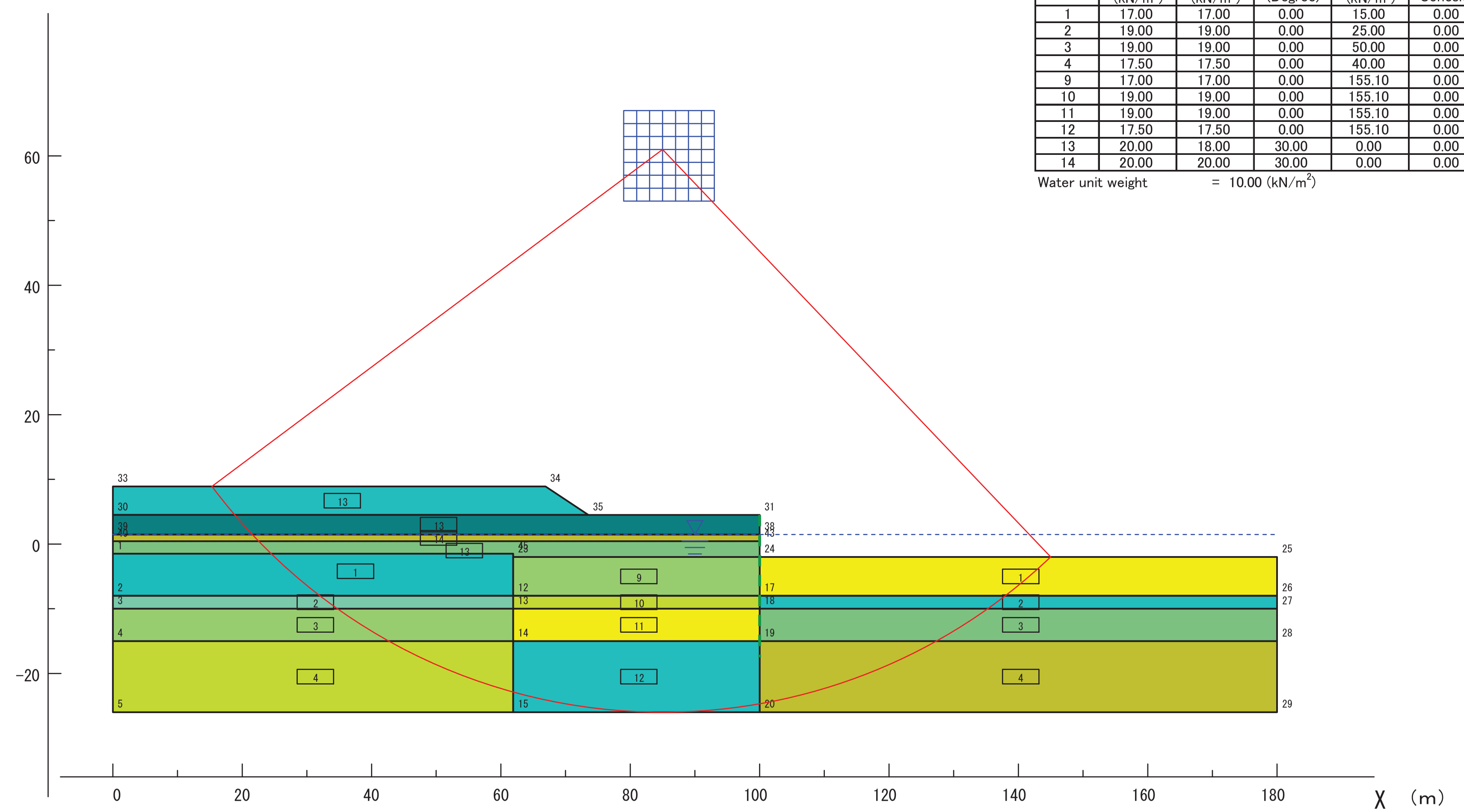
Section-① Preload

Scale ; 1/ 1000

Min. safty factor	$F_{S\,MIN}$	=	2.464	
Center of arc	X	=	85.00	(m)
	Y	=	61.00	(m)
Radius	R	=	87.00	(m)
Resisting moment	M_R	=	843803.6	(kN･m)
Sliding moment	M_D	=	342498.8	(kN･m)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
10	19.00	19.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^2)



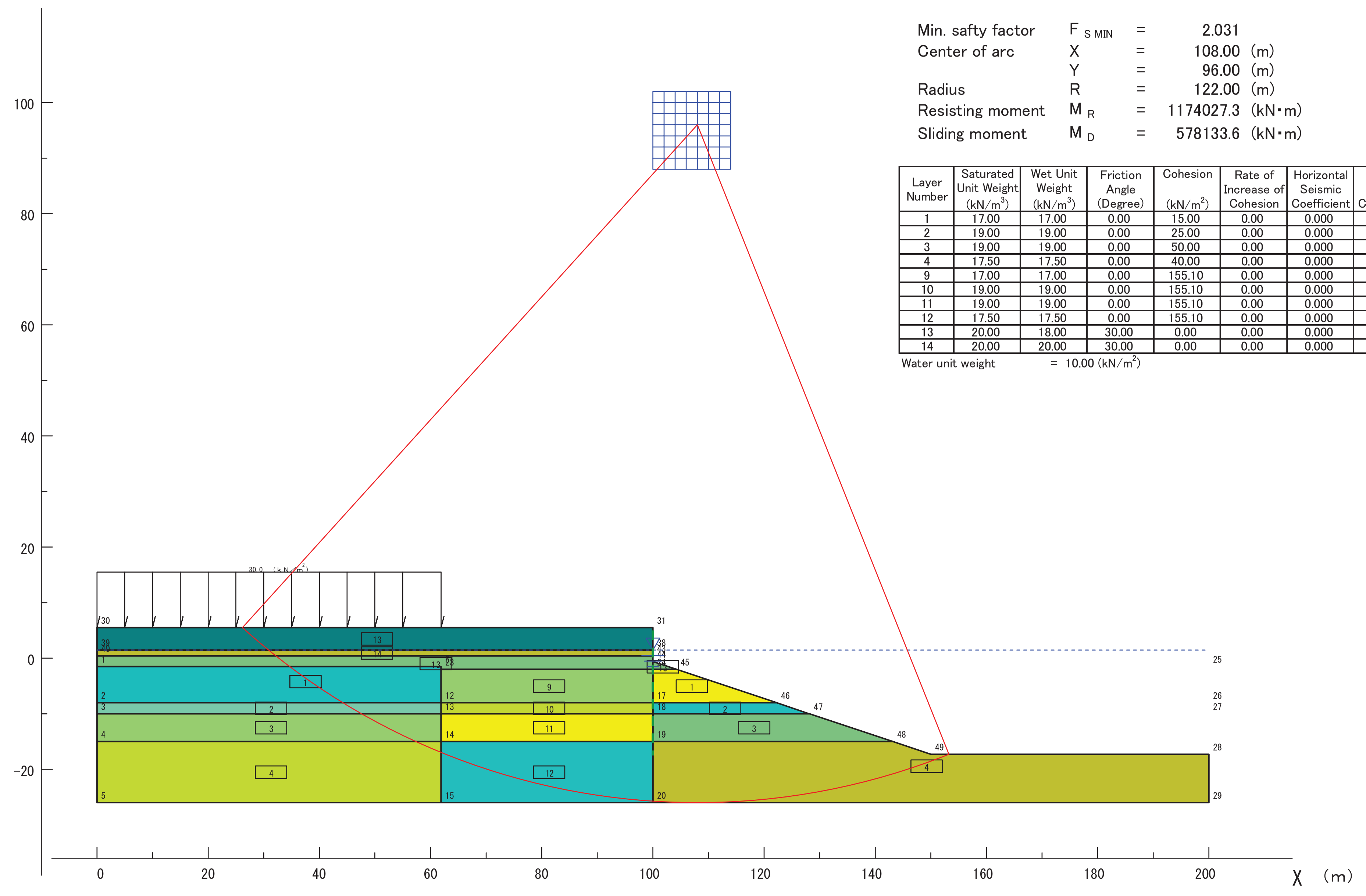
Section-① After Completion of Retaining Wall

Scale ; 1/ 1000

Min. safty factor	$F_{S\,MIN}$	=	2.031	
Center of arc	X	=	108.00	(m)
	Y	=	96.00	(m)
Radius	R	=	122.00	(m)
Resisting moment	M_R	=	1174027.3	(kN・m)
Sliding moment	M_D	=	578133.6	(kN・m)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
10	19.00	19.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^2)



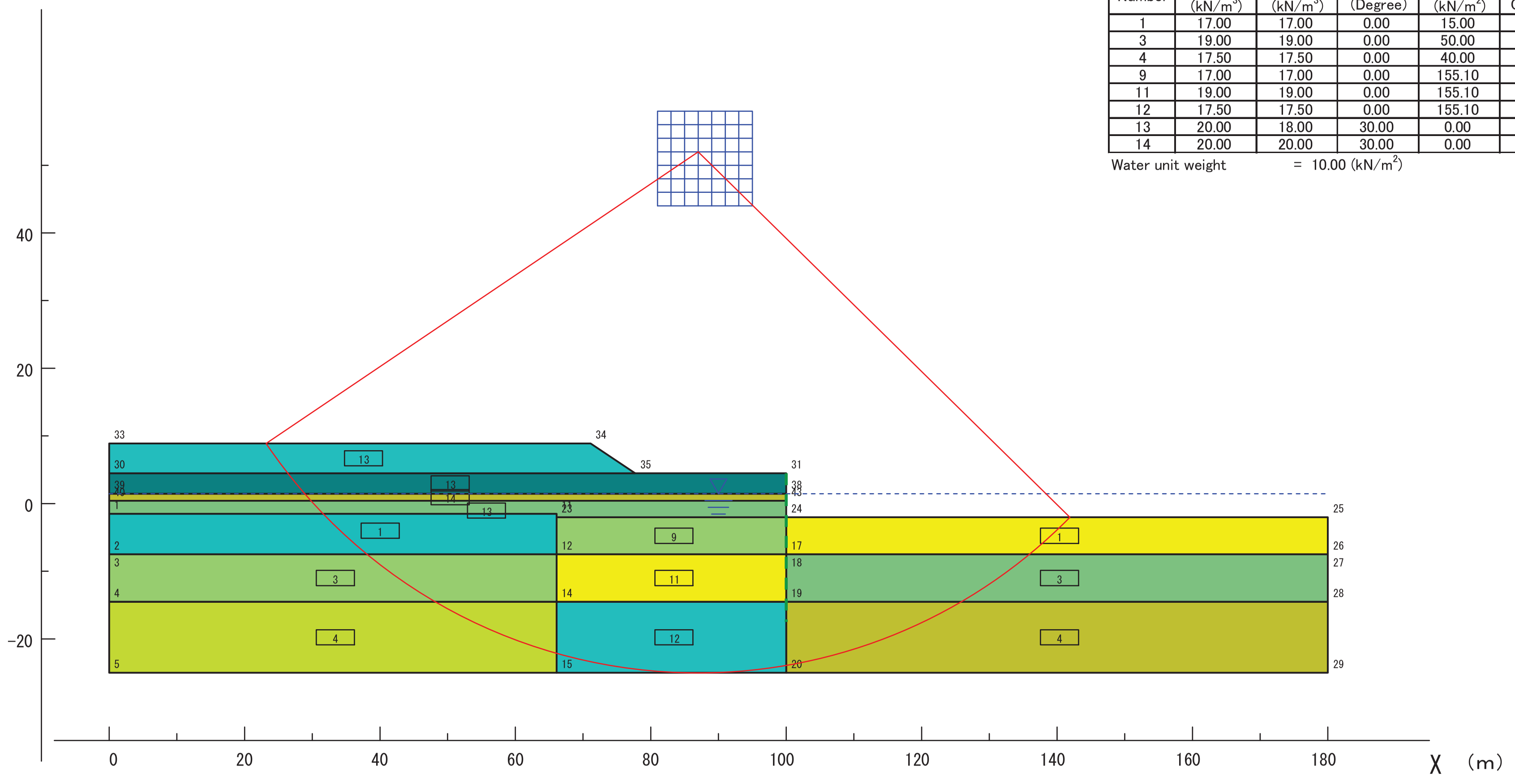
Section-a Preload

Scale ; 1/ 1000

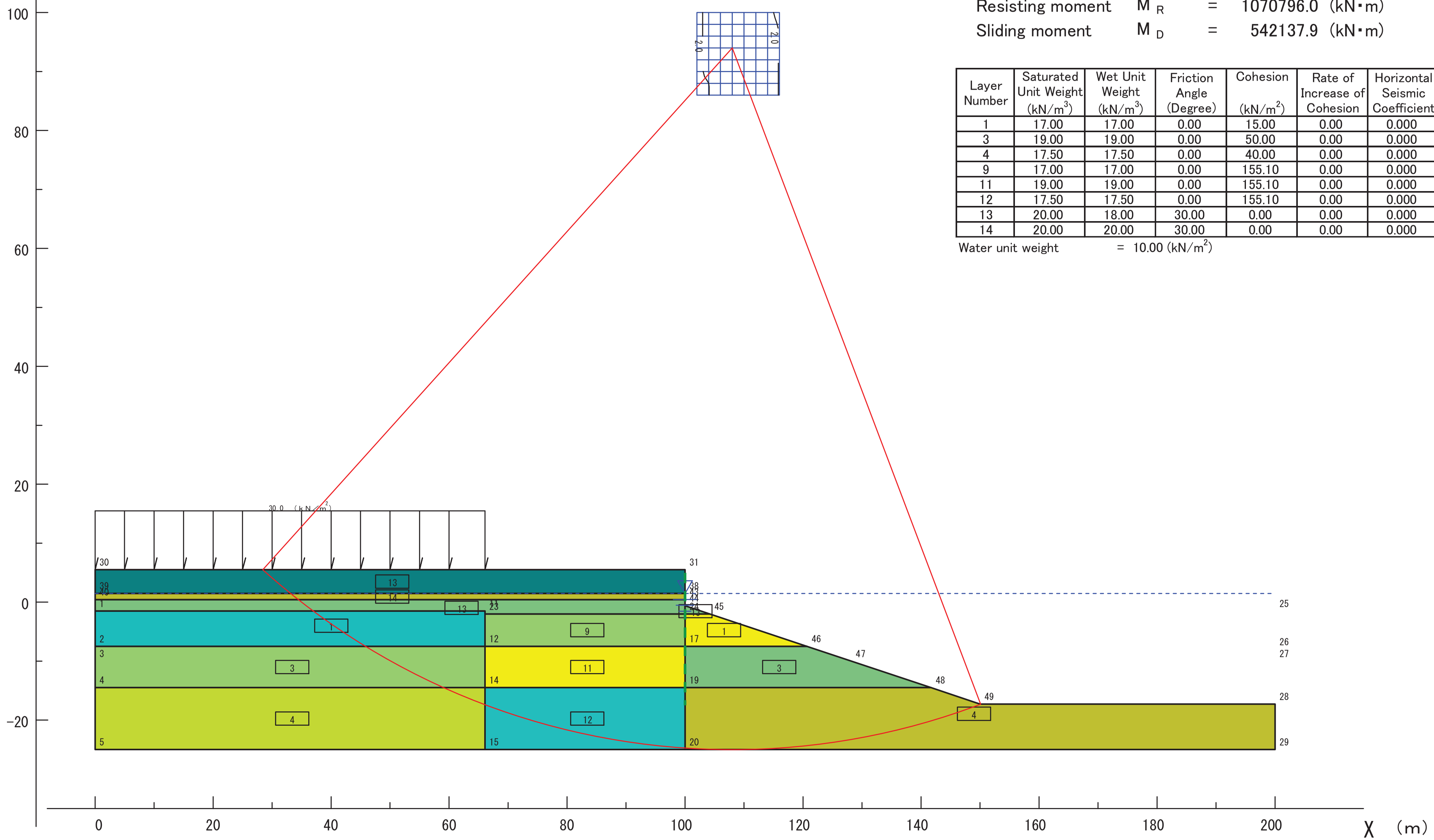
Min. safty factor	$F_{S\ MIN}$	=	2.391	
Center of arc	X	=	87.00	(m)
	Y	=	52.00	(m)
Radius	R	=	77.00	(m)
Resisting moment	M_R	=	691289.3	(kN·m)
Sliding moment	M_D	=	289129.8	(kN·m)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^2)



Section-a After Completion of Retaining Wall



Scale ; 1/ 1000

Min. safty factor	$F_{S\ MIN}$	=	1.975	
Center of arc	X	=	108.00	(m)
	Y	=	94.00	(m)
Radius	R	=	119.00	(m)
Resisting moment	M_R	=	1070796.0	(kN・m)
Sliding moment	M_D	=	542137.9	(kN・m)

Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m²)

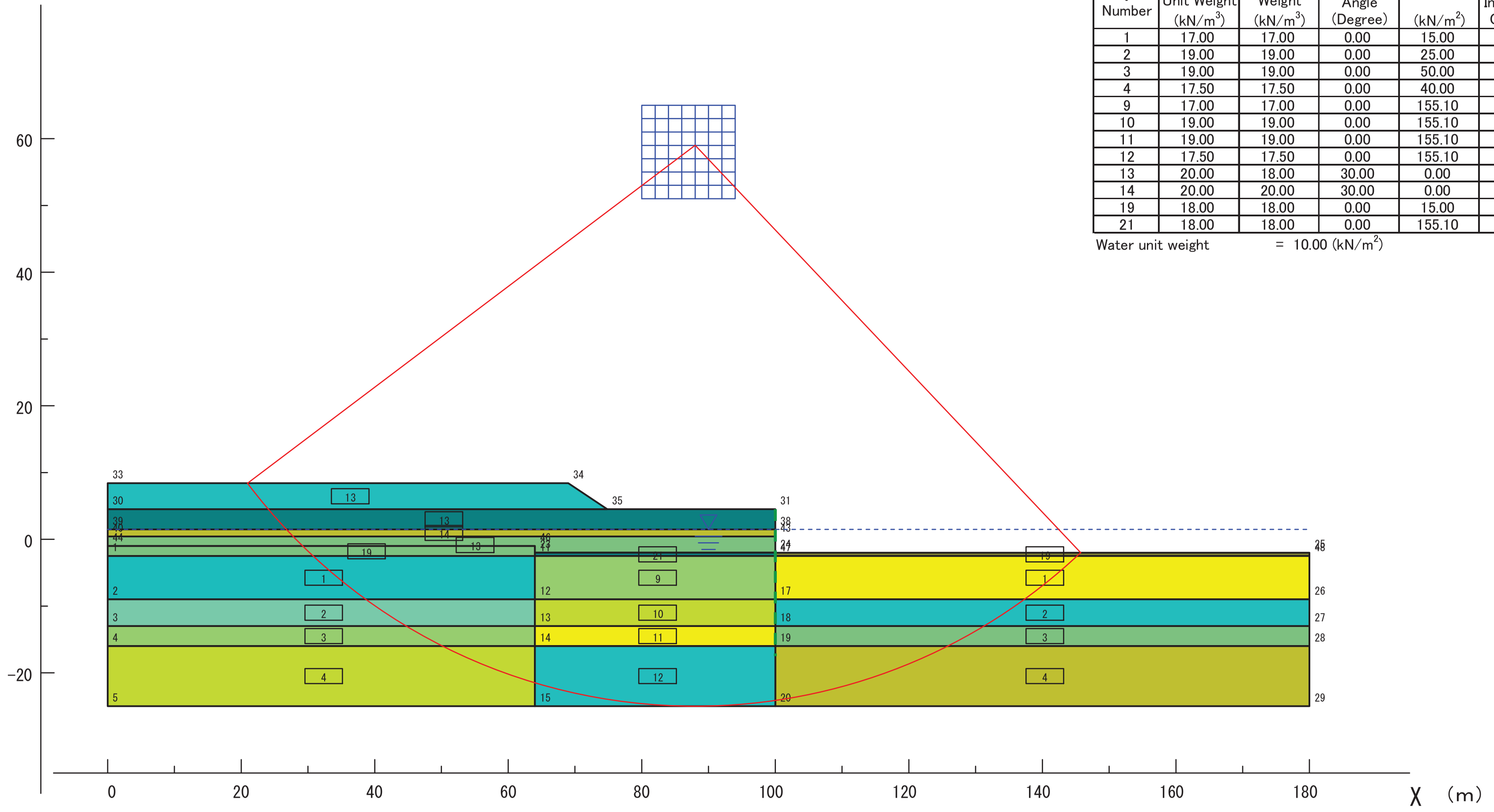
Section-b Preload

Scale ; 1/ 1000

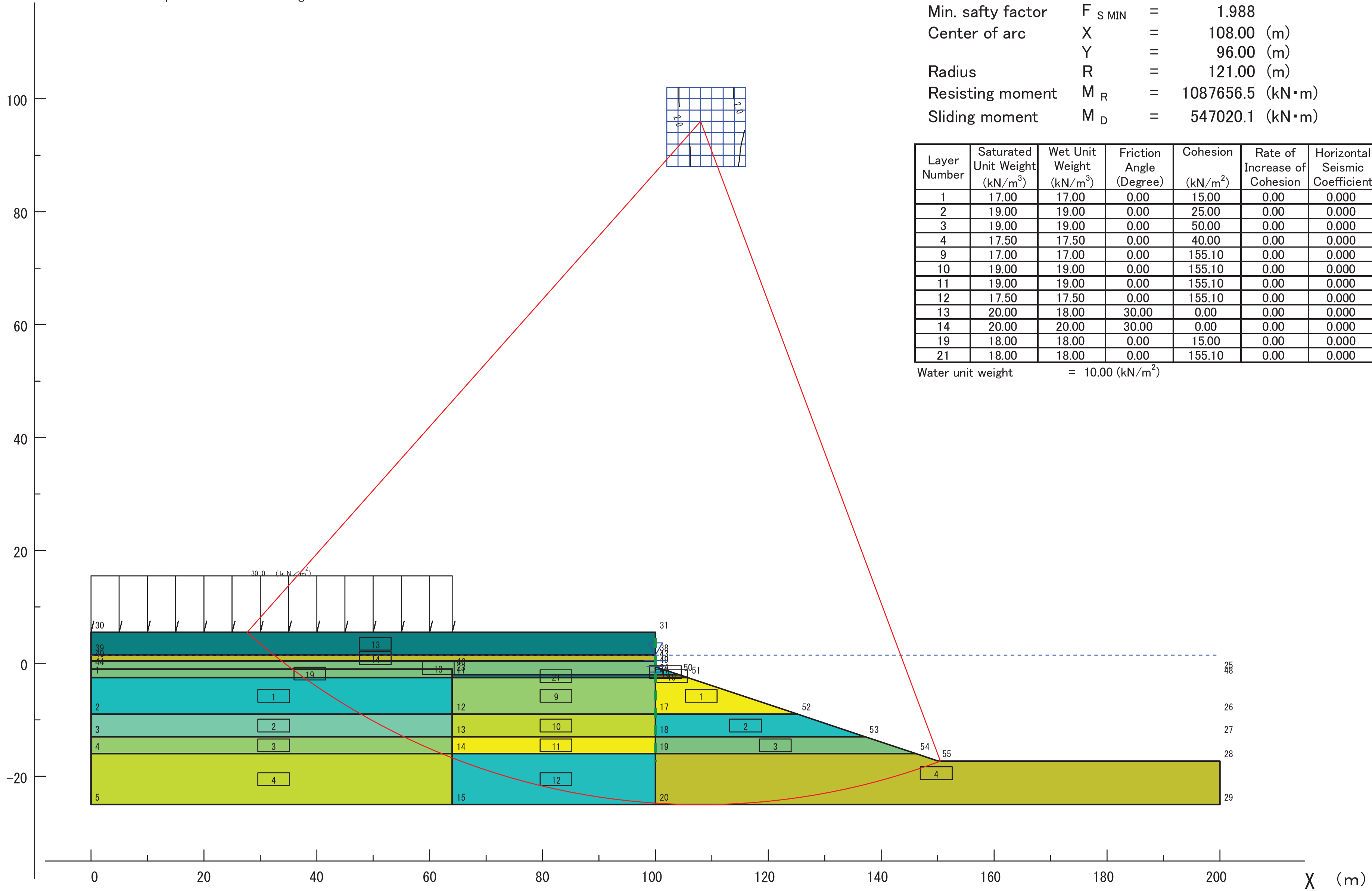
Min. safty factor	$F_{S\,MIN}$	=	2.498
Center of arc	X	=	88.00 (m)
	Y	=	59.00 (m)
Radius	R	=	84.00 (m)
Resisting moment	M_R	=	750854.9 (kN·m)
Sliding moment	M_D	=	300560.7 (kN·m)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
10	19.00	19.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000
19	18.00	18.00	0.00	15.00	0.00	0.000	0.000
21	18.00	18.00	0.00	155.10	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^2)



Section-b After Completion of Retaining Wall



Scale ; 1/ 1000

Min. safty factor	$F_{S\,MIN}$	=	1.988	
Center of arc	X	=	108.00	(m)
	Y	=	96.00	(m)
Radius	R	=	121.00	(m)
Resisting moment	M_R	=	1087656.5	(kN･m)
Sliding moment	M_D	=	547020.1	(kN･m)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
10	19.00	19.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000
19	18.00	18.00	0.00	15.00	0.00	0.000	0.000
21	18.00	18.00	0.00	155.10	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^2)

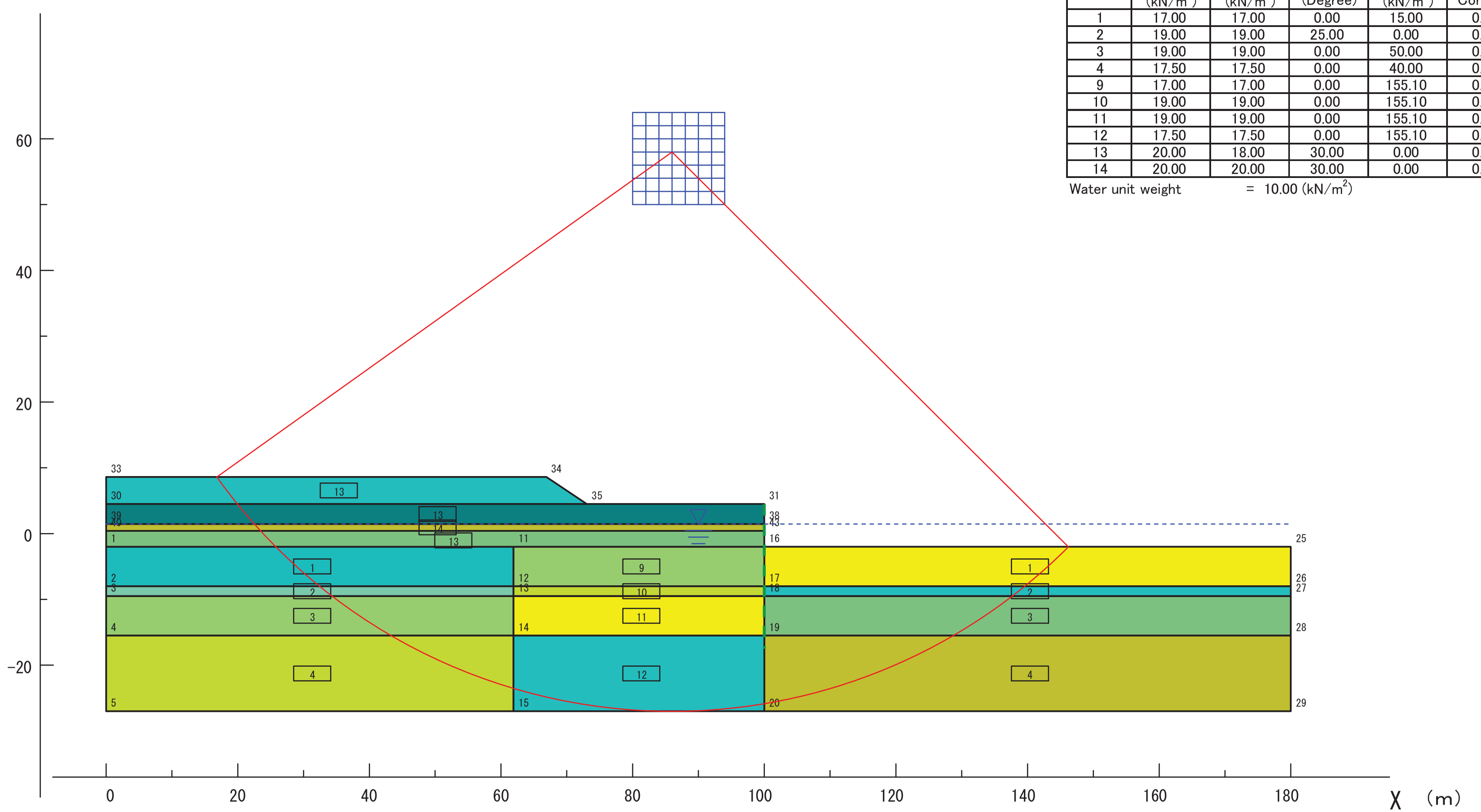
Section-c Preload

Scale ; 1/ 1000

Min. safty factor	$F_{S\,MIN}$	=	2.531	
Center of arc	X	=	86.00	(m)
	Y	=	58.00	(m)
Radius	R	=	85.00	(m)
Resisting moment	M_R	=	838798.0	(kN·m)
Sliding moment	M_D	=	331425.4	(kN·m)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	25.00	0.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
10	19.00	19.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^2)



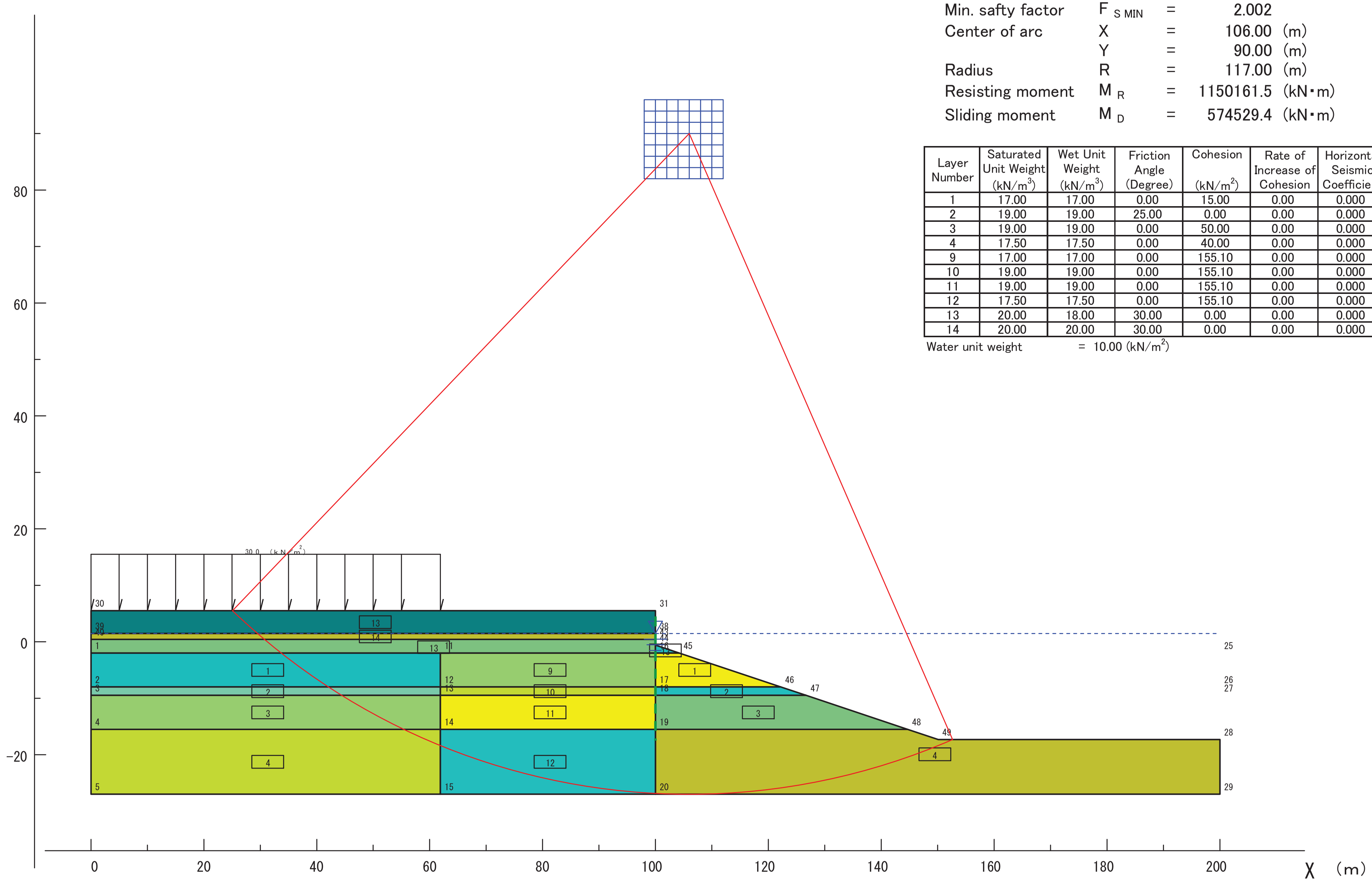
Section-c After Completion of Retaining Wall

Scale ; 1/ 1000

Min. safty factor	$F_{S\,MIN}$	=	2.002
Center of arc	X	=	106.00 (m)
	Y	=	90.00 (m)
Radius	R	=	117.00 (m)
Resisting moment	M_R	=	1150161.5 (kN・m)
Sliding moment	M_D	=	574529.4 (kN・m)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	25.00	0.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
10	19.00	19.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^2)



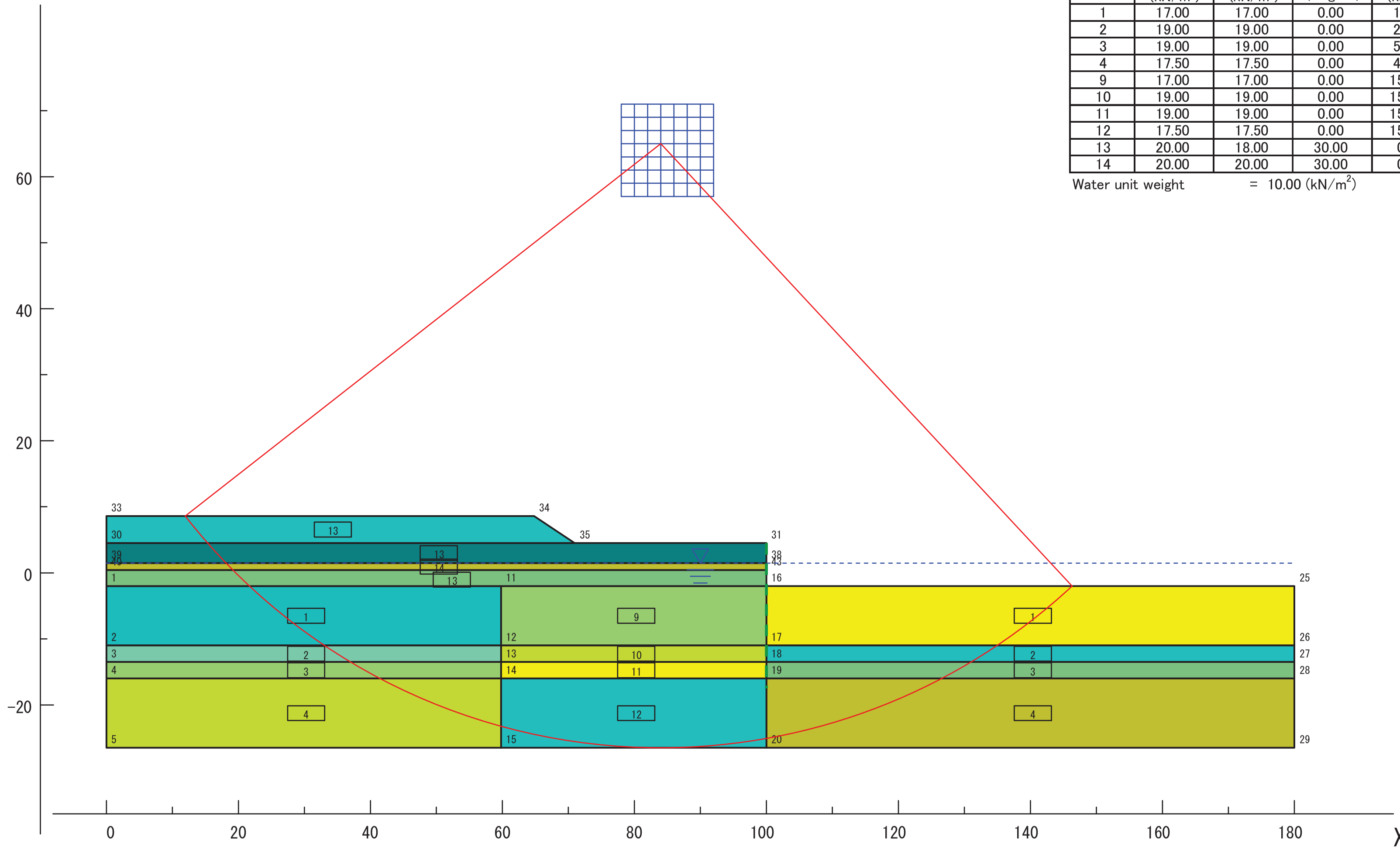
Section-d Preload

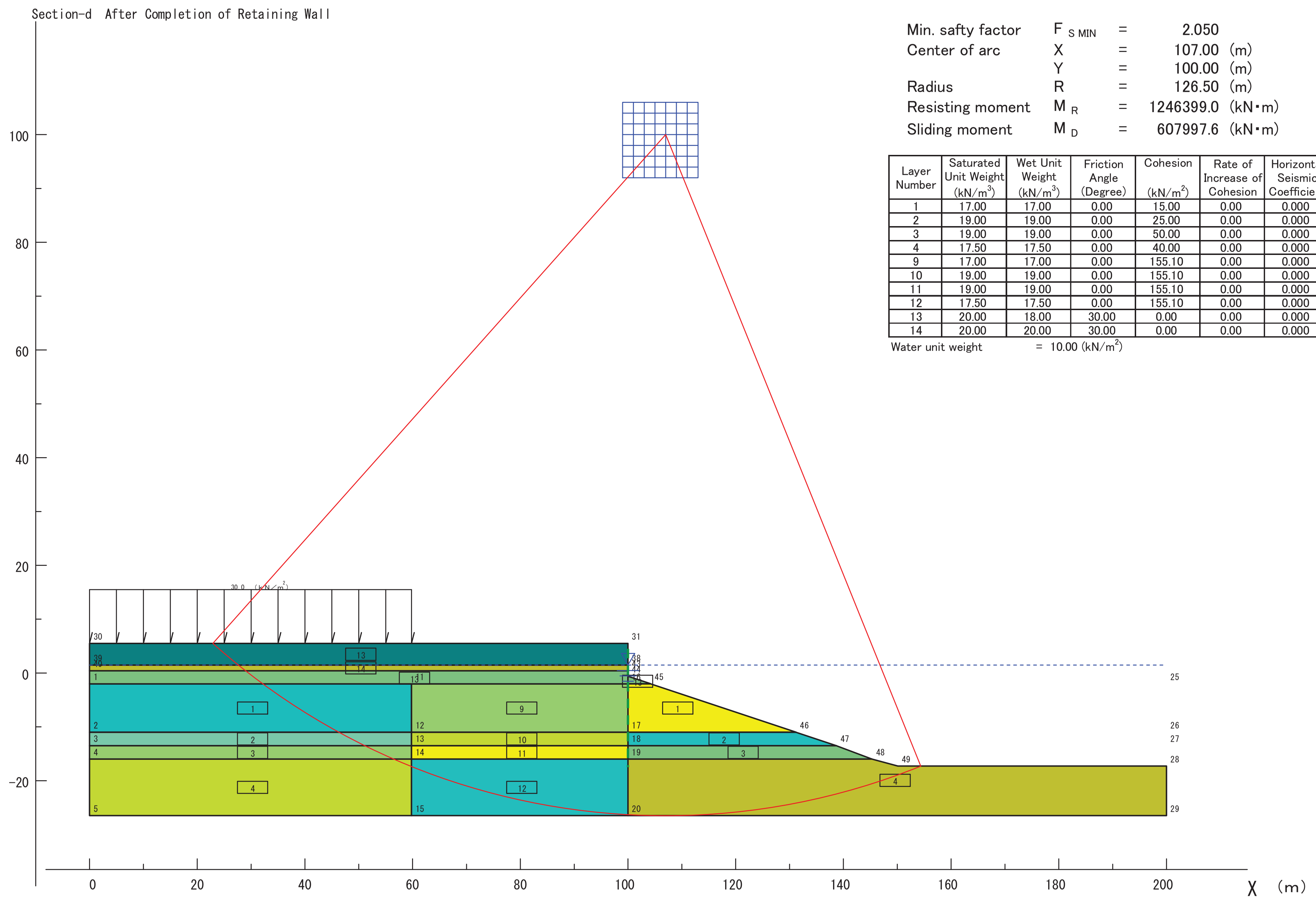
Scale ; 1/ 1000

Min. safty factor	$F_{S\,MIN}$	=	2.506	
Center of arc	X	=	84.00	(m)
	Y	=	65.00	(m)
Radius	R	=	91.50	(m)
Resisting moment	M_R	=	893255.7	(kN·m)
Sliding moment	M_D	=	356423.0	(kN·m)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
10	19.00	19.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^2)





Scale ; 1/ 1000

Min. safty factor	$F_{S\,MIN}$	=	2.050
Center of arc	X	=	107.00 (m)
	Y	=	100.00 (m)
Radius	R	=	126.50 (m)
Resisting moment	M_R	=	1246399.0 (kN·m)
Sliding moment	M_D	=	607997.6 (kN·m)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
10	19.00	19.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000

Water unit weight = 10.00 (kN/m^2)

Phụ lục 7-5

Áp lực đất chủ động tác động lên cọc ván thép

Determination of Active Earth Pressure on SPSP

1. Method of Active Earth Pressure Calculation

The active earth pressure on the steel pipe sheet pile (SPSP) will be calculated based on the "Technical Standards and Commentaries for Port and Harbour Facilities in Japan (TSCPHFJ)".

[For sandy soil – ordinary conditions]

14.2 Earth Pressure under Ordinary Conditions

14.2.1 Earth Pressure of Sandy Soil under Ordinary Conditions (Notification Article 11, Clause 1, Number 1)

The earth pressure of sandy soil acting on the backface wall of structure and the angle of sliding surface shall be calculated by the following equations:

(1) Active Earth Pressure and the Angle of Failure Surface.

$$p_{ai} = K_{ai}\left[\Sigma\gamma_i h_i + \frac{w\cos\psi}{\cos(\psi-\beta)}\right]\cos\psi \qquad (14.2.1)$$

$$\cot(\zeta_i-\beta) = -\tan(\phi_i+\delta+\psi-\beta)+\sec(\phi_i+\delta+\psi-\beta)\sqrt{\frac{\cos(\psi+\delta)\sin(\phi_i+\delta)}{\cos(\psi-\beta)\sin(\phi_i-\beta)}} \qquad (14.2.2)$$

where

$$K_{ai} = \frac{\cos^2(\phi_i-\psi)}{\cos^2\psi\cos(\delta+\psi)\left[1+\sqrt{\frac{\sin(\phi_i+\delta)\sin(\phi_i-\beta)}{\cos(\delta+\psi)\cos(\psi-\beta)}}\right]^2}$$

with

p_{ai}, p_{pi} : active and passive earth pressure, respectively, acting on the bottom level of the i-th soil layer (kN/m^2)
ϕ_i : angle of internal friction of the i-th soil layer (°)
γ_i : unit weight of the i-th soil layer (kN/m^3)
h_i : thickness of the i-th soil layer (m)
K_{ai}, K_{pi} : coefficients of active and passive earth pressures, respectively, in the i-th soil layer
ψ : angle of batter of backface wall from vertical line (°)
β : angle of backfill ground surface from horizontal line (°)
δ : angle of friction between backfilling material and backface wall (°)
ζ_i : angle of failure surface of the i-th soil layer (°)
w : uniformly distributed surcharge (kN/m^2)

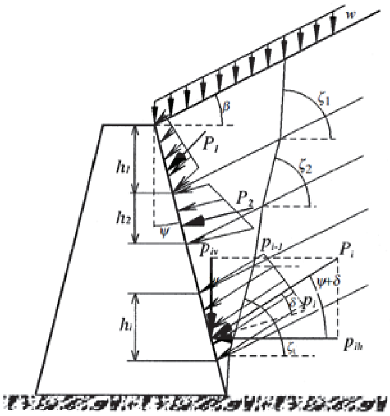


Fig. 14.2.1 Schematic Diagram of Earth Pressure Acting on Retaining Wall

[For cohesive soil – ordinary conditions]

14.2.2 Earth Pressure of Cohesive Soil under Ordinary Conditions (Notification Article 11, Clause 1, Number 2)

The earth pressure of cohesive soil acting on the backface wall of structure and the angle of failure surface shall be calculated by following equations:

(1) Active Earth Pressure

$$p_a = \Sigma\gamma_i h_i + w - 2c \tag{14.2.5}$$

(2) Passive Earth Pressure

$$p_p = \Sigma\gamma_i h_i + w + 2c \tag{14.2.6}$$

where

p_a : active earth pressure acting on the bottom level of the i-th soil layer (kN/m²)
p_p : passive earth pressure acts on the bottom level of the i-th soil layer (kN/m²)
γ_i : unit weight of the i-th soil layer (kN/m³)
h_i : thickness of the i-th soil layer (m)
w : uniformly distributed surcharge (kN/m²)
c : cohesion of soil in the i-th layer (kN/m²)

[For sandy soil – seismic conditions]

14.3 Earth Pressure during Earthquake

14.3.1 Earth Pressure of Sandy Soil during Earthquake (Notification Article 18, Clause 1, Number 1)

The earth pressure of sandy soil acting on a backface wall of structure during an earthquake and the angle of failure surface shall be calculated by following equations:

(1) Active Earth Pressure and the Angle of Failure Surface.

$$p_{ai} = K_{ai}\left[\Sigma\gamma_i h_i + \frac{w\cos\psi}{\cos(\psi-\beta)}\right]\cos\psi \tag{14.3.1}$$

$$\cot(\zeta_i - \beta) = -\tan(\phi_i + \delta + \psi - \beta) + \sec(\phi_i + \delta + \psi - \beta)\sqrt{\frac{\cos(\psi+\delta+\theta)\sin(\phi_i+\delta)}{\cos(\psi-\beta)\sin(\phi_i-\beta-\theta)}} \tag{14.3.2}$$

where

$$K_{ai} = \frac{\cos^2(\phi_i - \psi - \theta)}{\cos\theta\cos^2\psi\cos(\delta+\psi+\theta)\left[1+\sqrt{\frac{\sin(\phi_i+\delta)\sin(\phi_i-\beta-\theta)}{\cos(\delta+\psi+\theta)\cos(\psi-\beta)}}\right]^2}$$

where

θ : composite seismic angle (°) given by the following equations:
$\theta = \tan^{-1}k$ (above water level)
$\theta = \tan^{-1}k'$ (below water level)
k : seismic coefficient
k' : apparent seismic coefficient

The notations other than θ, k, and k' are the same as those defined in **14.2.1 Earth Pressure of Sandy Soil under Ordinary Conditions**. The apparent seismic coefficient k' is described in **14.3.3 Apparent Seismic Coefficient**.

[For cohesive soil – seismic conditions]

14.3.2 Earth Pressure of Cohesive Soil during Earthquake (Notification Article 18, Clause 1, Number 2)

The earth pressure of cohesive soil acting on a backface wall of structure during an earthquake shall be calculated by the following:

(1) Active Earth Pressure

Active earth pressure shall be calculated using an appropriate earth pressure equation which takes the seismic coefficient into account so that the structural stability will be secured during an earthquake.

[Commentary]

(1) The active earth pressure acting on a backface wall of structure during an earthquake and the angle of sliding surface should be calculated by following equations:

$$p_a = \frac{(\Sigma\gamma_i h_i + w)\sin(\zeta_a + \theta)}{\cos\theta \sin\zeta_a} - \frac{c}{\cos\zeta_a \sin\zeta_a} \tag{14.3.5}$$

$$\zeta_a = \tan^{-1}\sqrt{1 - \left(\frac{\Sigma\gamma_i h_i + 2w}{2c}\right)\tan\theta} \tag{14.3.6}$$

where

p_a : active earth pressure, acting on the bottom level of the i-th soil layer (kN/m^2)
γ_i : unit weight of the i-th soil layer (kN/m^3)
h_i : thickness of the i-th soil layer (m)
ζ_a : angle of failure surface of the i-th soil layer (°)
w : uniformly distributed surcharge (kN/m^2)
c : cohesion of the soil (kN/m^2)
θ : composite seismic angle (°) ($\theta = \tan^{-1}k$ or $\theta = \tan^{-1}k'$)
k : seismic coefficient
k' : apparent seismic coefficient

(2) There are many unknown items concerning the method for determining the passive earth pressure of cohesive soil during an earthquake. From the practical point of view, the passive earth pressure in ordinary condition discribed in **14.2.2 Earth Pressure of Cohesive Soil under Ordinary Conditions** can be used as passive earth pressure during an earthquake.

(3) The apparent seismic coefficient should be used to calculate the earth pressure of cohesive soil down to the sea bottom during an earthquake. The apparent seismic coefficient may be set as zero when calculating the earth pressure at the depth of 10 m from the sea bottom or deeper. The earth pressure between these two depths is determined assuming that the earth pressure is linearly distributed between them. If the earth pressure at the depth of 10 m below the sea bottom becomes less than the earth pressure at the sea bottom, the latter should be applied down to the depth of 10 m.

[Apparent seismic coefficient]

14.3.3 Apparent Seismic Coefficient (Notification Article 19)

It shall be standard to calculate the earth pressure acting below the residual water level during an earthquake according to the procedures given in **14.3.1 Earth Pressure of Sandy Soil during Earthquake and 14.3.2 Earth Pressure of Cohesive Soil during Earthquake**, by using the apparent seismic coefficient that is determined by equation (**14.3.7**).

$$k' = \frac{2(\Sigma\gamma_t h_i + \Sigma\gamma h_j + w) + \gamma h}{2[\Sigma\gamma_t h_i + \Sigma(\gamma - 10) h_j + w] + (\gamma - 10) h} k \qquad (14.3.7)$$

where

- k' : apparent seismic coefficient
- γ_t : unit weight of soil layer above the residual water level (kN/m^3)
- γ : unit weight (in the air) of saturated soil layer below the residual water level (kN/m^3)
- w : uniform external load at the ground surface (kN/m^2)
- h_i : thickness of the i-th soil layer above the residual water level (m)
- h_j : thickness of the j-th soil layer below the residual water level (m)
- h : thickness of soil layer to calculate earth pressure below the residual watere level (m)
- k : seismic coefficient

[Commentary]

(1) In case of stability analysis of quaywall with use of equation (**14.3.7**), the dynamic water pressure during an earthquake should be applied to the wall in the seaward direction.

(2) The concept of the apparent seismic coefficient k' is expressed by the following equation:

$$\gamma_t \times k = (\gamma - 10) \times k'$$

(3) A product of unit weight of a soil layer (in the air) and seismic coefficient becomes equal to the product of submerged unit weight of a soil layer and the apparent coefficient for the soil below the water level.

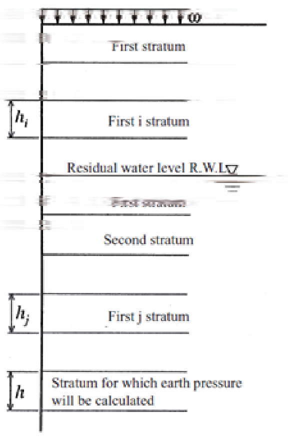


Fig. C- 14.3.2 Cross Section of Soil Layers and Symbols.

2. Special Consideration for Container Berth/Barge Berth

The active earth pressure on the steel pipe sheet pile (SPSP) needs special consideration due to the existence of the DMM block.

There will be a gap between the SPSP and the DMM as shown in Figure 1 to allow for possible construction deviations of the DMM installation.

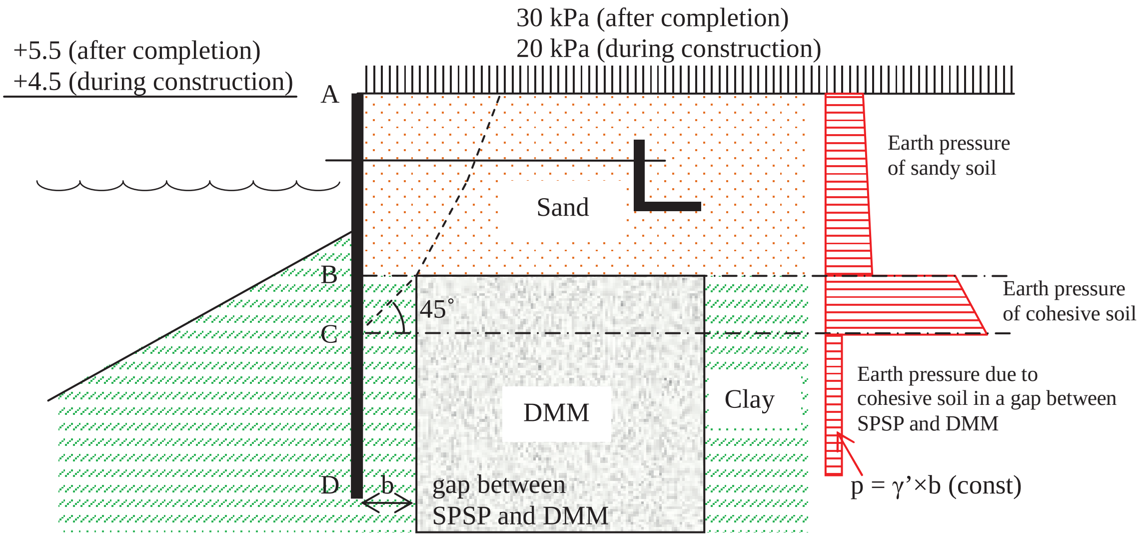
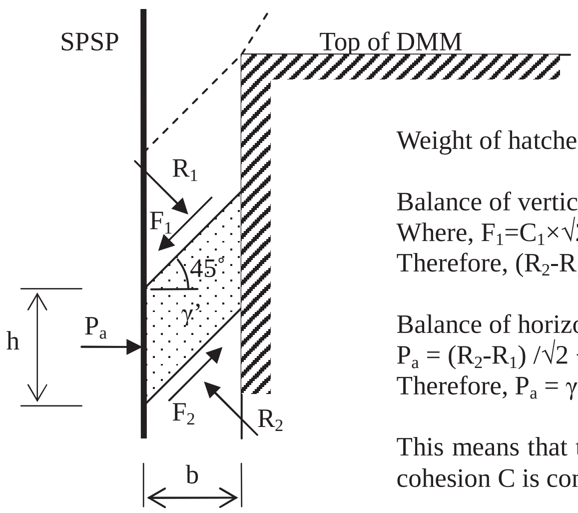


Figure 1 Active earth pressure on the SPSP

In this case, following active earth pressure shall be considered:

- Between points A and B : Earth pressure of sandy soil (not affected by DMM)
- Between points B and C : Earth pressure of cohesive soil (not affected by DMM)
- Between points C and D : Earth pressure of cohesive soil (reduced by DMM)

For the active earth pressure between points C and D is obtained as follows:



Weight of hatched area : $W = \gamma' bh$

Balance of vertical forces: $(R_1+F_1)/\sqrt{2} + W = (R_2+F_2)/\sqrt{2}$
Where, $F_1=C_1\times\sqrt{2}b$, $F_2=C_2\times\sqrt{2}b$; C_1 and C_2 are cohesion of soil
Therefore, $(R_2-R_1)/\sqrt{2} = \gamma' bh + (F_1-F_2)/\sqrt{2} = \gamma' bh + (C_1-C_2)b$

Balance of horizontal forces:
$P_a = (R_2-R_1)/\sqrt{2} + (F_1-F_2)/\sqrt{2}$
Therefore, $P_a = \gamma' bh + (C_1-C_2)b + (C_1-C_2)b = \gamma' bh + 2(C_1-C_2)b$

This means that the earth pressure p_a equals to $p_a=\gamma' b$ (const), when cohesion C is constant.

The gap between SPSP and DMM is set to be b=1.0m.

Active earth pressure below the point C is calculated in the following pages and summarized in Table 1.

Table 1 Summary of active earth pressure below point C

	Active earth pressure	Remarks
Layer 2	p_a = 7.0 kPa	
Layer 3	Generally in a range of 0 kPa ~ 9 kPa. However, averaged pressure is much smaller than that for Layer 2.	
Layer 4	Generally $p_a \approx 0$ kPa. For block a, c and 1, relatively larger values were obtained just below Layer 4 but are much smaller than 7.0kPa multiplied with the thickness of Layer 4.	
Layer 5	p_a = 7.5 kPa	

In conclusion, the design adopted the following values of earth pressure on the SPSP below the point C.

- **Design active earth pressure below point C : p_a = 7.00 kPa**

The above is considered to be conservative as explained below:

- As shown in Table 1, the values of earth pressure obtained for Layers 3 and 4 have generally smaller effect than p_a=7.0kPa (value of Layer-2).
- The values for Layer 5 is slightly larger than Layer 2 but has negligible effect to the SPSP design (i.e., penetration of SPSP into Layer 5 is very short). Also, such differences can be compensated by the conservative assumption made for Layers 3 and 4.

Block-1

Layer	Elev.		h	Cu	γ'	γ'h	Σγ'h	P	p
	Top	Bottom						(total)	{P(i) - P(i-1)}/h
	(m)	(m)	(m)	(kPa)	(kN/m3)	(kPa)	(kPa)	(kN/m)	(kPa)
2	-2.6	-3.0	0.4	15.0	7.0	2.8	2.8	2.8	7.00
2	-3.0	-3.5	0.5	15.0	7.0	3.5	6.3	6.3	7.00
2	-3.5	-4.0	0.5	15.0	7.0	3.5	9.8	9.8	7.00
2	-4.0	-4.5	0.5	15.0	7.0	3.5	13.3	13.3	7.00
2	-4.5	-5.0	0.5	15.0	7.0	3.5	16.8	16.8	7.00
2	-5.0	-5.5	0.5	15.0	7.0	3.5	20.3	20.3	7.00
2	-5.5	-6.0	0.5	15.0	7.0	3.5	23.8	23.8	7.00
2	-6.0	-6.5	0.5	15.0	7.0	3.5	27.3	27.3	7.00
2	-6.5	-7.0	0.5	15.0	7.0	3.5	30.8	30.8	7.00
2	-7.0	-7.5	0.5	15.0	7.0	3.5	34.3	34.3	7.00
2	-7.5	-8.0	0.5	15.0	7.0	3.5	37.8	37.8	7.00
3	-8.0	-8.5	0.5	25.0	9.0	4.5	42.3	37.8	0.00
3	-8.5	-9.0	0.5	25.0	9.0	4.5	46.8	37.8	0.00
3	-9.0	-9.5	0.5	25.0	9.0	4.5	51.3	37.8	0.00
3	-9.5	-10.0	0.5	25.0	9.0	4.5	55.8	37.8	0.00
4	-10.0	-10.5	0.5	50.0	9.0	4.5	60.3	37.8	0.00
4	-10.5	-11.0	0.5	50.0	9.0	4.5	64.8	37.8	0.00
4	-11.0	-11.5	0.5	50.0	9.0	4.5	69.3	37.8	0.00
4	-11.5	-12.0	0.5	50.0	9.0	4.5	73.8	37.8	0.00
4	-12.0	-12.5	0.5	50.0	9.0	4.5	78.3	37.8	0.00
4	-12.5	-13.0	0.5	50.0	9.0	4.5	82.8	37.8	0.00
4	-13.0	-13.5	0.5	50.0	9.0	4.5	87.3	37.8	0.00
4	-13.5	-14.0	0.5	50.0	9.0	4.5	91.8	37.8	0.00
4	-14.0	-14.5	0.5	50.0	9.0	4.5	96.3	37.8	0.00
4	-14.5	-15.0	0.5	50.0	9.0	4.5	100.8	37.8	0.00
5	-15.0	-15.5	0.5	40.0	7.5	3.8	104.6	54.6	33.50
5	-15.5	-16.0	0.5	40.0	7.5	3.8	108.3	58.3	7.50
5	-16.0	-16.5	0.5	40.0	7.5	3.8	112.1	62.1	7.50
5	-16.5	-17.0	0.5	40.0	7.5	3.8	115.8	65.8	7.50
5	-17.0	-17.5	0.5	40.0	7.5	3.8	119.6	69.6	7.50
5	-17.5	-18.0	0.5	40.0	7.5	3.8	123.3	73.3	7.50
5	-18.0	-18.5	0.5	40.0	7.5	3.8	127.1	77.1	7.50
5	-18.5	-19.0	0.5	40.0	7.5	3.8	130.8	80.8	7.50
5	-19.0	-19.5	0.5	40.0	7.5	3.8	134.6	84.6	7.50
5	-19.5	-20.0	0.5	40.0	7.5	3.8	138.3	88.3	7.50
5	-20.0	-20.5	0.5	40.0	7.5	3.8	142.1	92.1	7.50
5	-20.5	-21.0	0.5	40.0	7.5	3.8	145.8	95.8	7.50
5	-21.0	-21.5	0.5	40.0	7.5	3.8	149.6	99.6	7.50
5	-21.5	-22.0	0.5	40.0	7.5	3.8	153.3	103.3	7.50
5	-22.0	-22.5	0.5	40.0	7.5	3.8	157.1	107.1	7.50
5	-22.5	-23.0	0.5	40.0	7.5	3.8	160.8	110.8	7.50
5	-23.0	-23.5	0.5	40.0	7.5	3.8	164.6	114.6	7.50
5	-23.5	-24.0	0.5	40.0	7.5	3.8	168.3	118.3	7.50
5	-24.0	-24.5	0.5	40.0	7.5	3.8	172.1	122.1	7.50
5	-24.5	-25.0	0.5	40.0	7.5	3.8	175.8	125.8	7.50
5	-25.0	-25.5	0.5	40.0	7.5	3.8	179.6	129.6	7.50
5	-25.5	-26.0	0.5	40.0	7.5	3.8	183.3	133.3	7.50
5	-26.0	-26.5	0.5	40.0	7.5	3.8	187.1	137.1	7.50
5	-26.5	-27.0	0.5	40.0	7.5	3.8	190.8	140.8	7.50

Block-a

Layer	Elev.		h	Cu	γ'	γ'h	Σγ'h	P	p_normal
	Top	Bottom						(total)	{P(i) - P(i-1)}/h
	(m)	(m)	(m)	(kPa)	(kN/m3)	(kPa)	(kPa)	(kN/m)	(kPa)
2	-2.6	-3.0	0.4	15.0	7.0	2.8	2.8	2.8	7.00
2	-3.0	-3.5	0.5	15.0	7.0	3.5	6.3	6.3	7.00
2	-3.5	-4.0	0.5	15.0	7.0	3.5	9.8	9.8	7.00
2	-4.0	-4.5	0.5	15.0	7.0	3.5	13.3	13.3	7.00
2	-4.5	-5.0	0.5	15.0	7.0	3.5	16.8	16.8	7.00
2	-5.0	-5.5	0.5	15.0	7.0	3.5	20.3	20.3	7.00
2	-5.5	-6.0	0.5	15.0	7.0	3.5	23.8	23.8	7.00
2	-6.0	-6.5	0.5	15.0	7.0	3.5	27.3	27.3	7.00
2	-6.5	-7.0	0.5	15.0	7.0	3.5	30.8	30.8	7.00
2	-7.0	-7.5	0.5	15.0	7.0	3.5	34.3	34.3	7.00
4	-7.5	-8.0	0.5	50.0	9.0	4.5	38.8	34.3	0.00
4	-8.0	-8.5	0.5	50.0	9.0	4.5	43.3	34.3	0.00
4	-8.5	-9.0	0.5	50.0	9.0	4.5	47.8	34.3	0.00
4	-9.0	-9.5	0.5	50.0	9.0	4.5	52.3	34.3	0.00
4	-9.5	-10.0	0.5	50.0	9.0	4.5	56.8	34.3	0.00
4	-10.0	-10.5	0.5	50.0	9.0	4.5	61.3	34.3	0.00
4	-10.5	-11.0	0.5	50.0	9.0	4.5	65.8	34.3	0.00
4	-11.0	-11.5	0.5	50.0	9.0	4.5	70.3	34.3	0.00
4	-11.5	-12.0	0.5	50.0	9.0	4.5	74.8	34.3	0.00
4	-12.0	-12.5	0.5	50.0	9.0	4.5	79.3	34.3	0.00
4	-12.5	-13.0	0.5	50.0	9.0	4.5	83.8	34.3	0.00
4	-13.0	-13.5	0.5	50.0	9.0	4.5	88.3	34.3	0.00
4	-13.5	-14.0	0.5	50.0	9.0	4.5	92.8	34.3	0.00
4	-14.0	-14.5	0.5	50.0	9.0	4.5	97.3	34.3	0.00
5	-14.5	-15.0	0.5	40.0	7.5	3.8	101.1	51.1	33.50
5	-15.0	-15.5	0.5	40.0	7.5	3.8	104.8	54.8	7.50
5	-15.5	-16.0	0.5	40.0	7.5	3.8	108.6	58.6	7.50
5	-16.0	-16.5	0.5	40.0	7.5	3.8	112.3	62.3	7.50
5	-16.5	-17.0	0.5	40.0	7.5	3.8	116.1	66.1	7.50
5	-17.0	-17.5	0.5	40.0	7.5	3.8	119.8	69.8	7.50
5	-17.5	-18.0	0.5	40.0	7.5	3.8	123.6	73.6	7.50
5	-18.0	-18.5	0.5	40.0	7.5	3.8	127.3	77.3	7.50
5	-18.5	-19.0	0.5	40.0	7.5	3.8	131.1	81.1	7.50
5	-19.0	-19.5	0.5	40.0	7.5	3.8	134.8	84.8	7.50
5	-19.5	-20.0	0.5	40.0	7.5	3.8	138.6	88.6	7.50
5	-20.0	-20.5	0.5	40.0	7.5	3.8	142.3	92.3	7.50
5	-20.5	-21.0	0.5	40.0	7.5	3.8	146.1	96.1	7.50
5	-21.0	-21.5	0.5	40.0	7.5	3.8	149.8	99.8	7.50
5	-21.5	-22.0	0.5	40.0	7.5	3.8	153.6	103.6	7.50
5	-22.0	-22.5	0.5	40.0	7.5	3.8	157.3	107.3	7.50
5	-22.5	-23.0	0.5	40.0	7.5	3.8	161.1	111.1	7.50
5	-23.0	-23.5	0.5	40.0	7.5	3.8	164.8	114.8	7.50
5	-23.5	-24.0	0.5	40.0	7.5	3.8	168.6	118.6	7.50
5	-24.0	-24.5	0.5	40.0	7.5	3.8	172.3	122.3	7.50
5	-24.5	-25.0	0.5	40.0	7.5	3.8	176.1	126.1	7.50
5	-25.0	-25.5	0.5	40.0	7.5	3.8	179.8	129.8	7.50
5	-25.5	-26.0	0.5	40.0	7.5	3.8	183.6	133.6	7.50
5	-26.0	-26.5	0.5	40.0	7.5	3.8	187.3	137.3	7.50
5	-26.5	-27.0	0.5	40.0	7.5	3.8	191.1	141.1	7.50

Block-b

Layer	Elev. Top (m)	Elev. Bottom (m)	h (m)	Cu (kPa)	γ' (kN/m3)	γ'h (kPa)	Σγ'h (kPa)	P (total) (kN/m)	p {P(i) - P(i-1)}/h (kPa)
2	-2.6	-3.0	0.4	15.0	7.0	2.8	2.8	2.8	7.00
2	-3.0	-3.5	0.5	15.0	7.0	3.5	6.3	6.3	7.00
2	-3.5	-4.0	0.5	15.0	7.0	3.5	9.8	9.8	7.00
2	-4.0	-4.5	0.5	15.0	7.0	3.5	13.3	13.3	7.00
2	-4.5	-5.0	0.5	15.0	7.0	3.5	16.8	16.8	7.00
2	-5.0	-5.5	0.5	15.0	7.0	3.5	20.3	20.3	7.00
2	-5.5	-6.0	0.5	15.0	7.0	3.5	23.8	23.8	7.00
2	-6.0	-6.5	0.5	15.0	7.0	3.5	27.3	27.3	7.00
2	-6.5	-7.0	0.5	15.0	7.0	3.5	30.8	30.8	7.00
2	-7.0	-7.5	0.5	15.0	7.0	3.5	34.3	34.3	7.00
2	-7.5	-8.0	0.5	15.0	7.0	3.5	37.8	37.8	7.00
2	-8.0	-8.5	0.5	15.0	7.0	3.5	41.3	41.3	7.00
2	-8.5	-9.0	0.5	15.0	7.0	3.5	44.8	44.8	7.00
3	-9.0	-9.5	0.5	25.0	9.0	4.5	49.3	44.8	0.00
3	-9.5	-10.0	0.5	25.0	9.0	4.5	53.8	44.8	0.00
3	-10.0	-10.5	0.5	25.0	9.0	4.5	58.3	44.8	0.00
3	-10.5	-11.0	0.5	25.0	9.0	4.5	62.8	44.8	0.00
3	-11.0	-11.5	0.5	25.0	9.0	4.5	67.3	47.3	5.00
3	-11.5	-12.0	0.5	25.0	9.0	4.5	71.8	51.8	9.00
3	-12.0	-12.5	0.5	25.0	9.0	4.5	76.3	56.3	9.00
3	-12.5	-13.0	0.5	25.0	9.0	4.5	80.8	60.8	9.00
4	-13.0	-13.5	0.5	50.0	9.0	4.5	85.3	60.8	0.00
4	-13.5	-14.0	0.5	50.0	9.0	4.5	89.8	60.8	0.00
4	-14.0	-14.5	0.5	50.0	9.0	4.5	94.3	60.8	0.00
4	-14.5	-15.0	0.5	50.0	9.0	4.5	98.8	60.8	0.00
4	-15.0	-15.5	0.5	50.0	9.0	4.5	103.3	60.8	0.00
4	-15.5	-16.0	0.5	50.0	9.0	4.5	107.8	60.8	0.00
5	-16.0	-16.5	0.5	40.0	7.5	3.8	111.6	61.6	1.50
5	-16.5	-17.0	0.5	40.0	7.5	3.8	115.3	65.3	7.50
5	-17.0	-17.5	0.5	40.0	7.5	3.8	119.1	69.1	7.50
5	-17.5	-18.0	0.5	40.0	7.5	3.8	122.8	72.8	7.50
5	-18.0	-18.5	0.5	40.0	7.5	3.8	126.6	76.6	7.50
5	-18.5	-19.0	0.5	40.0	7.5	3.8	130.3	80.3	7.50
5	-19.0	-19.5	0.5	40.0	7.5	3.8	134.1	84.1	7.50
5	-19.5	-20.0	0.5	40.0	7.5	3.8	137.8	87.8	7.50
5	-20.0	-20.5	0.5	40.0	7.5	3.8	141.6	91.6	7.50
5	-20.5	-21.0	0.5	40.0	7.5	3.8	145.3	95.3	7.50
5	-21.0	-21.5	0.5	40.0	7.5	3.8	149.1	99.1	7.50
5	-21.5	-22.0	0.5	40.0	7.5	3.8	152.8	102.8	7.50
5	-22.0	-22.5	0.5	40.0	7.5	3.8	156.6	106.6	7.50
5	-22.5	-23.0	0.5	40.0	7.5	3.8	160.3	110.3	7.50
5	-23.0	-23.5	0.5	40.0	7.5	3.8	164.1	114.1	7.50
5	-23.5	-24.0	0.5	40.0	7.5	3.8	167.8	117.8	7.50
5	-24.0	-24.5	0.5	40.0	7.5	3.8	171.6	121.6	7.50
5	-24.5	-25.0	0.5	40.0	7.5	3.8	175.3	125.3	7.50
5	-25.0	-25.5	0.5	40.0	7.5	3.8	179.1	129.1	7.50
5	-25.5	-26.0	0.5	40.0	7.5	3.8	182.8	132.8	7.50
5	-26.0	-26.5	0.5	40.0	7.5	3.8	186.6	136.6	7.50
5	-26.5	-27.0	0.5	40.0	7.5	3.8	190.3	140.3	7.50

Block-c

Layer	Elev.		h	Cu	γ'	γ'h	Σγ'h	P	p
	Top	Bottom						(total)	{P(i) - P(i-1)}/h
	(m)	(m)	(m)	(kPa)	(kN/m3)	(kPa)	(kPa)	(kN/m)	(kPa)
2	-3.0	-3.5	0.5	15.0	7.0	3.5	3.5	3.5	7.00
2	-3.5	-4.0	0.5	15.0	7.0	3.5	7.0	7.0	7.00
2	-4.0	-4.5	0.5	15.0	7.0	3.5	10.5	10.5	7.00
2	-4.5	-5.0	0.5	15.0	7.0	3.5	14.0	14.0	7.00
2	-5.0	-5.5	0.5	15.0	7.0	3.5	17.5	17.5	7.00
2	-5.5	-6.0	0.5	15.0	7.0	3.5	21.0	21.0	7.00
2	-6.0	-6.5	0.5	15.0	7.0	3.5	24.5	24.5	7.00
2	-6.5	-7.0	0.5	15.0	7.0	3.5	28.0	28.0	7.00
2	-7.0	-7.5	0.5	15.0	7.0	3.5	31.5	31.5	7.00
2	-7.5	-8.0	0.5	15.0	7.0	3.5	35.0	35.0	7.00
2	-8.0	-8.5	0.5	15.0	7.0	3.5	38.5	38.5	7.00
2	-8.5	-9.0	0.5	15.0	7.0	3.5	42.0	42.0	7.00
4	-9.0	-9.5	0.5	50.0	9.0	4.5	46.5	42.0	0.00
4	-9.5	-10.0	0.5	50.0	9.0	4.5	51.0	42.0	0.00
4	-10.0	-10.5	0.5	50.0	9.0	4.5	55.5	42.0	0.00
4	-10.5	-11.0	0.5	50.0	9.0	4.5	60.0	42.0	0.00
4	-11.0	-11.5	0.5	50.0	9.0	4.5	64.5	42.0	0.00
4	-11.5	-12.0	0.5	50.0	9.0	4.5	69.0	42.0	0.00
4	-12.0	-12.5	0.5	50.0	9.0	4.5	73.5	42.0	0.00
4	-12.5	-13.0	0.5	50.0	9.0	4.5	78.0	42.0	0.00
4	-13.0	-13.5	0.5	50.0	9.0	4.5	82.5	42.0	0.00
4	-13.5	-14.0	0.5	50.0	9.0	4.5	87.0	42.0	0.00
4	-14.0	-14.5	0.5	50.0	9.0	4.5	91.5	42.0	0.00
4	-14.5	-15.0	0.5	50.0	9.0	4.5	96.0	42.0	0.00
4	-15.0	-15.5	0.5	50.0	9.0	4.5	100.5	42.0	0.00
5	-15.5	-16.0	0.5	40.0	7.5	3.8	104.3	54.3	24.50
5	-16.0	-16.5	0.5	40.0	7.5	3.8	108.0	58.0	7.50
5	-16.5	-17.0	0.5	40.0	7.5	3.8	111.8	61.8	7.50
5	-17.0	-17.5	0.5	40.0	7.5	3.8	115.5	65.5	7.50
5	-17.5	-18.0	0.5	40.0	7.5	3.8	119.3	69.3	7.50
5	-18.0	-18.5	0.5	40.0	7.5	3.8	123.0	73.0	7.50
5	-18.5	-19.0	0.5	40.0	7.5	3.8	126.8	76.8	7.50
5	-19.0	-19.5	0.5	40.0	7.5	3.8	130.5	80.5	7.50
5	-19.5	-20.0	0.5	40.0	7.5	3.8	134.3	84.3	7.50
5	-20.0	-20.5	0.5	40.0	7.5	3.8	138.0	88.0	7.50
5	-20.5	-21.0	0.5	40.0	7.5	3.8	141.8	91.8	7.50
5	-21.0	-21.5	0.5	40.0	7.5	3.8	145.5	95.5	7.50
5	-21.5	-22.0	0.5	40.0	7.5	3.8	149.3	99.3	7.50
5	-22.0	-22.5	0.5	40.0	7.5	3.8	153.0	103.0	7.50
5	-22.5	-23.0	0.5	40.0	7.5	3.8	156.8	106.8	7.50
5	-23.0	-23.5	0.5	40.0	7.5	3.8	160.5	110.5	7.50
5	-23.5	-24.0	0.5	40.0	7.5	3.8	164.3	114.3	7.50
5	-24.0	-24.5	0.5	40.0	7.5	3.8	168.0	118.0	7.50
5	-24.5	-25.0	0.5	40.0	7.5	3.8	171.8	121.8	7.50
5	-25.0	-25.5	0.5	40.0	7.5	3.8	175.5	125.5	7.50
5	-25.5	-26.0	0.5	40.0	7.5	3.8	179.3	129.3	7.50
5	-26.0	-26.5	0.5	40.0	7.5	3.8	183.0	133.0	7.50
5	-26.5	-27.0	0.5	40.0	7.5	3.8	186.8	136.8	7.50
5	-27.0	-27.5	0.5	40.0	7.5	3.8	190.5	140.5	7.50

Block-d

Layer	Elev.		h	Cu	γ'	γ'h	Σγ'h	P	p
	Top (m)	Bottom (m)	(m)	(kPa)	(kN/m3)	(kPa)	(kPa)	(total) (kN/m)	{P(i) - P(i-1)}/h (kPa)
2	-2.0	-2.5	0.5	15.0	7.0	3.5	3.5	3.5	7.00
2	-2.5	-3.0	0.5	15.0	7.0	3.5	7.0	7.0	7.00
2	-3.0	-3.5	0.5	15.0	7.0	3.5	10.5	10.5	7.00
2	-3.5	-4.0	0.5	15.0	7.0	3.5	14.0	14.0	7.00
2	-4.0	-4.5	0.5	15.0	7.0	3.5	17.5	17.5	7.00
2	-4.5	-5.0	0.5	15.0	7.0	3.5	21.0	21.0	7.00
2	-5.0	-5.5	0.5	15.0	7.0	3.5	24.5	24.5	7.00
2	-5.5	-6.0	0.5	15.0	7.0	3.5	28.0	28.0	7.00
2	-6.0	-6.5	0.5	15.0	7.0	3.5	31.5	31.5	7.00
2	-6.5	-7.0	0.5	15.0	7.0	3.5	35.0	35.0	7.00
2	-7.0	-7.5	0.5	15.0	7.0	3.5	38.5	38.5	7.00
2	-7.5	-8.0	0.5	15.0	7.0	3.5	42.0	42.0	7.00
2	-8.0	-8.5	0.5	15.0	7.0	3.5	45.5	45.5	7.00
2	-8.5	-9.0	0.5	15.0	7.0	3.5	49.0	49.0	7.00
2	-9.0	-9.5	0.5	15.0	7.0	3.5	52.5	52.5	7.00
2	-9.5	-10.0	0.5	15.0	7.0	3.5	56.0	56.0	7.00
2	-10.0	-10.5	0.5	15.0	7.0	3.5	59.5	59.5	7.00
2	-10.5	-11.0	0.5	15.0	7.0	3.5	63.0	63.0	7.00
3	-11.0	-11.5	0.5	25.0	9.0	4.5	67.5	63.0	0.00
3	-11.5	-12.0	0.5	25.0	9.0	4.5	72.0	63.0	0.00
3	-12.0	-12.5	0.5	25.0	9.0	4.5	76.5	63.0	0.00
3	-12.5	-13.0	0.5	25.0	9.0	4.5	81.0	63.0	0.00
3	-13.0	-13.5	0.5	25.0	9.0	4.5	85.5	65.5	5.00
4	-13.5	-14.0	0.5	50.0	9.0	4.5	90.0	65.5	0.00
4	-14.0	-14.5	0.5	50.0	9.0	4.5	94.5	65.5	0.00
4	-14.5	-15.0	0.5	50.0	9.0	4.5	99.0	65.5	0.00
4	-15.0	-15.5	0.5	50.0	9.0	4.5	103.5	65.5	0.00
4	-15.5	-16.0	0.5	50.0	9.0	4.5	108.0	65.5	0.00
5	-16.0	-16.5	0.5	40.0	7.5	3.8	111.8	65.5	0.00
5	-16.5	-17.0	0.5	40.0	7.5	3.8	115.5	65.5	0.00
5	-17.0	-17.5	0.5	40.0	7.5	3.8	119.3	69.3	7.50
5	-17.5	-18.0	0.5	40.0	7.5	3.8	123.0	73.0	7.50
5	-18.0	-18.5	0.5	40.0	7.5	3.8	126.8	76.8	7.50
5	-18.5	-19.0	0.5	40.0	7.5	3.8	130.5	80.5	7.50
5	-19.0	-19.5	0.5	40.0	7.5	3.8	134.3	84.3	7.50
5	-19.5	-20.0	0.5	40.0	7.5	3.8	138.0	88.0	7.50
5	-20.0	-20.5	0.5	40.0	7.5	3.8	141.8	91.8	7.50
5	-20.5	-21.0	0.5	40.0	7.5	3.8	145.5	95.5	7.50
5	-21.0	-21.5	0.5	40.0	7.5	3.8	149.3	99.3	7.50
5	-21.5	-22.0	0.5	40.0	7.5	3.8	153.0	103.0	7.50
5	-22.0	-22.5	0.5	40.0	7.5	3.8	156.8	106.8	7.50
5	-22.5	-23.0	0.5	40.0	7.5	3.8	160.5	110.5	7.50
5	-23.0	-23.5	0.5	40.0	7.5	3.8	164.3	114.3	7.50
5	-23.5	-24.0	0.5	40.0	7.5	3.8	168.0	118.0	7.50
5	-24.0	-24.5	0.5	40.0	7.5	3.8	171.8	121.8	7.50
5	-24.5	-25.0	0.5	40.0	7.5	3.8	175.5	125.5	7.50
5	-25.0	-25.5	0.5	40.0	7.5	3.8	179.3	129.3	7.50
5	-25.5	-26.0	0.5	40.0	7.5	3.8	183.0	133.0	7.50
5	-26.0	-26.5	0.5	40.0	7.5	3.8	186.8	136.8	7.50

3. Active Earth Pressure

Active earth pressure

1) After completion

Surcharge load w = 30.00 kPa

	Above W or Below W	Sand or Clay	h (m)	γ (kN/m3)	γsat (kN/m3)	ϕ (deg)	δ (deg)	c (kPa)	γ' h+w (kPa)	γsat h+w	For Sand Kai x cos ϕ	For Sand ζa (rad)	For Sand pa (kPa)	For Clay ζa (rad)	For Clay pa (kPa)	Adopted pa (kPa)
5.50									30.0	30.0	0.291	0.992	8.73			8.730
	Above	Sand	1.95	18	20	30	15	0								
3.55									65.1	65.1	0.291	0.992	18.94			18.940
3.55									65.1	65.1	0.291	0.992	18.94			18.940
	Below	Sand	5.55	18	20	30	15	0								
-2.00									120.6	176.1	0.291	0.992	35.09			35.090
-2.00									120.6	176.1				0.785	90.60	90.600
	Below	Clay	1.00	17	17	0	0	15								
-3.00									127.6	193.1				0.785	97.60	97.600
-3.00																7.000
	Below	Clay	22.00	As explaind in section 2, pa = 7.0 kPa is used.												
-25.00																7.000

2) During construction

Surcharge load w = 20.00 kPa

	Above W or Below W	Sand or Clay	h (m)	γ (kN/m3)	γsat (kN/m3)	ϕ (deg)	δ (deg)	c (kPa)	γ' h+w (kPa)	γsat h+w	For Sand Kai x cos ϕ	For Sand ζa (rad)	For Sand pa (kPa)	For Clay ζa (rad)	For Clay pa (kPa)	Adopted pa (kPa)
4.50									20.0	20.0	0.291	0.992	5.82			5.820
	Above	Sand	0.95	18	20	30	15	0								
3.55									37.1	37.1	0.291	0.992	10.80			10.800
3.55									37.1	37.1	0.291	0.992	10.80			10.800
	Below	Sand	5.55	18	20	30	15	0								
-2.00									92.6	148.1	0.291	0.992	26.95			26.950
-2.00									92.6	148.1				0.785	62.60	62.600
	Below	Clay	1.00	17	17	0	0	15								
-3.00									99.6	165.1				0.785	69.60	69.600
-3.00																7.000
	Below	Clay	22.00	As explaind in section 2, pa = 7.0 kPa is used.												
-25.00																7.000

Phụ lục 7-6

Áp lực đất bị động tác động lên cọc ván thép

Determination of Passive Earth Pressure on SPSP

1. Method of Passive Earth Pressure Calculation

A magnitude of the passive earth pressure acting on the steel pipe wall for the revetment of the Container Berth and the Barge Berth is the most important factor for the steel pipe wall design.

A calculation method of the passive earth pressure in the case of the sloped cohesive ground is not indicated in the "Technical Standards and Commentaries for Port and Harbour Facilities in Japan (TSCPHFJ)" but the following method is recommended in the "Guidelines for Port and Harbour Design 1989", which is a draft TSCPHFJ with more detailed commentaries than the published TSCPHFJ. This method is called as the "circular slip method" in this document.

(Extracted from 5.2.2 of Chapter 5, Part 8 of Guidelines for Port and Harbour Design)

$$P_{2h} = \cos\delta W_2' \cdot \frac{\cos(\phi - \theta - \varepsilon)}{\sin(\theta - \phi + \delta)} \qquad (5.5)$$

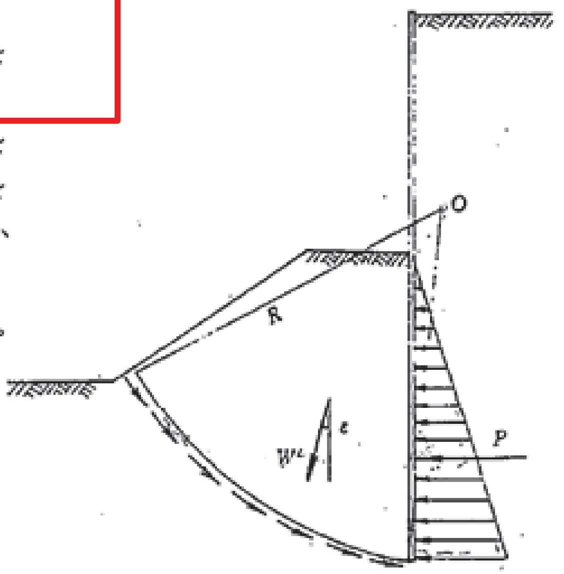
また、作用点は矢板根入れ長の 1/3 点とする簡便法を用いることがある。

粘性土地盤の場合には、図−5.17 のように、すべり面を矢板下端から発生する円弧とし、円弧の中心及び半径を変えてモーメントの釣り合いにより P を求め、その最小値を受働土圧合力とする。

ただし、P の作用点は矢板根入れ長の 1/3 点とする。

図−5.17 において

O ：円弧の中心点
R ：円弧の半径（m）
W'：地震時の土けいの重量（tf/m）
P ：受働土圧（tf/m）
c ：粘着力（tf/m²）



図−5.17 斜面をもった矢板根入れ部の受働土圧（粘性土地盤）

(4) クレーン等の荷役機械がある場合には、そのための基礎を設けることがのぞましいが、設けない場合には集中荷重あるいは線荷重に換算して、土圧の増加分を第 5 編 5.1 地中応力 により求める。

English translation:
In the case of the (sloped) ground of the cohesive soil, a circular passive failure surface starting from the bottom of the sheet pile as shown in Figure 5.17 is assumed. The force P is obtained for the assumed center and radius of the circle so that the moment about the center of the circle will be balance. The passive earth pressure is obtained as the minimum value of P, which is obtained by changing the center and radius of the circle. For this calculation, the acting point of P shall be one third of the embedded length of the sheet pile.

Where in Figure 5.17;

O	: the center of the circular slip surface
R	: the radius of the circular slip surface (m)
W'	: the weight of soil above the circular slip surface (tf/m)
P	: the passive earth pressure (tf/m)
c	: the shear strength of the soil (tf/m^2)

2. Verification of Circular Slip Method

At first, the passive earth pressure in the case of the horizontal ground was obtained by the following two methods for a purpose to ensure an appropriateness of the use of the circular slip method:

- Ordinary formula (i.e., $p_p = \sum \gamma h + 2c$)
- Circular slip method

The soil parameters of Block b were used for the comparison.

1) Ordinary formula

$$p_p = \sum \gamma h + 2c$$

where;

p_p : the passive earth pressure (kPa)
γ : the effective weight of the soil (kN/m3)
h : the thickness of the soil layer (m)
c : the shear strength of the soil (kPa)

Theoretical passive earth pressure by the above formula is obtained as shown in Figure 1.

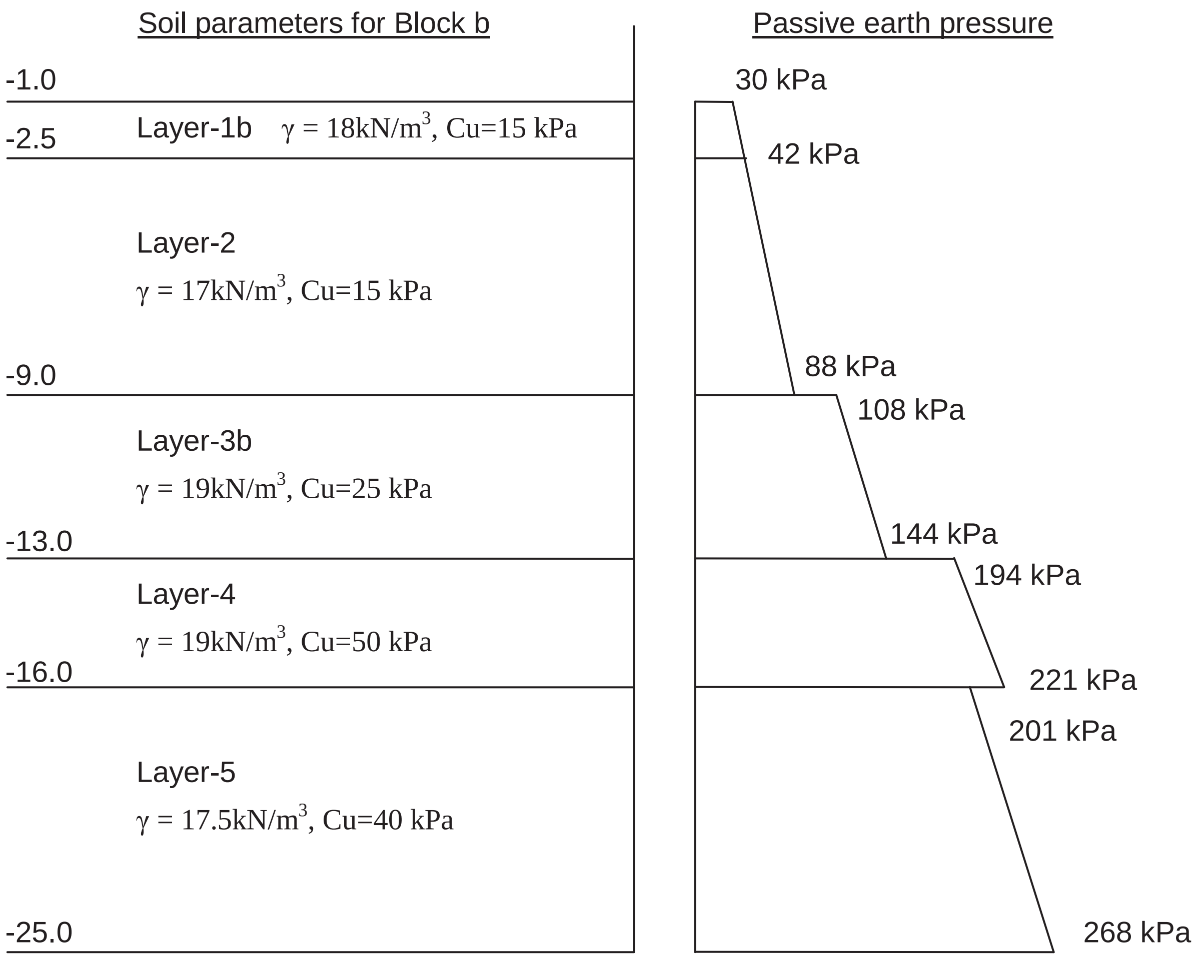


Figure 1 Passive earth pressure (ordinary formula)

2) Circular slip method

The spreadsheet calculation was carried out by using Microsoft Excel. Figure 2 presents a part of the spreadsheet for reference.

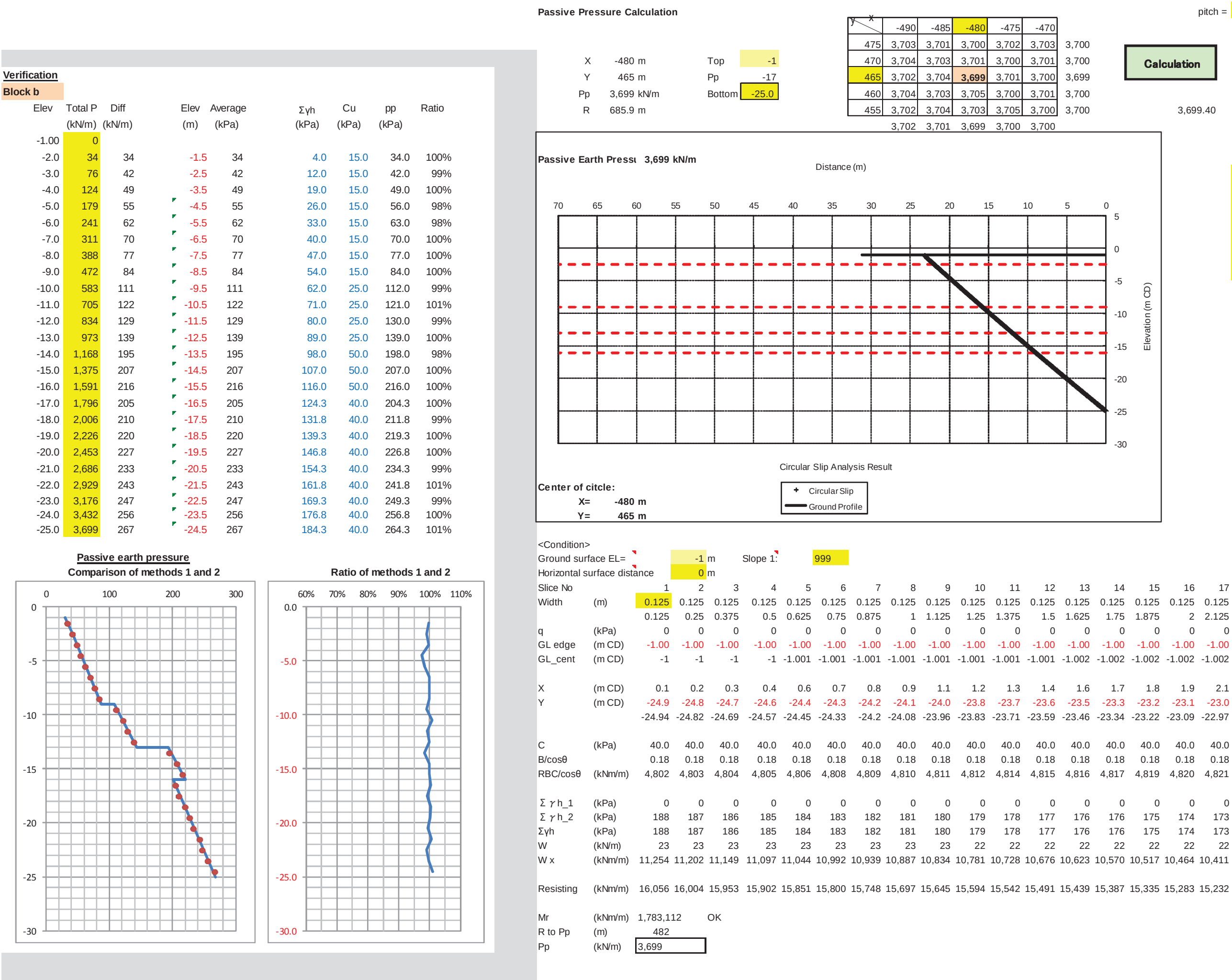


Figure 2 Part of spreadsheet for calculation of circular slip method

The slope of the ground is taken as 1 : 999 (≈ horizontal).

The starting point of the circular slip failure surface has been changed by every 1m. The passive earth pressure was obtained by the following formula.

$$p(z+\Delta z/2) = \{P(z+\Delta z) - P(z)\}/ \Delta z$$

where; p (z) is the passive earth pressure at depth z (kPa)

P (z) is the sum of the passive earth pressure above the depth z (kN/m)

Δz is the change in depth from the previous calculation (= 1m)

As shown in Figure 2, the failure line obtained is nearly straight with 45 degrees to horizontal which is similar to the ordinary formula.

Figure 3 presents the comparison of the ordinary formula and the circular slip method. Although there are slight deviations of the circular slip method from the theoretical method (i.e. ordinary formula) which is considered due to the setting of slice width and/or decimal treatment, etc., the results of these two methods could be said nearly equal.

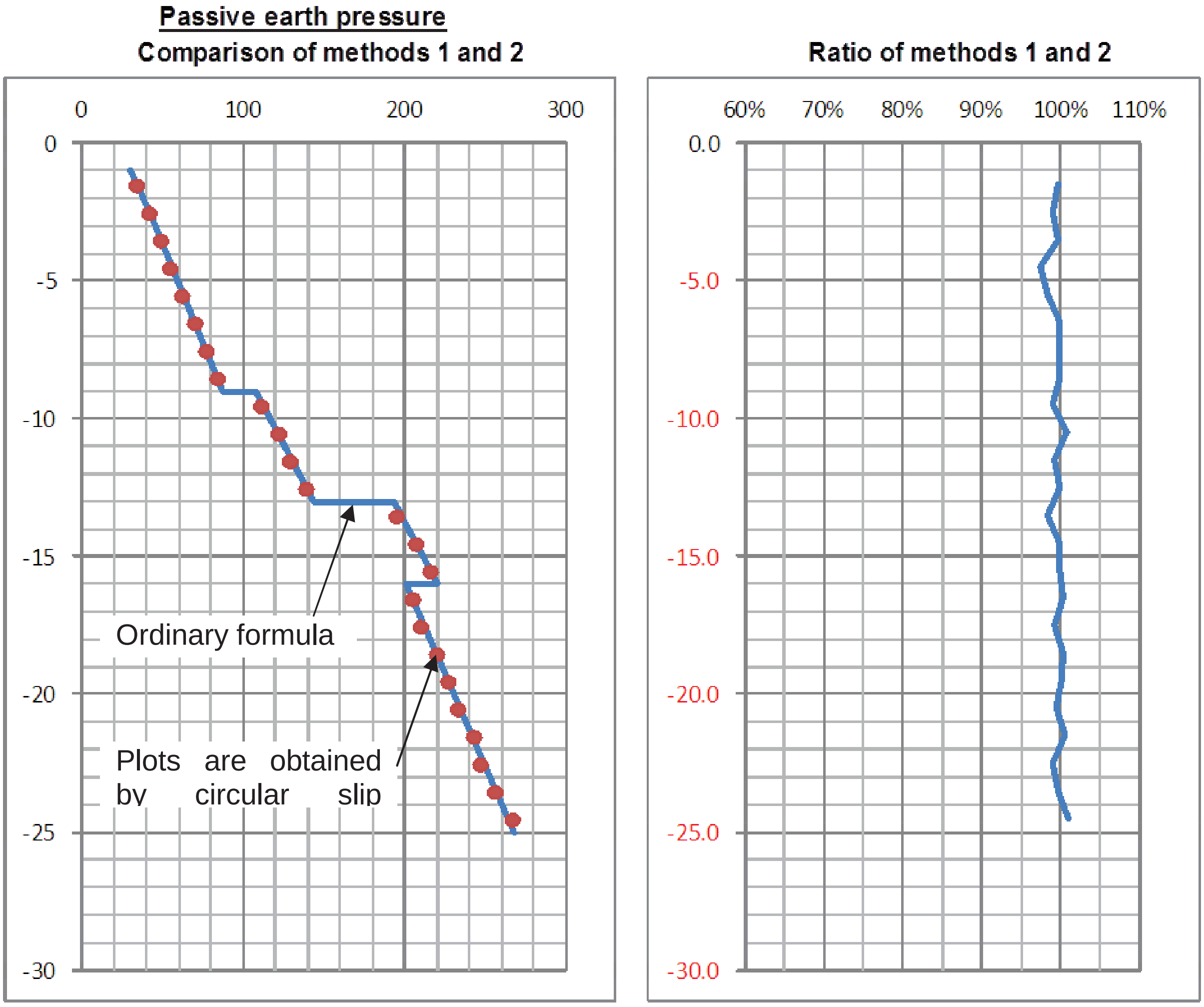


Figure 3 Comparison of ordinary formula and circular slip method

From the above, it is concluded that the circular slip method can be applied for this design and also appropriateness of the spreadsheet in Figure 2 was verified.

3. Passive Earth Pressure Calculation for Sloped Ground

The passive earth pressure of the slope ground is estimated in a similar manner to the chapter 2 with slope angle of 1 in 3. A part of the spreadsheet is presented in Figure 4.

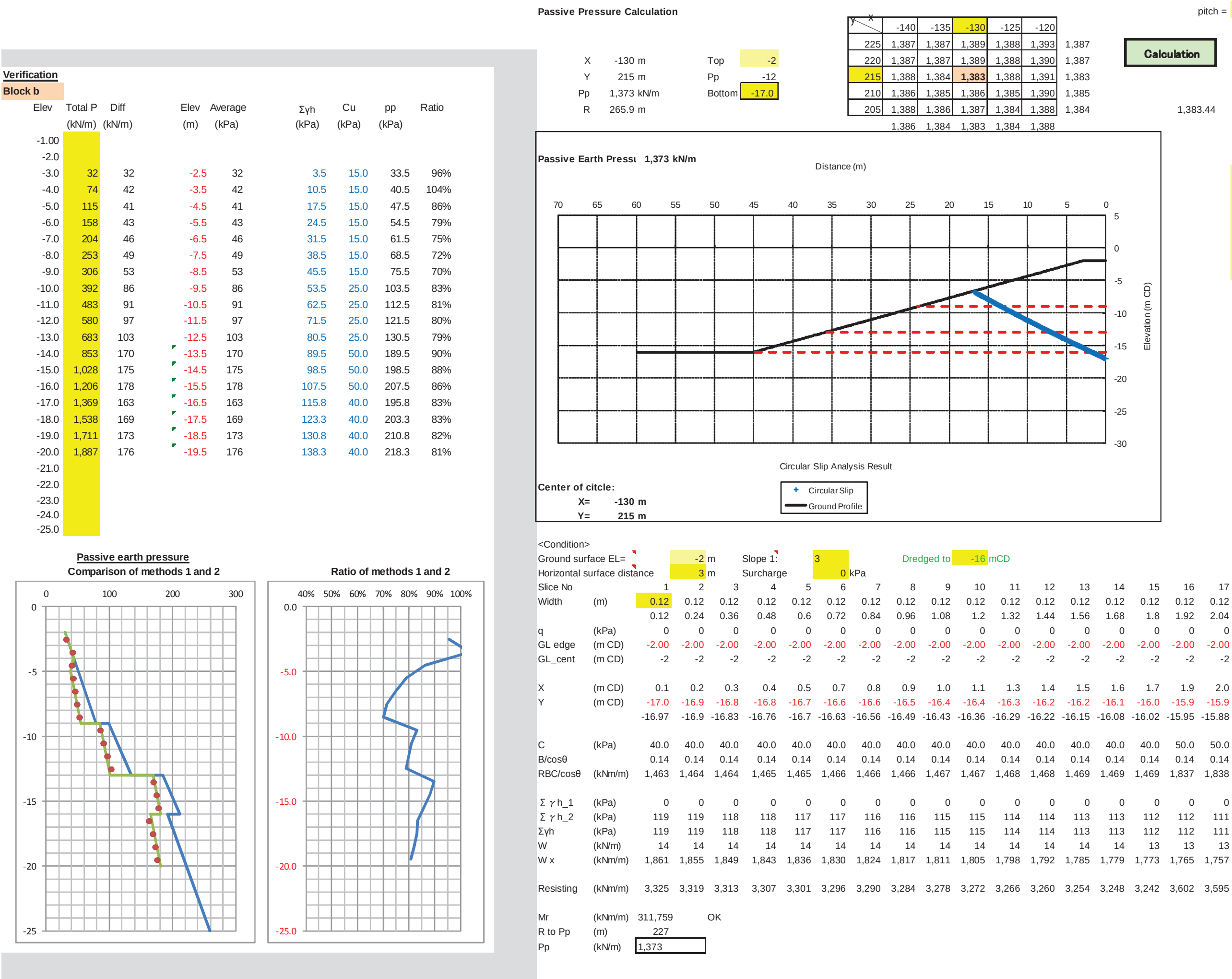


Figure 4 Part of spreadsheet for calculation of circular slip method (sloped ground)

As shown in Figure 4, the failure surface will be nearly straight but with the angle to horizontal rather gentle than 45˚.

Figure 5 presents the comparison of the ordinary formula and the circular slip method.

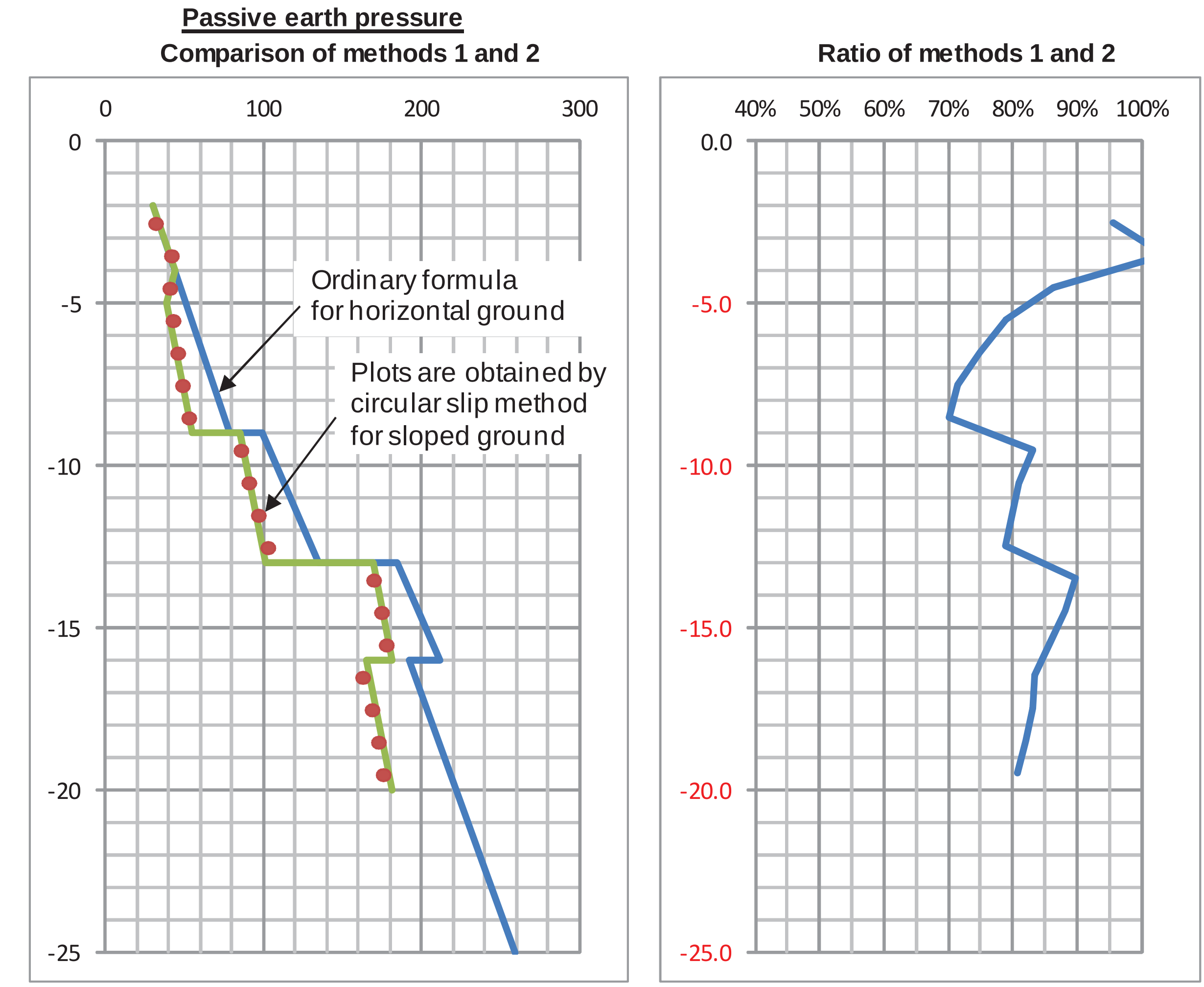


Figure 5 Comparison of ordinary formula and circular slip method (Sloped ground)

From Figure 5, it is obvious that the passive earth pressure of the sloped ground will be generally decreased from that of the horizontal ground.

4. Passive Earth Pressure of Sloped Ground for Design of Revetment

The seabed profile for the passive earth pressure calculation for each block is shown in Figure 6.

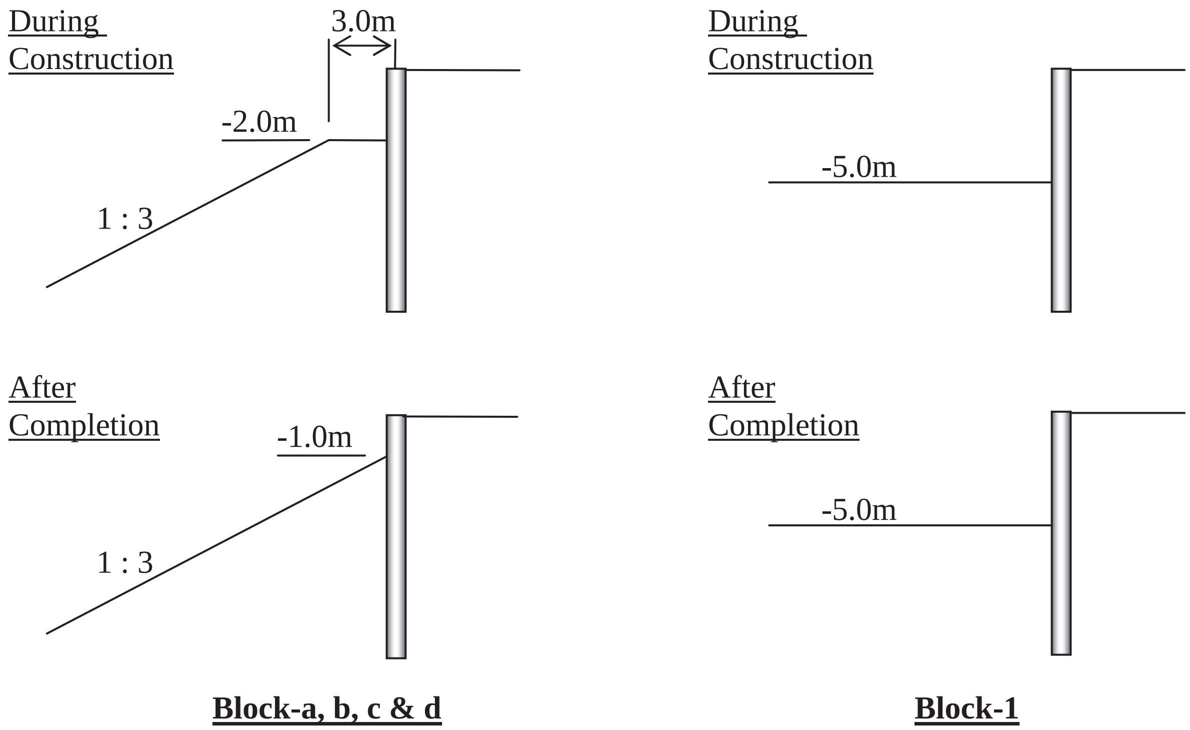


Figure 6 Seabed profiles for passive earth pressure calculation

In Block c, there is a 1.5m thk loose sand layer (Layer 3a) from -8.0mCD to -9.5mCD. However, in the calculation of the passive earth pressure, this layer was regarded as the soft clay layer (Layer 2) for simple and conservative calculation.

For Block-a, b, c and d, the passive earth pressures of sloped ground are obtained by the circular slip method as shown in Figures 7 and 8. These will be used for the revetment design.

For Block 1, the design will be done with the horizontal seabed level at -5.0m and therefore ordinary formula of the passive earth pressure (i.e. $p=\sum\gamma h+2C$) was used to obtain the passive earth pressure. The passive earth pressure for the Block 1 is shown in Table 1 and Figure 9.

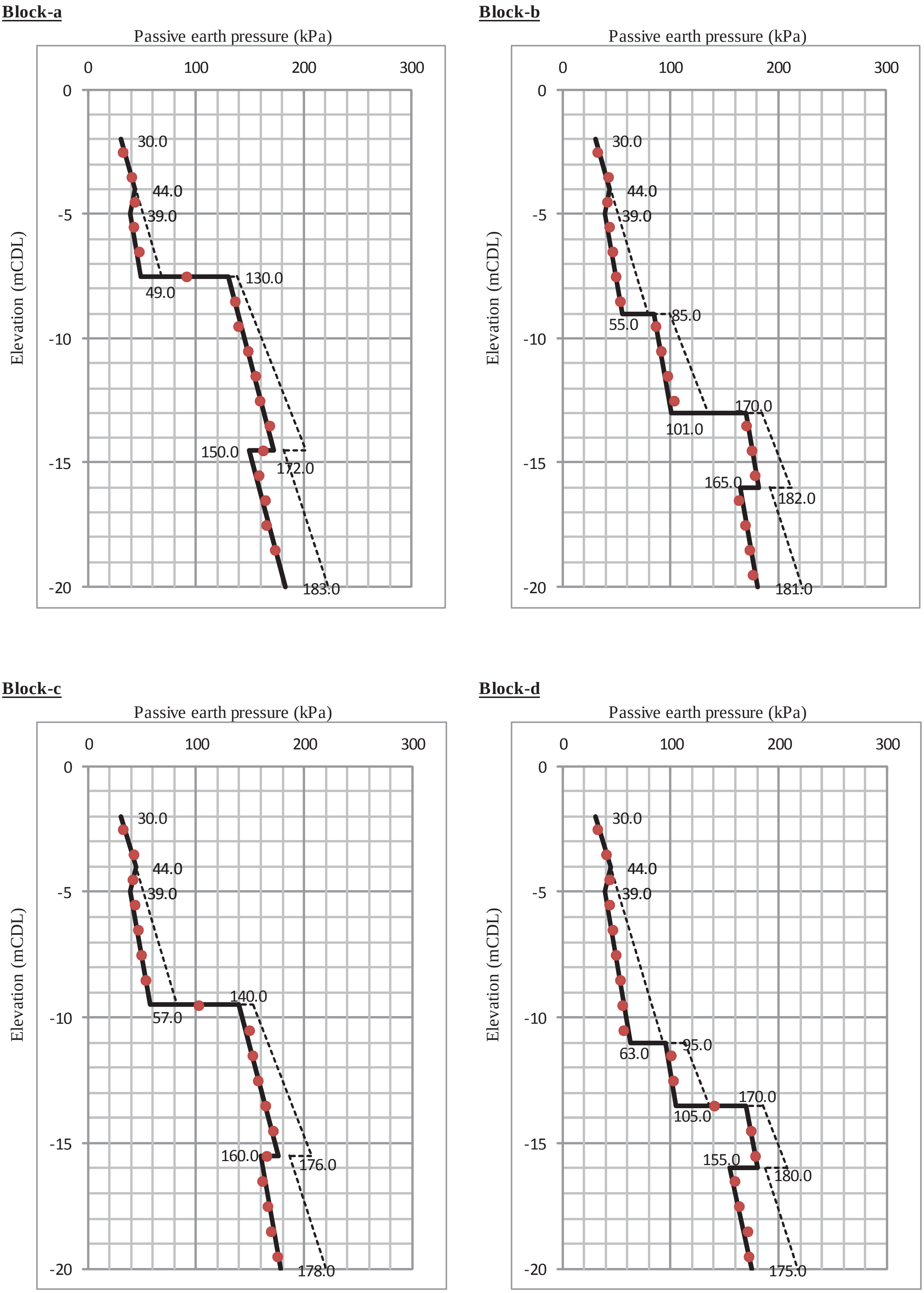


Figure 7 Passive earth pressures for revetment design (Block a, b, c & d) – During Construction

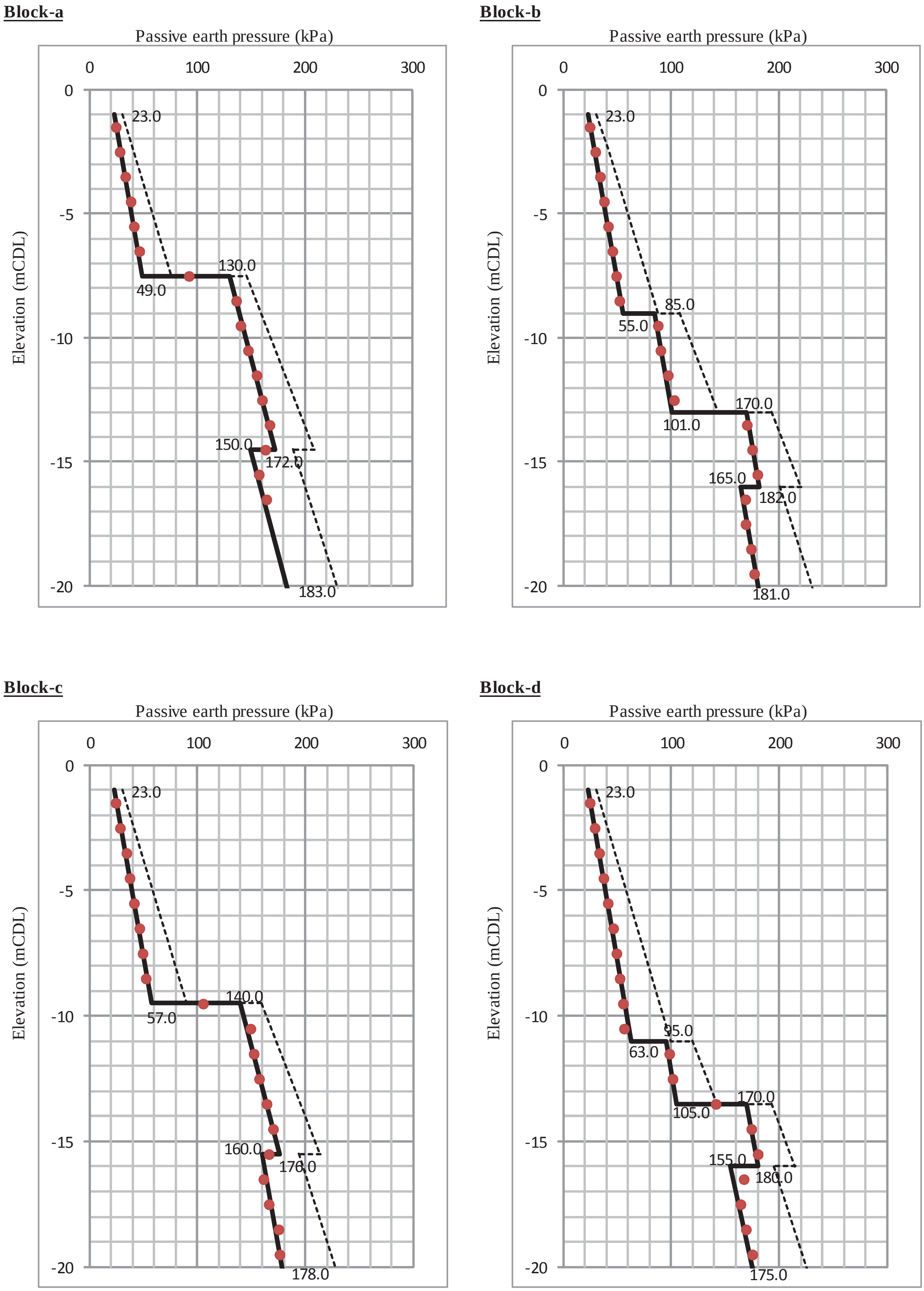


Figure 8 Passive earth pressures for revetment design (Block a, b, c & d) – After Completion

Table 1 Passive earth pressures for revetment design (Block 1)

Layer	Elev.	h (m)	C (kPa)	γ ’ (kN/m^3)	∑γh (kPa)	Passive earth pressure p_p = ∑γh+2C (kPa)
2	-5.0	3.0	15	7.0	0.0	0.0 + 2×15 = 30.0
	-8.0				21.0	21.0 + 2×15 = 51.0
3	-8.0	2.0	25	9.0	21.0	21.0 + 2×25 = 71.0
	-10.0				39.0	39.0 + 2×25 = 89.0
4	-10.0	5.0	50	9.0	39.0	39.0 + 2×50 = 139.0
	-15.0				84.0	84.0 + 2×50 = 184.0
5	-15.0	11.0	40	7.5	84.0	84.0 + 2×40 = 164.0
	-26.0				166.5	166.5 + 2×40 = 246.5

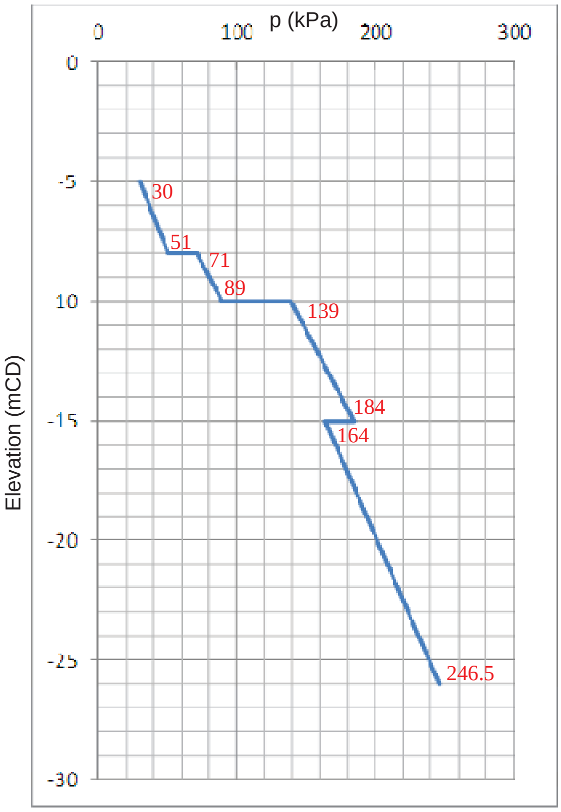


Figure 9 Passive earth pressures for revetment design (Block 1)
– both During Construction and After Completion

Phụ lục 7-7

Kết quả tính toán tường cọc ván thép (sau khi hoàn thành)

Output of Design Software for Anchor Wall (After Completion) – Junction to Service Berth

1. Design Conditions

1-1 Dimensions

Ground elevation		+5.50 m
Top of cope concrete		+5.50 m
Top of pipe wall		+3.50 m
Tie elevation		+3.00 m
Seabed elevation		-5.00 m
Angle of seabed slope		0.0˚

1-2 Tide Levels

H.W.L		+3.55 m
L.W.L		+0.43 m

1-3 Residual Water Level

R.W.L		+3.55 m

1-4 Base Elevation of Cohesion Increment: +0.00 m (not used)

1-5 Surcharge Load	(Active side)	30 kPa
	(Passive side)	0 kPa

1-6 Unit Weight of Water: 10.10 kN/m^3

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

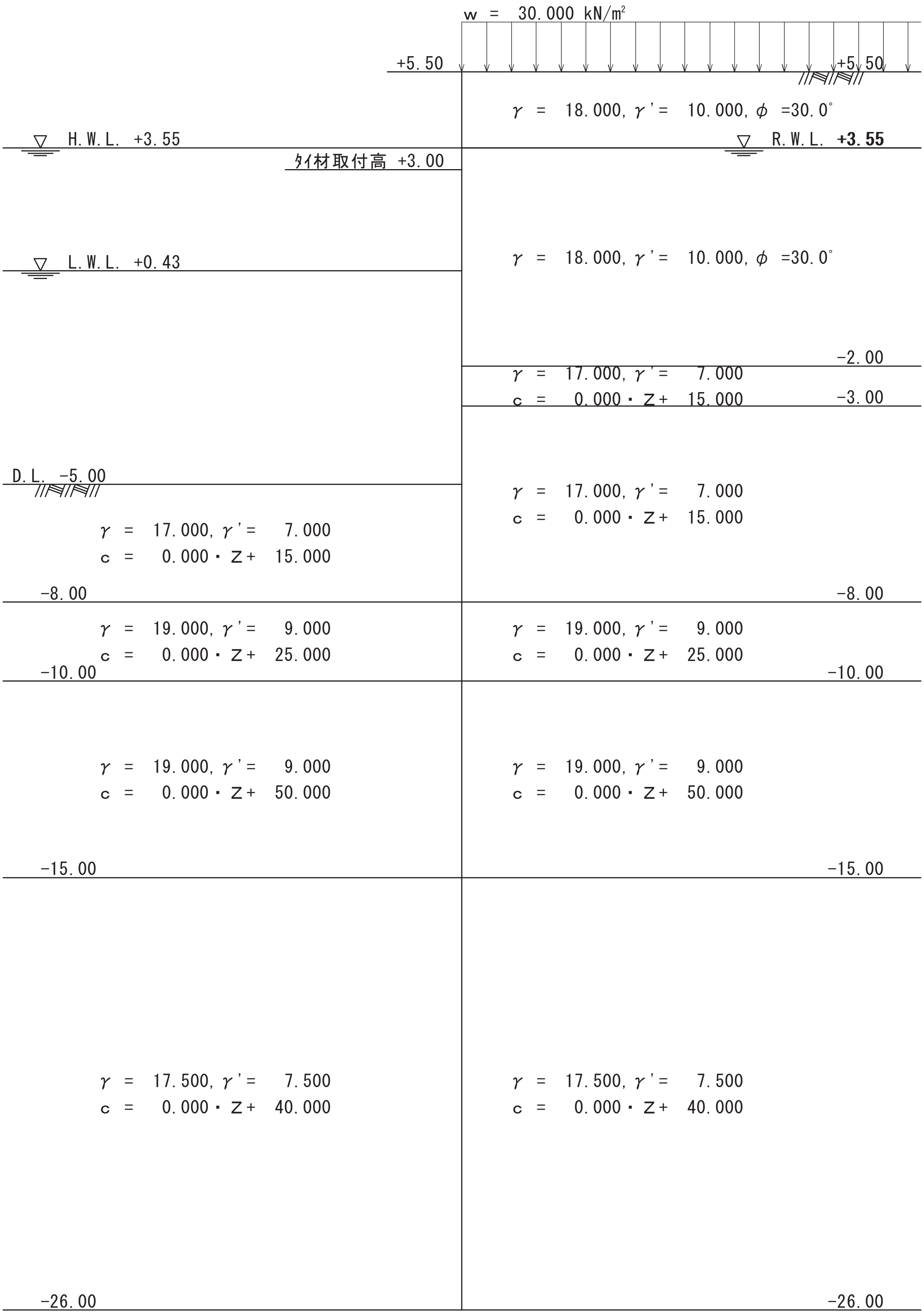
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	:	Deflection Curve Method
Calculation Method 2	:	Free Earth Support Method
Factor of Safety	:	FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
5.50 3.55	1.95	8.730 18.940
3.55 3.00	0.55	18.940 20.540
3.00 -2.00	5.00	20.540 35.090
-2.00 -3.00	1.00	90.600 97.600
-3.00 -8.00	5.00	7.000 7.000
-8.00 -10.00	2.00	7.000 7.000
-10.00 -15.00	5.00	7.000 7.000
-15.00 -26.00	11.00	7.000 7.000

(2) Residual water pressure

$p_w = \gamma_w \times h_w$

where; p_w is the residual water pressure (kPa)

h_w is the height of the tidal lag (m)

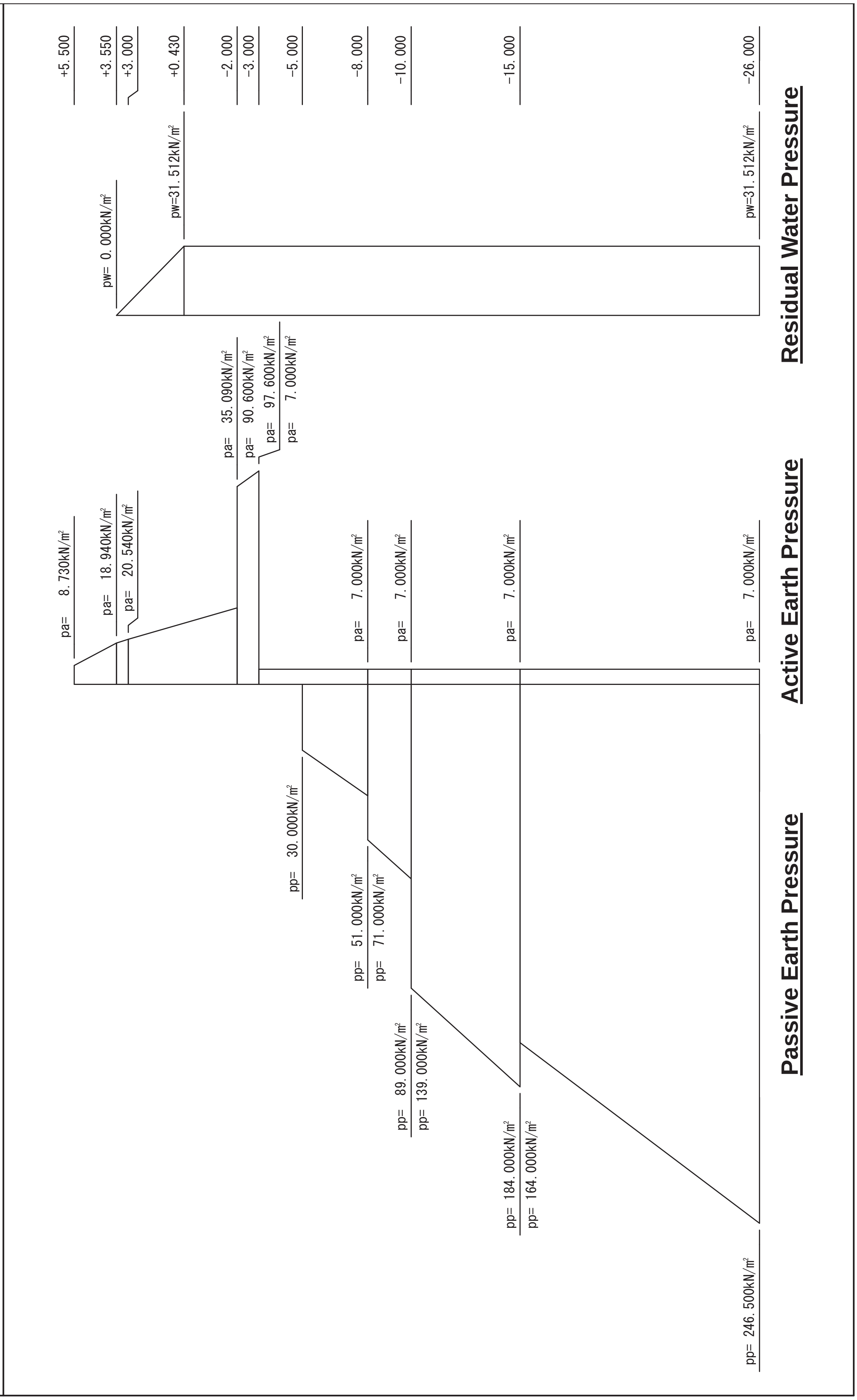
γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-5.00 -8.00	3.00	30.000 51.000
-8.00 -10.00	2.00	71.000 89.000
-10.00 -15.00	5.00	139.000 184.000
-15.00 -26.00	11.00	164.000 246.500

Earth Pressure and Water Pressure



(4) Summary of Forces on the Wall

Elev (m)	Active side (kPa) $P_a + P_w$	Passive side(kPa) P_p
5.50 3.55	8.730+ 0.000= 8.730 18.940+ 0.000= 18.940	——— ———
3.55 3.00	18.940+ 0.000= 18.940 20.540+ 5.555= 26.095	——— ———
3.00 0.43	20.540+ 5.555= 26.095 28.019+ 31.512= 59.531	——— ———
0.43 -2.00	28.019+ 31.512= 59.531 35.090+ 31.512= 66.602	——— ———
-2.00 -3.00	90.600+ 31.512= 122.112 97.600+ 31.512= 129.112	——— ———
-3.00 -5.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	——— ———
-5.00 -8.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	30.000 51.000
-8.00 -10.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	71.000 89.000
-10.00 -15.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	139.000 184.000
-15.00 -26.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	164.000 246.500

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -5.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
-5.000	-1369.207	263.678	241.600
-6.000	-1833.725	290.866	219.424
-7.000	-2274.387	312.767	195.535
-8.000	-2676.627	330.188	169.126
-9.000	-2982.565	342.803	119.523
-10.000	-3123.607	350.285	66.053
-11.000	-2951.847	351.307	-39.957
-12.000	-2311.902	344.894	-147.532
-13.000	-1148.645	331.877	-257.503
-14.000	600.285	312.893	-370.507

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -13.00 and -14.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-13.695	0.000	319.295	-335.643

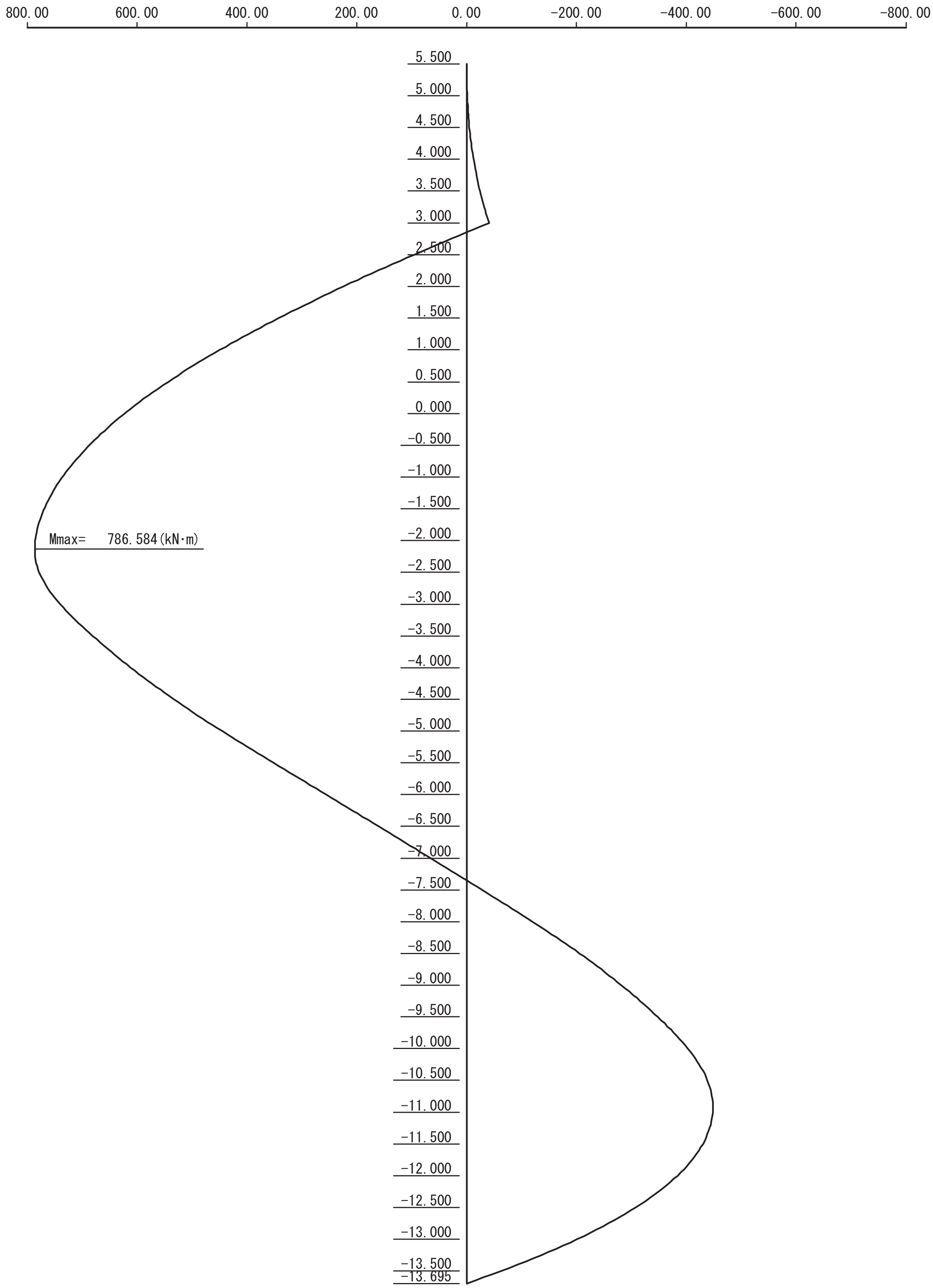
Embedded length of the pipe wall : L = 1.2 × (-5.000 + 13.695) = 10.434 m
Toe elevation : D = -5.000 – 10.434 = -15.434 m
Reaction force at tie setting point : 319.295 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	-1.200	-5.019
4.500	-5.238	-11.348
4.000	-12.766	-18.985
3.550	-23.069	-26.978
3.050	-39.196	-38.074
3.000	-41.132	-39.363
2.500	95.301	265.258
2.000	223.584	247.332
1.500	342.091	226.153
1.000	449.195	201.722
0.500	543.271	174.038
0.430	555.309	169.903
-0.070	632.759	139.773
-0.570	694.962	108.917
-1.070	741.554	77.333
-1.570	772.173	45.021
-2.000	785.452	16.651
-2.500	778.367	-45.280
-3.000	739.880	-108.961
-3.500	680.586	-128.217
-4.000	611.663	-147.473
-4.500	533.113	-166.729
-5.000	444.934	-185.985
-5.500	351.024	-189.366
-6.000	255.860	-190.997
-6.500	160.319	-190.878
-7.000	65.274	-189.009
-7.500	-28.399	-185.390
-8.000	-119.824	-180.021
-8.500	-205.586	-162.652
-9.000	-282.101	-143.033
-9.500	-348.244	-121.164
-10.000	-402.890	-97.045
-10.500	-438.664	-45.676
-11.000	-448.191	7.943
-11.500	-430.346	63.812
-12.000	-384.004	121.931
-12.500	-308.040	182.300
-13.000	-201.329	244.919
-13.500	-62.746	309.788
-13.695	0.000	335.643

Maximum bending moment : 786.584 kN-m/m
Elevation of maximum bending moment : -2.136 m
Depth of 1st steady point (moment=0) : -7.347 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

M_p = FOS×M_a

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of FOS×M_a

NO	Elev (m)	Calculation			S (kN/m)	L (m)	M (kN-m/m)	FOS×M_a (kN-m/m)
1	5.50	1/2x	8.730x	1.950	8.512	-1.850	-15.747	
2	3.55	1/2x	18.940x	1.950	18.466	-1.200	-22.159	-45.487
3	3.55	1/2x	18.940x	0.550	5.208	-0.367	-1.911	
4	3.00	1/2x	26.095x	0.550	7.176	-0.183	-1.313	-49.356
5	3.00	1/2x	26.095x	2.570	33.532	0.857	28.737	
6	0.43	1/2x	59.531x	2.570	76.497	1.713	131.039	142.375
7	0.43	1/2x	59.531x	2.430	72.330	3.380	244.475	
8	-2.00	1/2x	66.602x	2.430	80.921	4.190	339.059	842.616
9	-2.00	1/2x	122.112x	1.000	61.056	5.333	325.612	
10	-3.00	1/2x	129.112x	1.000	64.556	5.667	365.839	1672.357
11	-3.00	1/2x	38.512x	2.000	38.512	6.667	256.760	
12	-5.00	1/2x	38.512x	2.000	38.512	7.333	282.408	2319.359
13	-5.00	1/2x	38.512x	3.000	57.768	9.000	519.912	
14	-8.00	1/2x	38.512x	3.000	57.768	10.000	577.680	3636.469
15	-8.00	1/2x	38.512x	2.000	38.512	11.667	449.320	
16	-10.00	1/2x	38.512x	2.000	38.512	12.333	474.968	4745.615
17	-10.00	1/2x	38.512x	5.000	96.280	14.667	1412.139	
18	-15.00	1/2x	38.512x	5.000	96.280	16.333	1572.541	8327.231
19	-15.00	1/2x	38.512x	11.000	211.816	21.667	4589.417	
20	-26.00	1/2x	38.512x	11.000	211.816	25.333	5365.935	20273.653

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

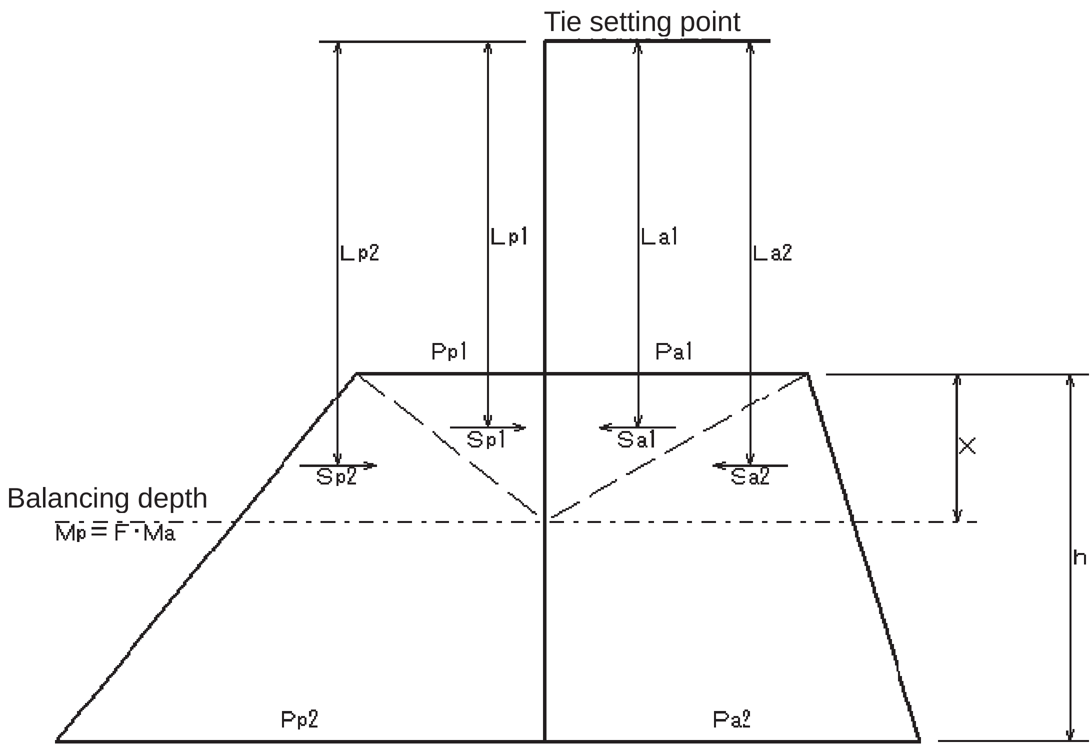
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-5.00	1/2x 30.000x 3.000	45.000	9.000	405.000	
2	-8.00	1/2x 51.000x 3.000	76.500	10.000	765.000	1170.000
3	-8.00	1/2x 71.000x 2.000	71.000	11.667	828.357	
4	-10.00	1/2x 89.000x 2.000	89.000	12.333	1097.637	3095.994
5	-10.00	1/2x 139.000x 5.000	347.500	14.667	5096.782	
6	-15.00	1/2x 184.000x 5.000	460.000	16.333	7513.180	15705.956
7	-15.00	1/2x 164.000x 11.000	902.000	21.667	19543.634	
8	-26.00	1/2x 246.500x 11.000	1355.750	25.333	34345.215	69594.805

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1}X}{2}, \quad L_{a(p)1} = L + \frac{1}{3}X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \frac{P_{a(p)2} - P_{a(p)1}}{h} X\right] X}{2} \text{ , } L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

$M_{a(p)}$	: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)
$M_{a(p)1}$	: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)
$M_{a(p)1'}$	: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$M_{a(p)2'}$	: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$S_{a(p)1}$	: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$S_{a(p)2}$	: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$L_{a(p)1}$	: the arm length of $S_{a(p)1}$ from the tie setting point (m)
$L_{a(p)2}$	: the arm length of $S_{a(p)2}$ from the tie setting point (m)
$P_{a(p)1}$	: the active (passive) side pressure at the top elevation of the soil layer (kPa)
$P_{a(p)1}$	: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)
h	: the thickness of the soil layer (m)
L	: the vertical distance from the tie setting point to the top elevation of the soil layer (m)
X	: the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -10.00 m	FOS×M_{a1} = 4745.615	> M_{p1} = 3095.994
at -15.00 m	FOS×M_{a2} = 8327.231	< M_{p2} = 15705.956

[Moment on active side]

$$S_{a1} = \frac{38.512X}{2} = 19.256X \ , \quad L_{a1} = 13.00 + \frac{1}{3}X$$

$$M_{a1'} = 6.419X^2 + 250.328X$$

$$S_{a2} = \frac{\left[38.512 + \frac{38.512 - 38.512}{5.000}X\right]X}{2} = 0.000X^2 + 19.256X \ , \quad L_{a2} = 13.000 + \frac{2}{3}X$$

$$M_{a2'} = 0.000X^3 + 12.837X^2 + 250.328X$$

$$M_a = 0.000X^3 + 19.256X^2 + 500.656X + 3954.679$$

[Moment on passive side]

$$S_{p1} = \frac{139.000X}{2} = 69.500X \ , \quad L_{p1} = 13.000 + \frac{1}{3}X$$

$$M_{p1'} = 23.167X^2 + 903.500X$$

$$S_{p2} = \frac{\left[139.000 + \frac{184.000 - 139.000}{5.000}X\right]X}{2} = 4.500X^2 + 69.500X \ , \quad L_{p2} = 13.000 + \frac{2}{3}X$$

$$M_{p2'} = 3.000X^3 + 104.833X^2 + 903.500X$$

$$M_p = 3.000X^3 + 128.000X^2 + 1807.000X + 3095.994$$

[Balancing depth]

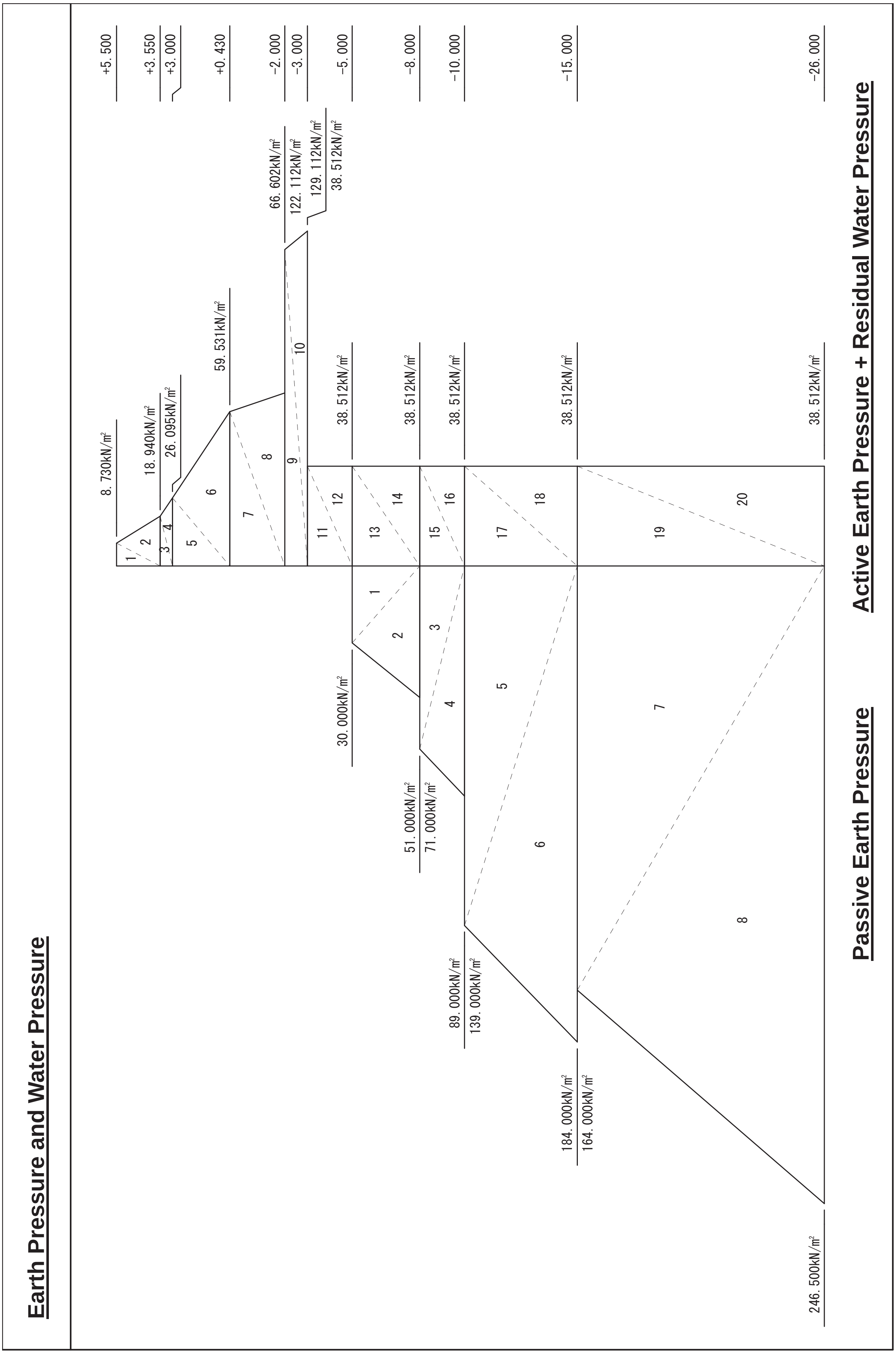
$$FOS \cdot M_a = M_p$$

$$1.2 \times (0.000X^3 + 19.256X^2 + 500.656X + 3954.679)$$

$$= 3.000X^3 + 128.000X^2 + 1807.000X + 3095.994$$

X= 1.231 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -10.000 – 1.231 = -11.231 m


Earth Pressure and Water Pressure
Passive Earth Pressure
Active Earth Pressure + Residual Water Pressure
+5.500
+3.550
+3.000
+0.430
-2.000
-3.000
-5.000
-8.000
-10.000
-15.000
-26.000
8.730kN/m²
18.940kN/m²
26.095kN/m²
59.531kN/m²
66.602kN/m²
122.112kN/m²
129.112kN/m²
38.512kN/m²
30.000kN/m²
51.000kN/m²
71.000kN/m²
89.000kN/m²
139.000kN/m²
184.000kN/m²
164.000kN/m²
246.500kN/m²

(2) Calculation of maximum bending moment

1) External forces

Elev (m)	$P_a + P_w$ (kN/m^2)	P_p (kN/m^2)	$P_a - P_p$ (kN/m^2)
5.50 3.55	8.730 18.940	——— ———	8.730 18.940
3.55 3.00	18.940 26.095	——— ———	18.940 26.095
3.00 0.43	26.095 59.531	——— ———	26.095 59.531
0.43 -2.00	59.531 66.602	——— ———	59.531 66.602
-2.00 -3.00	122.112 129.112	——— ———	122.112 129.112
-3.00 -5.00	38.512 38.512	——— ———	38.512 38.512
-5.00 -8.00	38.512 38.512	30.000 51.000	8.512 -12.488
-8.00 -10.00	38.512 38.512	71.000 89.000	-32.488 -50.488
-10.00 -15.00	38.512 38.512	139.000 184.000	-100.488 -145.488
-15.00 -26.00	38.512 38.512	164.000 246.500	-125.488 -207.988

2) Virtual seabed level

The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -5.00 m $\quad P_{a1} = 38.512 \quad > \quad P_{p1} = 30.000$
at -8.00 m $\quad P_{a2} = 38.512 \quad < \quad P_{p2} = 51.000$

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

EL_{top} : the top elevation of the soil layer in question (m)

P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)

P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)

P_{p1} : the passive earth pressure at the top of the soil layer (kPa)

P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)

h : the thickness of the soil layer (m)

$$X = -5.00 - \frac{3.00 \times (30.000 - 38.512)}{(38.512 - 38.512) - (51.000 - 30.000)} = -6.216m$$

Accordingly, the virtual seabed level is obtained as -6.216m.

3) Moment about tie setting point

No	Calculation	S (kN/m)	L (m)	M (kN-m/m)
1	1/2x 8.730x 1.950	8.512	-1.850	-15.747
2	1/2x 18.940x 1.950	18.466	-1.200	-22.159
3	1/2x 18.940x 0.550	5.208	-0.367	-1.911
4	1/2x 26.095x 0.550	7.176	-0.183	-1.313
5	1/2x 26.095x 2.570	33.532	0.857	28.737
6	1/2x 59.531x 2.570	76.497	1.713	131.039
7	1/2x 59.531x 2.430	72.330	3.380	244.475
8	1/2x 66.602x 2.430	80.921	4.190	339.059
9	1/2x 122.112x 1.000	61.056	5.333	325.612
10	1/2x 129.112x 1.000	64.556	5.667	365.839
11	1/2x 38.512x 2.000	38.512	6.667	256.760
12	1/2x 38.512x 2.000	38.512	7.333	282.408
13	1/2x 8.512x 1.216	5.175	8.405	43.496
Total		510.453	———	1976.295

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

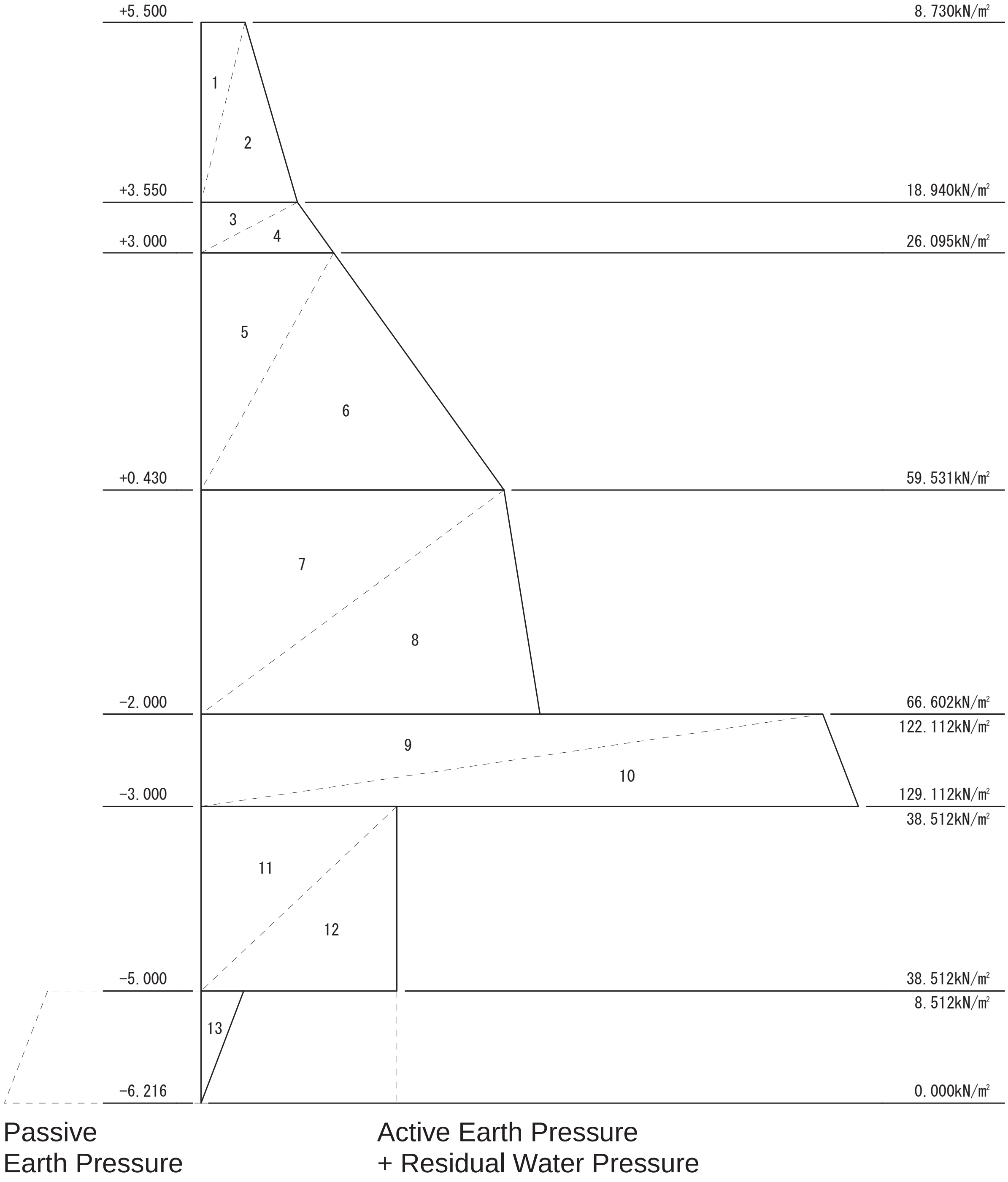
4) Reaction forces

Distance between supports : L_T = 3.000 – (-6.216) = 9.216 m

Reaction at virtual seabed : $R_0 = \dfrac{\Sigma M}{L_T} = \dfrac{1976.295}{9.216} = 214.442 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 510.453 - 214.442 = 296.011 kN/m$

External Force Diagram



5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 3.55	8.512 18.466	26.978		-26.978
3.55 3.00	5.208 7.176	39.362	296.011	256.649
3.00 0.43	33.532 76.497	149.391	296.011	146.620
0.43 -2.00	72.330 80.921	302.642	296.011	-6.631
-2.00 -3.00	61.056 64.556	428.254	296.011	-132.243
-3.00 -5.00	38.512 38.512	505.278	296.011	-209.267
-5.00 -6.22	5.175 0.000	510.453	296.011	-214.442

Shear force Q = A_p - ∑S

The above table suggests that the shear force zero point exists in between 0.430m and -2.000m.

$$Q = 146.620 - \frac{[59.531 + (59.531 + 2.910X)]X}{2} = 0$$

X = 2.330 m

Shear force zero point : DL = 0.430 – 2.330 = -1.900m

6) Calculation of moment

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	8.730x	1.950	-8.512	6.750	-57.456
2	1/2x	18.940x	1.950	-18.466	6.100	-112.643
3	1/2x	18.940x	0.550	-5.208	5.267	-27.431
4	1/2x	26.095x	0.550	-7.176	5.083	-36.476
5	1/2x	26.095x	2.570	-33.532	4.043	-135.570
6	1/2x	59.531x	2.570	-76.497	3.187	-243.796
7	1/2x	59.531x	2.330	-69.354	1.553	-107.707
8	1/2x	66.311x	2.330	-77.252	0.777	-60.025
Total				———	———	-781.104

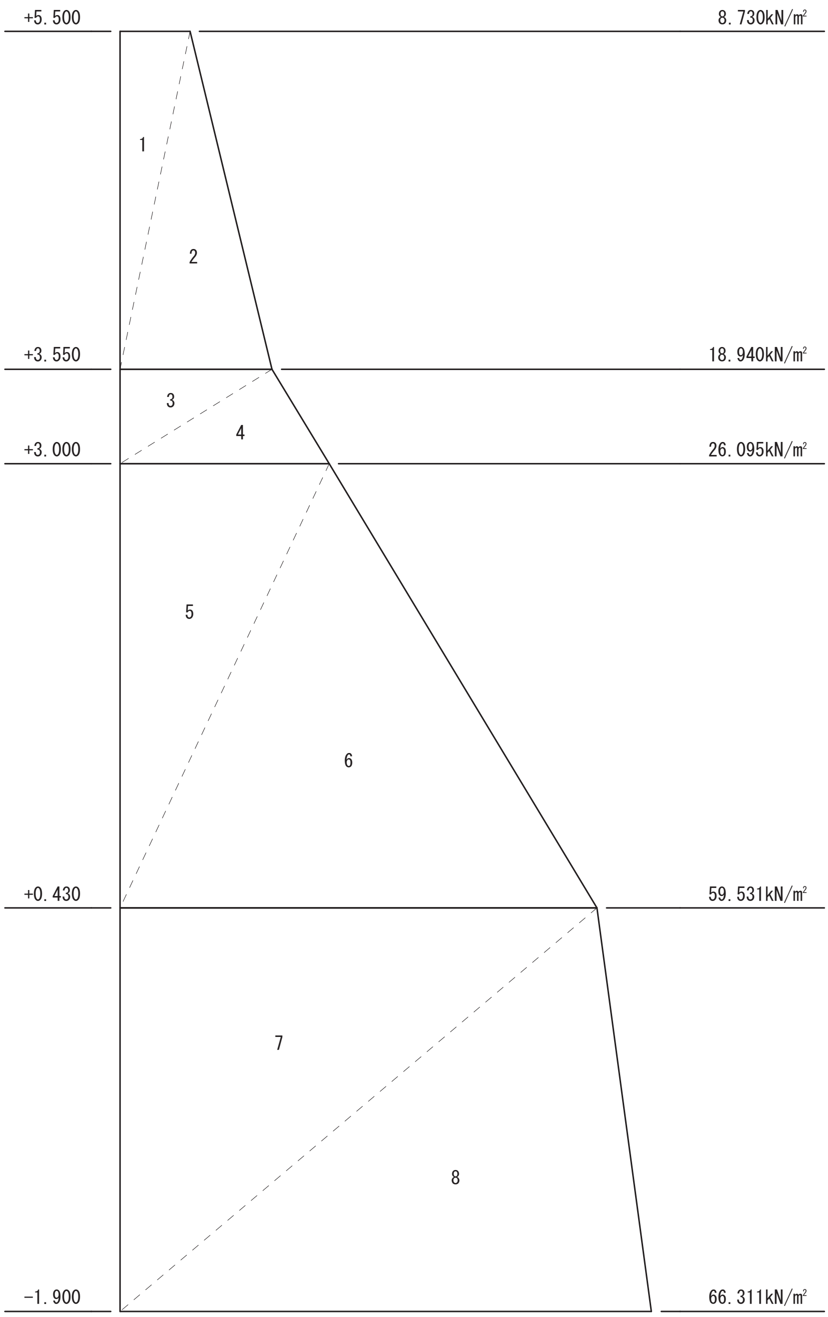
where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

7) Maximum bending moment

- Distance of the shear zero point to the tie setting point
  h = 3.000 – (-1.900) = 4.900 m

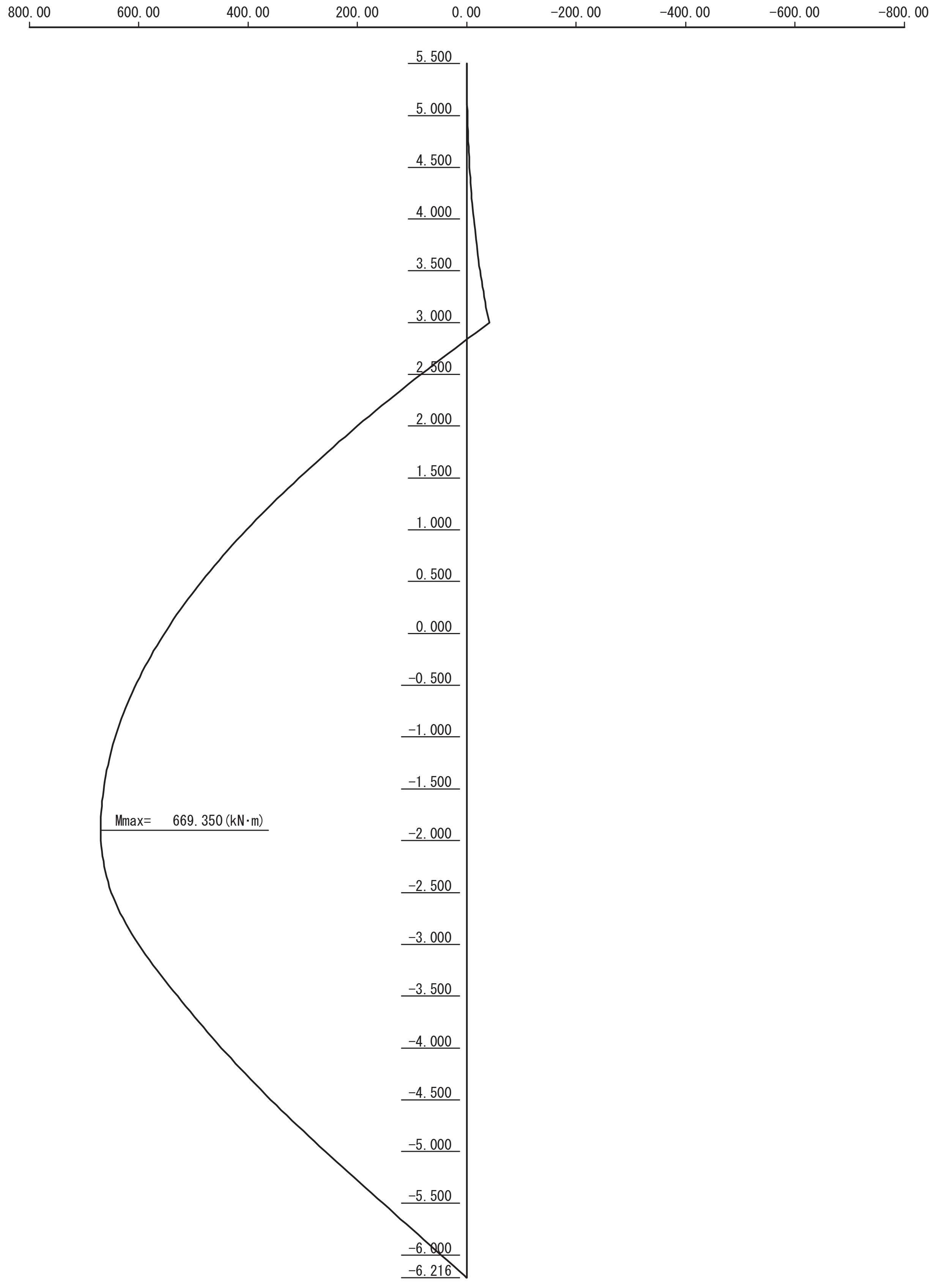
- Maximum bending moment
  $M_{max} = A_p \times h + \sum M = 296.011 \times 4.900 - 781.104 = 669.350$ kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type	: ϕ800 × t14 (P-T joint)
Modulus of elasticity	: E = 200.0 kN/mm^2
Moment of inertia	: I = 267050 cm^4
Section modulus	: Z = 6676 cm^3

Section property (per 1m) before corrosion

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 272500 cm^4/m
- Section modulus : Z = 6812 cm^3/m

Section property (per 1m) after corrosion

- Design life time : 50 years
- Effect of cathodic protection : 90%
- Corrosion rate : 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance : t = 0.030 × 50 years = 1.50 mm

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 241898 cm^4/m
- Section modulus : Z = 6070 cm^3/m

(2) Embedded depth of pipe wall
Toe level of the pipe wall is obtained as follows:

- Deflection curve method : -15.434 m --- adopted
- Free earth support method : -11.231 m

Therefore, the minimum length of the pipe wall is;
L = 3.500 – (-15.434) = 18.934m → 19.000 m

Accordingly the design toe level of the pipe wall is;
EL = +3.500 – 19.000 = -15.500 m

(3) Stress on pipe wall section
Maximum bending moment on the pipe wall is as follows:

- Deflection curve method : 786.584 kN-m/m --- adopted
- Free earth support method : 669.350 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{786.584 \times 10^6}{6070 \times 10^3} = 129.6MPa \quad \leq \quad \sigma_a = 140MPa \quad .... \ OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

- T is the tension force on tie wire (kN/wire)
- A_p is the reaction force of the pipe wall at tie setting point (kN/m)
- L is the spacing of the tie wire (m)
- θ_1 is the vertical angle of the tie wire to horizontal (deg.)
- θ_2 is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 319.295 kN-m/m --- adopted
- Free earth support method : 296.011 kN-m/m

T = 319.295 × 1.960 × sec(0.000) × sec (0.000) = 625.818 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 625.818 × 3.8 = 2378.108 kN/wire

Tie wire shall have minimum tensile strength of <u>2379 kN</u>.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max} is the maximum bending moment on the waling beam (kN-m)
T is the tension force on tie wire (kN/wire)
L is the spacing of the tie wire (m)

$$M_{maz} = \frac{625.818 \times 1.960}{10.0} = 122.660 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[300×90×10.0×15.5

Steel grade : SS400
Section modulus : Z = 494.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \le \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{122.660 \times 10^6}{2 \times 494.0 \times 10^3} = 124.1 MPa \quad \le \quad \sigma_a = 140 MPa \text{ .... } OK$$

Output of Design Software for Anchor Wall (After Completion)
– Revetment Block a

1. Design Conditions

1-1 Dimensions

Ground elevation	+5.50 m
Top of cope concrete	+5.50 m
Top of pipe wall	+3.50 m
Tie elevation	+3.00 m
Seabed elevation	-1.00 m
Angle of seabed slope	18.4°

1-2 Tide Levels

H.W.L	+3.55 m
L.W.L	+0.43 m

1-3 Residual Water Level

R.W.L	+3.55 m

1-4 Base Elevation of Cohesion Increment +0.00 m (not used)

1-5 Surcharge Load	(Active side)	30 kPa
	(Passive side)	0 kPa

1-6 Unit Weight of Water 10.10 kN/m^3

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

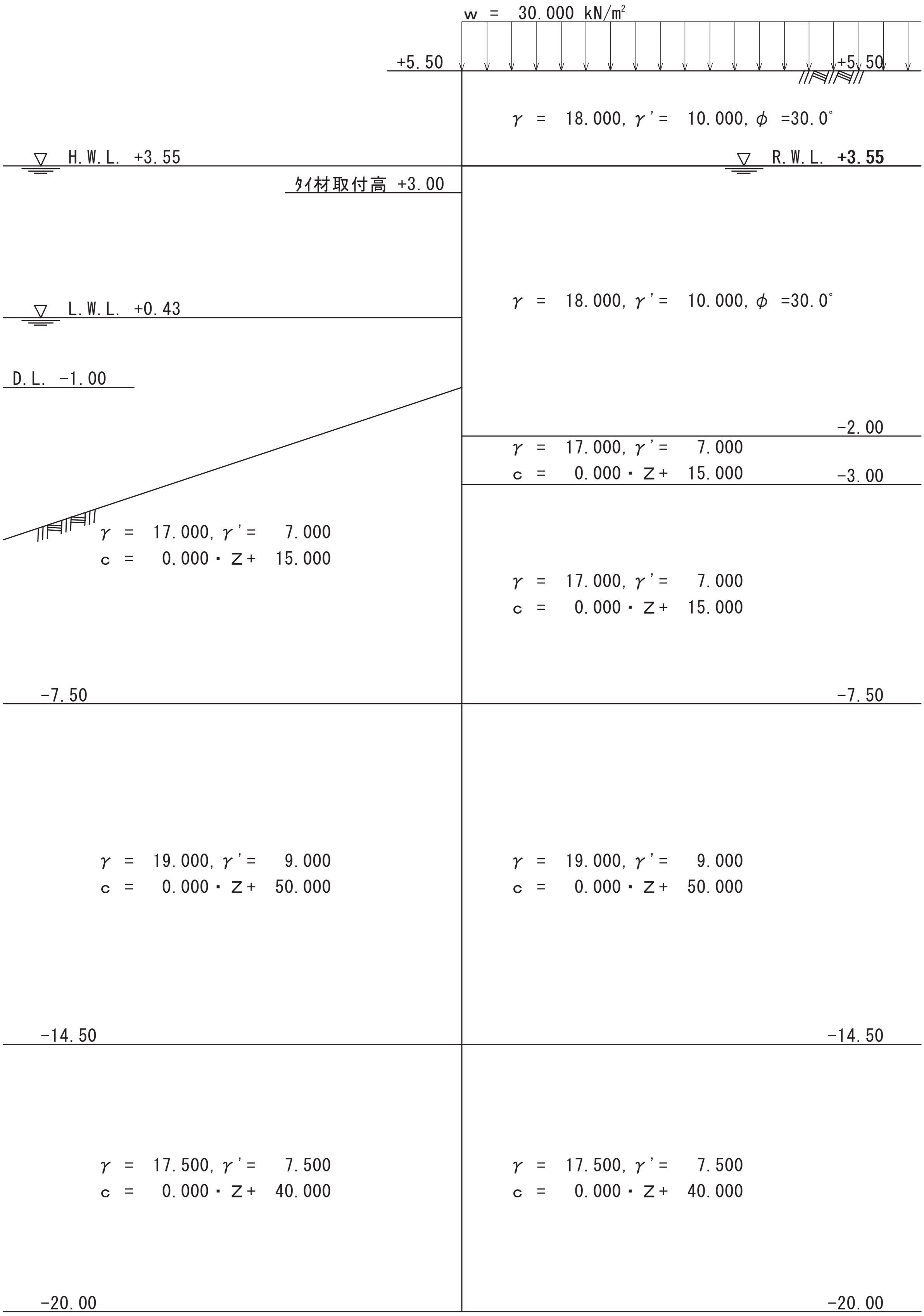
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	:	Deflection Curve Method
Calculation Method 2	:	Free Earth Support Method
Factor of Safety	:	FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
5.50 3.55	1.95	8.730 18.940
3.55 3.00	0.55	18.940 20.540
3.00 -2.00	5.00	20.540 35.090
-2.00 -3.00	1.00	90.600 97.600
-3.00 -7.50	4.50	7.000 7.000
-7.50 -11.00	3.50	7.000 7.000
-11.00 -14.50	3.50	7.000 7.000
-14.50 -25.00	10.50	7.000 7.000

(2) Residual water pressure

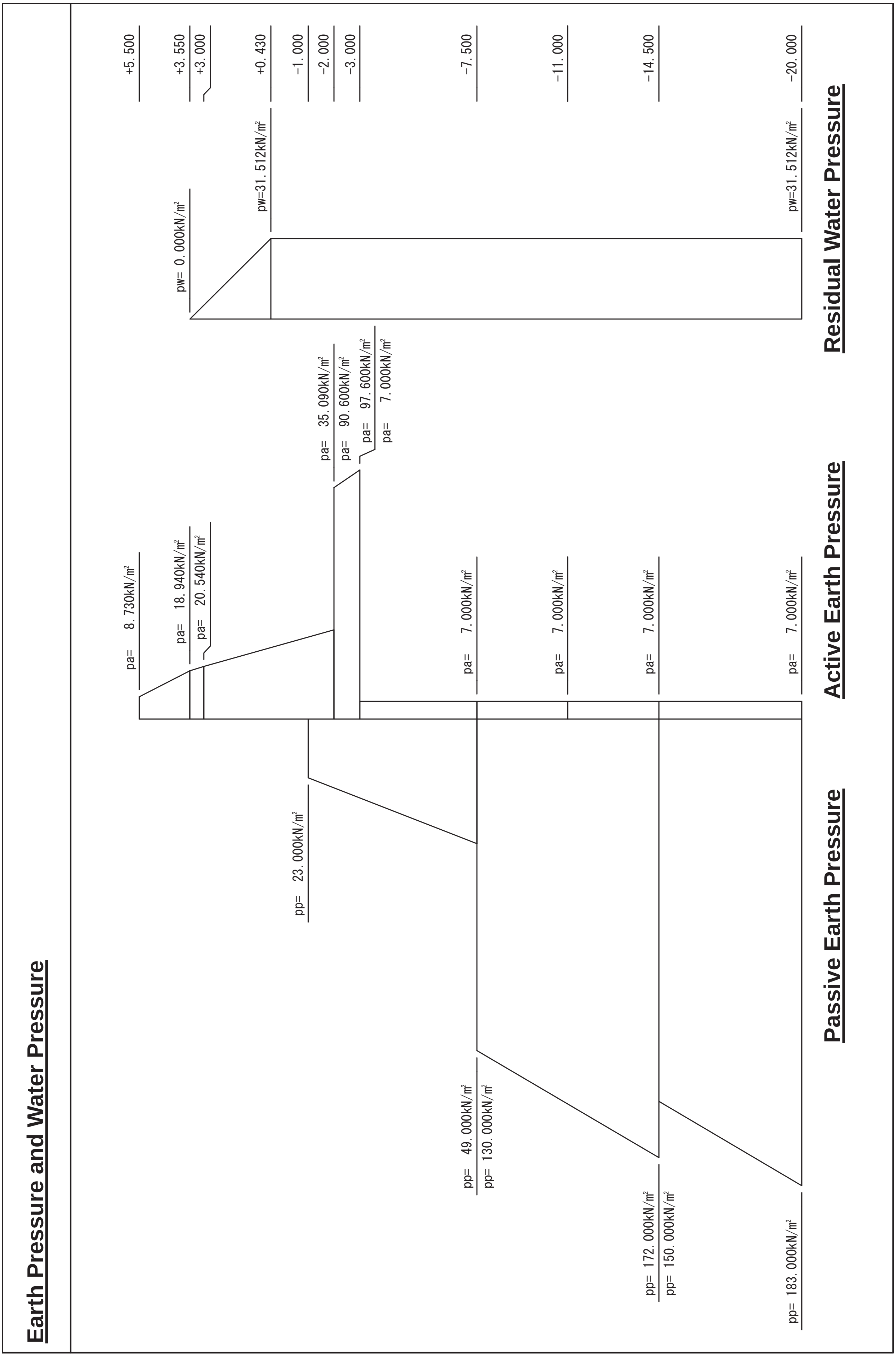
$p_w = \gamma_w \times h_w$

where; p_w is the residual water pressure (kPa)
h_w is the height of the tidal lag (m)
γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-1.00 -7.50	6.50	23.000 49.000
-7.50 -14.50	7.00	130.000 172.000
-14.50 -20.00	5.50	150.000 183.000


Earth Pressure and Water Pressure
+5.500
+3.550
+3.000
+0.430
−1.000
−2.000
−3.000
−7.500
−11.000
−14.500
−20.000
pw= 0.000kN/m²
pw=31.512kN/m²
pw=31.512kN/m²
Residual Water Pressure
pa= 35.090kN/m²
pa= 90.600kN/m²
pa= 97.600kN/m²
pa= 7.000kN/m²
pa= 8.730kN/m²
pa= 18.940kN/m²
pa= 20.540kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
Active Earth Pressure
pp= 23.000kN/m²
pp= 49.000kN/m²
pp= 130.000kN/m²
pp= 172.000kN/m²
pp= 150.000kN/m²
pp= 183.000kN/m²
Passive Earth Pressure

(4) Summary of Forces on the Wall

Elev (m)	Active side (kPa) $P_a + P_w$	Passive side(kPa) P_p
5.50 3.55	8.730+ 0.000= 8.730 18.940+ 0.000= 18.940	——— ———
3.55 3.00	18.940+ 0.000= 18.940 20.540+ 5.555= 26.095	——— ———
3.00 0.43	20.540+ 5.555= 26.095 28.019+ 31.512= 59.531	——— ———
0.43 -1.00	28.019+ 31.512= 59.531 32.180+ 31.512= 63.692	——— ———
-1.00 -2.00	32.180+ 31.512= 63.692 35.090+ 31.512= 66.602	23.000 27.000
-2.00 -3.00	90.600+ 31.512= 122.112 97.600+ 31.512= 129.112	27.000 31.000
-3.00 -7.50	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	31.000 49.000
-7.50 -11.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	130.000 151.000
-11.00 -14.50	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	151.000 172.000
-14.50 -20.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	150.000 183.000

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -1.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
-1.000	-111.249	135.301	102.195
-2.000	-238.845	159.773	117.870
-3.000	-459.920	187.428	186.827
-4.000	-747.349	214.559	165.208
-5.000	-1017.829	235.345	145.934
-6.000	-1269.787	251.459	127.332
-7.000	-1496.898	263.902	108.400
-8.000	-1653.670	272.385	48.680
-9.000	-1509.613	272.422	-48.845
-10.000	-1000.244	264.723	-144.634
-11.000	-88.979	250.516	-239.915
-12.000	1266.775	230.706	-335.593

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -11.00 and -12.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-11.078	0.000	249.166	-247.337

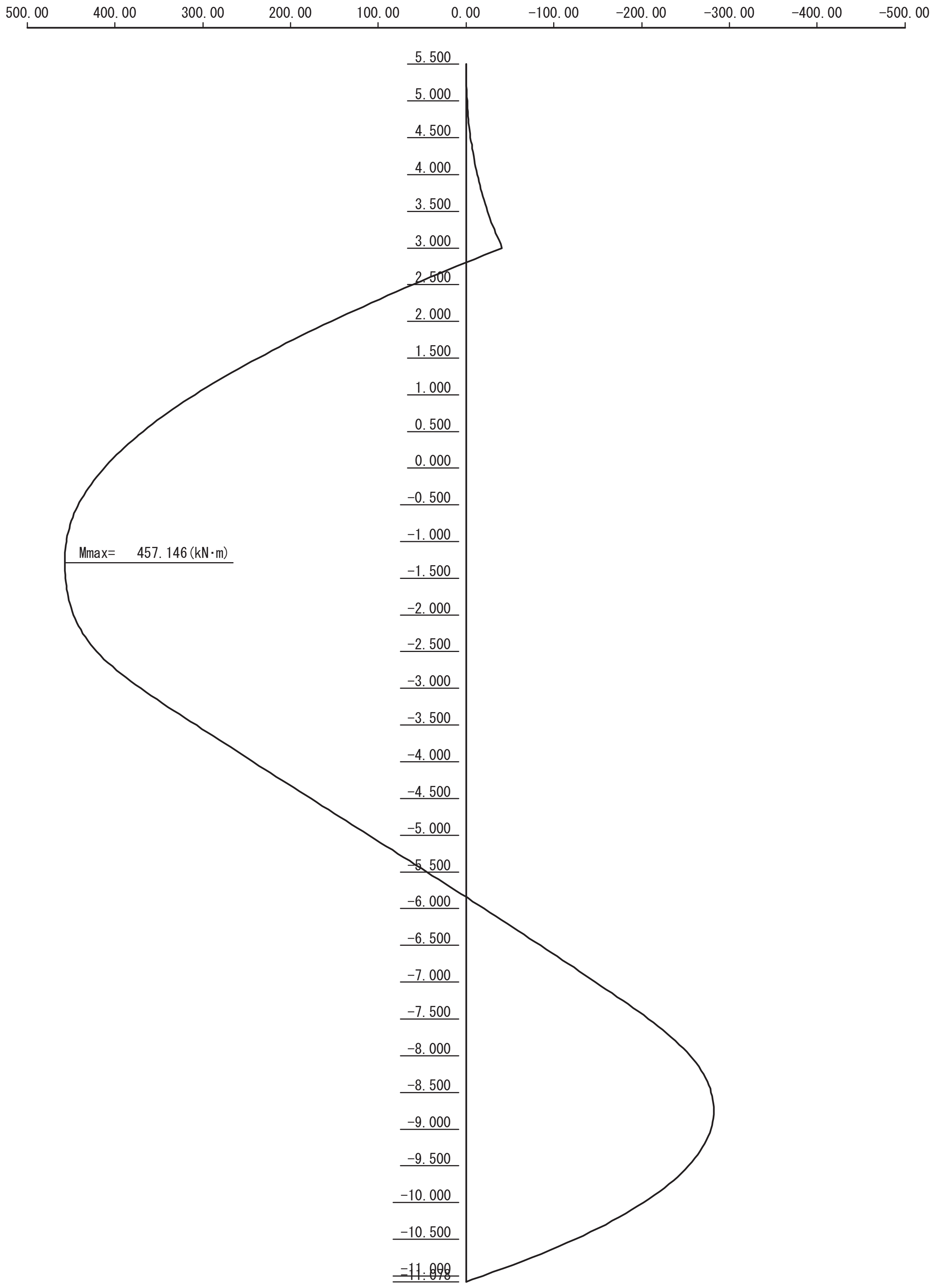
Embedded length of the pipe wall : L = 1.2 × (-1.000 + 11.078) = 12.094 m
Toe elevation : D = -1.000 – 12.094 = -13.094 m
Reaction force at tie setting point : 249.166 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	-1.200	-5.019
4.500	-5.238	-11.348
4.000	-12.766	-18.985
3.550	-23.069	-26.978
3.050	-39.196	-38.074
3.000	-41.132	-39.363
2.500	60.237	195.129
2.000	153.455	177.203
1.500	236.898	156.024
1.000	308.937	131.593
0.500	367.948	103.909
0.430	375.078	99.774
-0.070	417.463	69.644
-0.570	444.601	38.788
-1.000	455.469	11.669
-1.500	456.239	-8.540
-2.000	446.973	-28.478
-2.500	420.783	-76.409
-3.000	370.440	-125.090
-3.500	307.039	-128.346
-4.000	242.261	-130.602
-4.500	176.604	-131.858
-5.000	110.570	-132.114
-5.500	44.657	-131.370
-6.000	-20.633	-129.626
-6.500	-84.802	-126.882
-7.000	-147.348	-123.138
-7.500	-207.773	-118.394
-8.000	-255.409	-71.900
-8.500	-279.423	-23.906
-9.000	-279.065	25.588
-9.500	-253.584	76.582
-10.000	-202.232	129.076
-10.500	-124.258	183.070
-11.000	-18.912	238.564
-11.078	0.000	247.337

Maximum bending moment : 457.146 kN-m/m
Elevation of maximum bending moment : -1.288 m
Depth of 1st steady point (moment=0) : -5.841 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

M_p = FOS×M_a

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of FOS×M_a

NO	Elev (m)	Calculation			S (kN/m)	L (m)	M (kN-m/m)	FOS×M_a (kN-m/m)
1	5.50	1/2x	8.730x	1.950	8.512	-1.850	-15.747	
2	3.55	1/2x	18.940x	1.950	18.466	-1.200	-22.159	-45.487
3	3.55	1/2x	18.940x	0.550	5.208	-0.367	-1.911	
4	3.00	1/2x	26.095x	0.550	7.176	-0.183	-1.313	-49.356
5	3.00	1/2x	26.095x	2.570	33.532	0.857	28.737	
6	0.43	1/2x	59.531x	2.570	76.497	1.713	131.039	142.375
7	0.43	1/2x	59.531x	1.430	42.565	3.047	129.696	
8	-1.00	1/2x	63.692x	1.430	45.540	3.523	160.437	490.535
9	-1.00	1/2x	63.692x	1.000	31.846	4.333	137.989	
10	-2.00	1/2x	66.602x	1.000	33.301	4.667	155.416	842.621
11	-2.00	1/2x	122.112x	1.000	61.056	5.333	325.612	
12	-3.00	1/2x	129.112x	1.000	64.556	5.667	365.839	1672.362
13	-3.00	1/2x	38.512x	4.500	86.652	7.500	649.890	
14	-7.50	1/2x	38.512x	4.500	86.652	9.000	779.868	3388.072
15	-7.50	1/2x	38.512x	3.500	67.396	11.667	786.309	
16	-11.00	1/2x	38.512x	3.500	67.396	12.833	864.893	5369.514
17	-11.00	1/2x	38.512x	3.500	67.396	15.167	1022.195	
18	-14.50	1/2x	38.512x	3.500	67.396	16.333	1100.779	7917.083
19	-14.50	1/2x	38.512x	5.500	105.908	19.333	2047.519	
20	-20.00	1/2x	38.512x	5.500	105.908	21.167	2241.755	13064.212

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

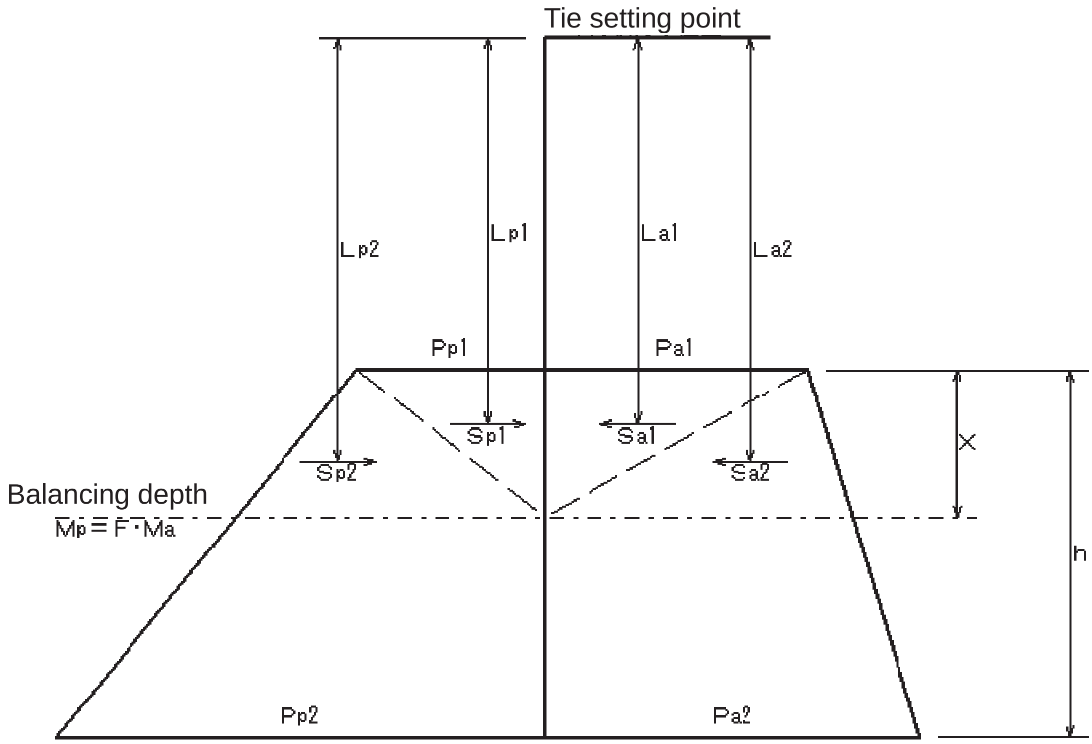
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-1.00	1/2x 23.000x 1.000	11.500	4.333	49.830	
2	-2.00	1/2x 27.000x 1.000	13.500	4.667	63.004	112.834
3	-2.00	1/2x 27.000x 1.000	13.500	5.333	71.996	
4	-3.00	1/2x 31.000x 1.000	15.500	5.667	87.838	272.668
5	-3.00	1/2x 31.000x 4.500	69.750	7.500	523.125	
6	-7.50	1/2x 49.000x 4.500	110.250	9.000	992.250	1788.043
7	-7.50	1/2x 130.000x 3.500	227.500	11.667	2654.242	
8	-11.00	1/2x 151.000x 3.500	264.250	12.833	3391.120	7833.405
9	-11.00	1/2x 151.000x 3.500	264.250	15.167	4007.880	
10	-14.50	1/2x 172.000x 3.500	301.000	16.333	4916.233	16757.518
11	-14.50	1/2x 150.000x 5.500	412.500	19.333	7974.862	
12	-20.00	1/2x 183.000x 5.500	503.250	21.167	10652.293	35384.673

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1} X}{2}, \quad L_{a(p)1} = L + \frac{1}{3} X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \frac{P_{a(p)2} - P_{a(p)1}}{h} X \right] X}{2} \ , \quad L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

$M_{a(p)}$: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)

$M_{a(p)1}$: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)

$M_{a(p)1'}$: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)

$M_{a(p)2'}$: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)

$S_{a(p)1}$: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)

$S_{a(p)2}$: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)

$L_{a(p)1}$: the arm length of $S_{a(p)1}$ from the tie setting point (m)

$L_{a(p)2}$: the arm length of $S_{a(p)2}$ from the tie setting point (m)

$P_{a(p)1}$: the active (passive) side pressure at the top elevation of the soil layer (kPa)

$P_{a(p)1}$: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)

h : the thickness of the soil layer (m)

L : the vertical distance from the tie setting point to the top elevation of the soil layer (m)

X : the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -7.50 m FOS×M_{a1} = 3388.072 > M_{p1} = 1788.043
at -11.00 m FOS×M_{a2} = 5369.514 < M_{p2} = 7833.405

[Moment on active side]

$$S_{a1} = \frac{38.512X}{2} = 19.256X \ , \quad L_{a1} = 10.50 + \frac{1}{3}X$$

$$M_{a1'} = 6.419X^2 + 202.188X$$

$$S_{a2} = \frac{\left[38.512 + \frac{38.512 - 38.512}{3.500}X\right]X}{2} = 0.000X^2 + 19.256X \ , \quad L_{a2} = 10.500 + \frac{2}{3}X$$

$$M_{a2'} = 0.000X^3 + 12.837X^2 + 202.188X$$

$$M_a = 0.000X^3 + 19.256X^2 + 404.376X + 2823.393$$

[Moment on passive side]

$$S_{p1} = \frac{130.000X}{2} = 65.000X \ , \quad L_{p1} = 10.500 + \frac{1}{3}X$$

$$M_{p1'} = 21.667X^2 + 682.500X$$

$$S_{p2} = \frac{\left[130.000 + \frac{151.000 - 130.000}{3.500}X\right]X}{2} = 3.000X^2 + 65.000X \ , \quad L_{p2} = 10.500 + \frac{2}{3}X$$

$$M_{p2'} = 2.000X^3 + 74.833X^2 + 682.500X$$

$$M_p = 2.000X^3 + 96.500X^2 + 1365.000X + 1788.043$$

[Balancing depth]

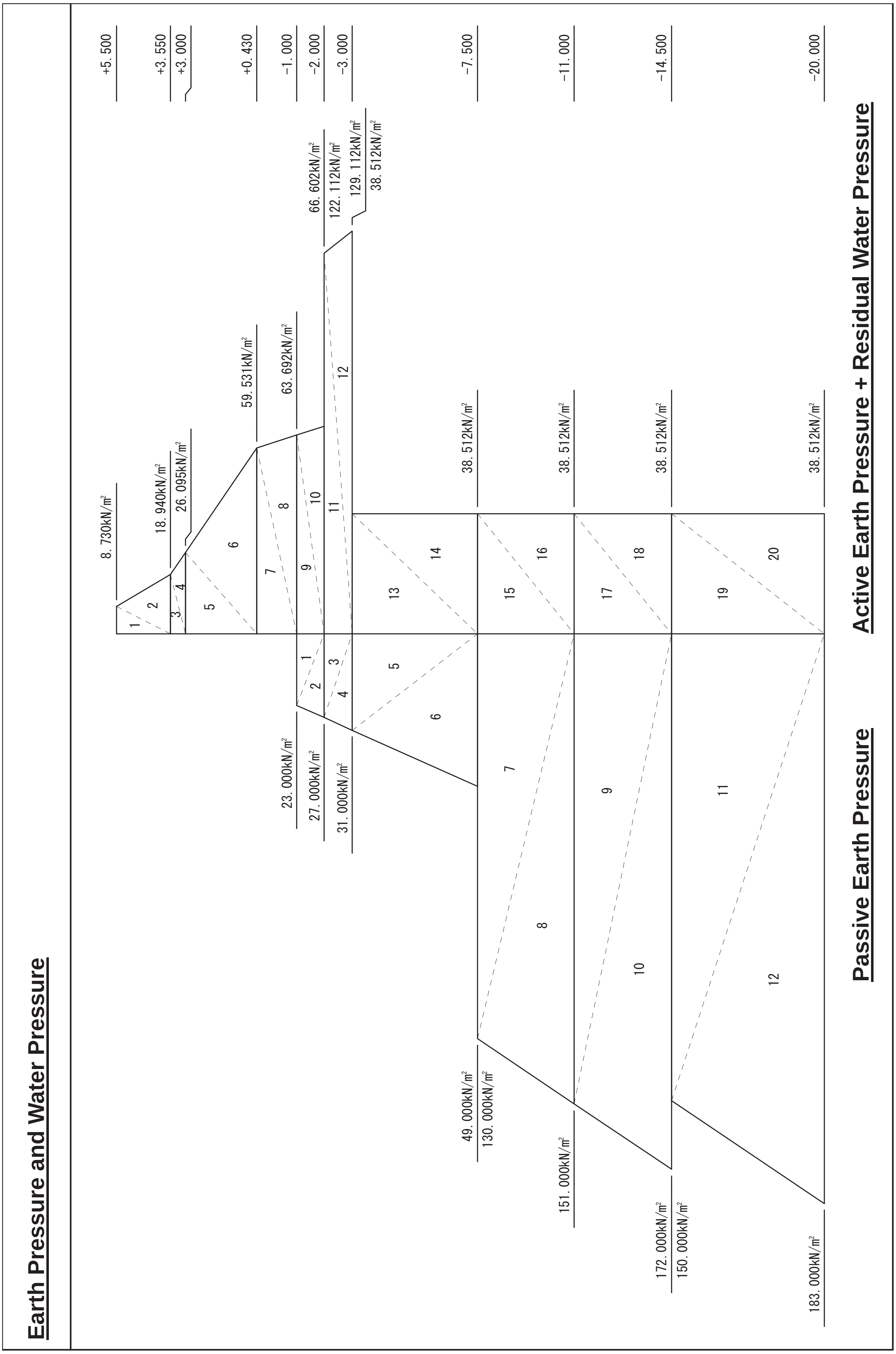
$$FOS \cdot M_a = M_p$$

$$1.2 \times (0.000X^3 + 19.256X^2 + 404.376X + 2823.393)$$

$$= 2.000X^3 + 96.500X^2 + 1365.000X + 1788.043$$

X= 1.597 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -7.500 – 1.597 = -9.097 m


Earth Pressure and Water Pressure
Active Earth Pressure + Residual Water Pressure
Passive Earth Pressure
+5. 500
+3. 550
+3. 000
+0. 430
−1. 000
−2. 000
−3. 000
−7. 500
−11. 000
−14. 500
−20. 000
8. 730kN/m²
18. 940kN/m²
26. 095kN/m²
59. 531kN/m²
63. 692kN/m²
66. 602kN/m²
122. 112kN/m²
129. 112kN/m²
38. 512kN/m²
38. 512kN/m²
38. 512kN/m²
38. 512kN/m²
38. 512kN/m²
23. 000kN/m²
27. 000kN/m²
31. 000kN/m²
49. 000kN/m²
130. 000kN/m²
151. 000kN/m²
172. 000kN/m²
150. 000kN/m²
183. 000kN/m²

(2) Calculation of maximum bending moment

1) External forces

Elev (m)	$P_a + P_w$ (kN/m^2)	P_p (kN/m^2)	$P_a - P_p$ (kN/m^2)
5.50 3.55	8.730 18.940	——— ———	8.730 18.940
3.55 3.00	18.940 26.095	——— ———	18.940 26.095
3.00 0.43	26.095 59.531	——— ———	26.095 59.531
0.43 -1.00	59.531 63.692	——— ———	59.531 63.692
-1.00 -2.00	63.692 66.602	23.000 27.000	40.692 39.602
-2.00 -3.00	122.112 129.112	27.000 31.000	95.112 98.112
-3.00 -7.50	38.512 38.512	31.000 49.000	7.512 -10.488
-7.50 -11.00	38.512 38.512	130.000 151.000	-91.488 -112.488
-11.00 -14.50	38.512 38.512	151.000 172.000	-112.488 -133.488
-14.50 -20.00	38.512 38.512	150.000 183.000	-111.488 -144.488

2) Virtual seabed level

The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -3.00 m $\quad P_{a1} = 38.512 \quad > \quad P_{p1} = 31.000$

at -7.50 m $\quad P_{a2} = 38.512 \quad < \quad P_{p2} = 49.000$

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

EL_{top} : the top elevation of the soil layer in question (m)

P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)

P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)

P_{p1} : the passive earth pressure at the top of the soil layer (kPa)

P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)

h : the thickness of the soil layer (m)

$$X = -3.00 - \frac{4.50 \times (31.000 - 38.512)}{(38.512 - 38.512) - (49.000 - 31.000)} = -4.878m$$

Accordingly, the virtual seabed level is obtained as -4.878m.

3) Moment about tie setting point

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	8.730x	1.950	8.512	-1.850	-15.747
2	1/2x	18.940x	1.950	18.466	-1.200	-22.159
3	1/2x	18.940x	0.550	5.208	-0.367	-1.911
4	1/2x	26.095x	0.550	7.176	-0.183	-1.313
5	1/2x	26.095x	2.570	33.532	0.857	28.737
6	1/2x	59.531x	2.570	76.497	1.713	131.039
7	1/2x	59.531x	1.430	42.565	3.047	129.696
8	1/2x	63.692x	1.430	45.540	3.523	160.437
9	1/2x	40.692x	1.000	20.346	4.333	88.159
10	1/2x	39.602x	1.000	19.801	4.667	92.411
11	1/2x	95.112x	1.000	47.556	5.333	253.616
12	1/2x	98.112x	1.000	49.056	5.667	278.000
13	1/2x	7.512x	1.878	7.054	6.626	46.740
Total				381.309	———	1167.705

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

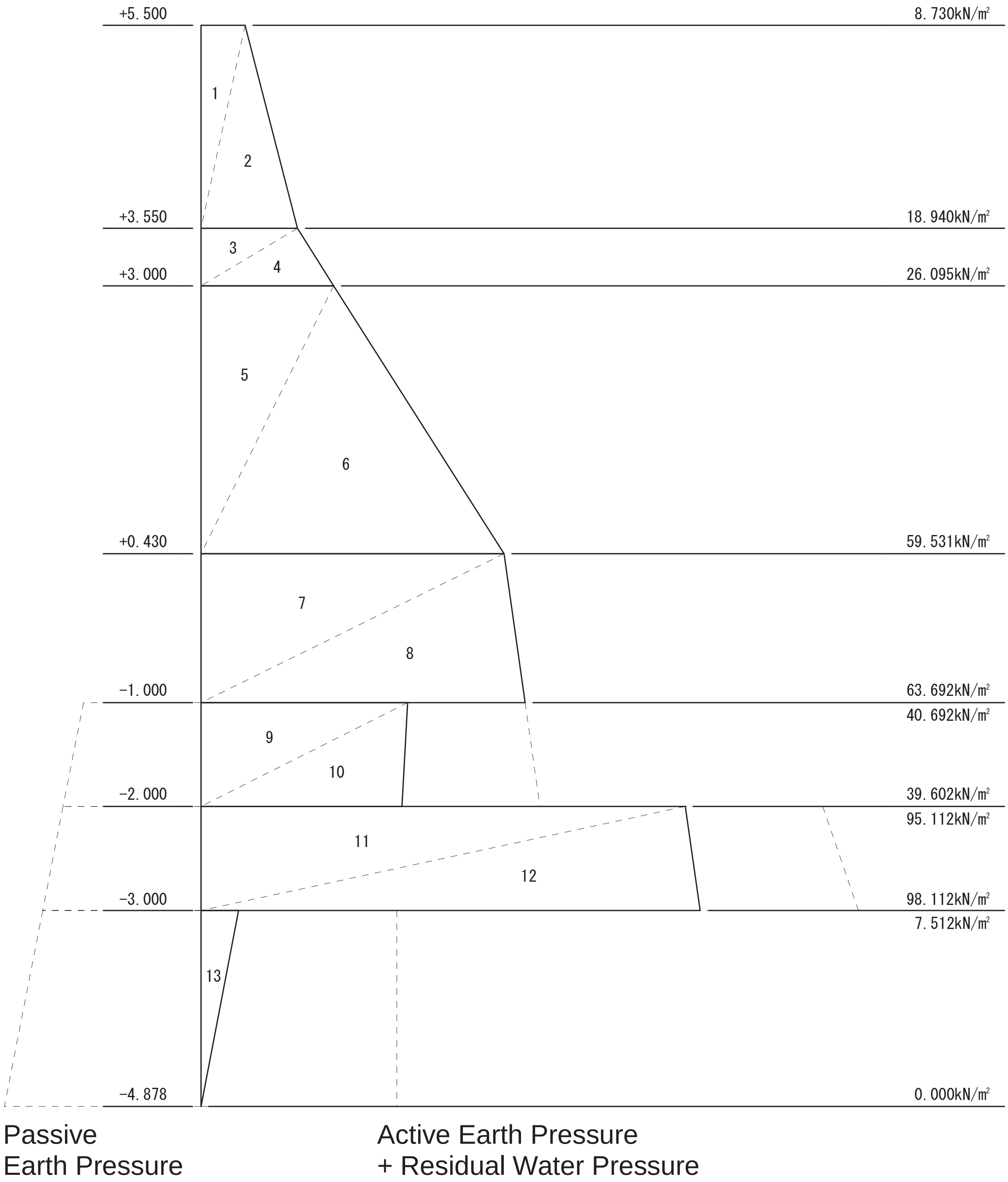
4) Reaction forces

Distance between supports : $L_T = 3.000 - (-4.878) = 7.878$ m

Reaction at virtual seabed : $R_0 = \dfrac{\Sigma M}{L_T} = \dfrac{1167.705}{7.878} = 148.224 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 381.309 - 148.224 = 233.085 kN/m$

External Force Diagram



5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 3.55	8.512 18.466	26.978		-26.978
3.55 3.00	5.208 7.176	39.362	233.085	193.723
3.00 0.43	33.532 76.497	149.391	233.085	83.694
0.43 -1.00	42.565 45.540	237.496	233.085	-4.411
-1.00 -2.00	20.346 19.801	277.643	233.085	-44.558
-2.00 -3.00	47.556 49.056	374.255	233.085	-141.170
-3.00 -4.88	7.054 0.000	381.309	233.085	-148.224

Shear force $Q = A_p - \sum S$

The above table suggests that the shear force zero point exists in between 0.430m and -1.000m.

$$Q = 83.694 - \frac{[59.531 + (59.531 + 2.910X)]X}{2} = 0$$

X = 1.361 m

Shear force zero point : DL = +0.43 – 1.361 = -0.931m

6) Calculation of moment

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	8.730x	1.950	-8.512	5.781	-49.208
2	1/2x	18.940x	1.950	-18.466	5.131	-94.749
3	1/2x	18.940x	0.550	-5.208	4.298	-22.384
4	1/2x	26.095x	0.550	-7.176	4.114	-29.522
5	1/2x	26.095x	2.570	-33.532	3.074	-103.077
6	1/2x	59.531x	2.570	-76.497	2.218	-169.670
7	1/2x	59.531x	1.361	-40.511	0.907	-36.743
8	1/2x	63.491x	1.361	-43.206	0.454	-19.616
Total				———	———	-524.969

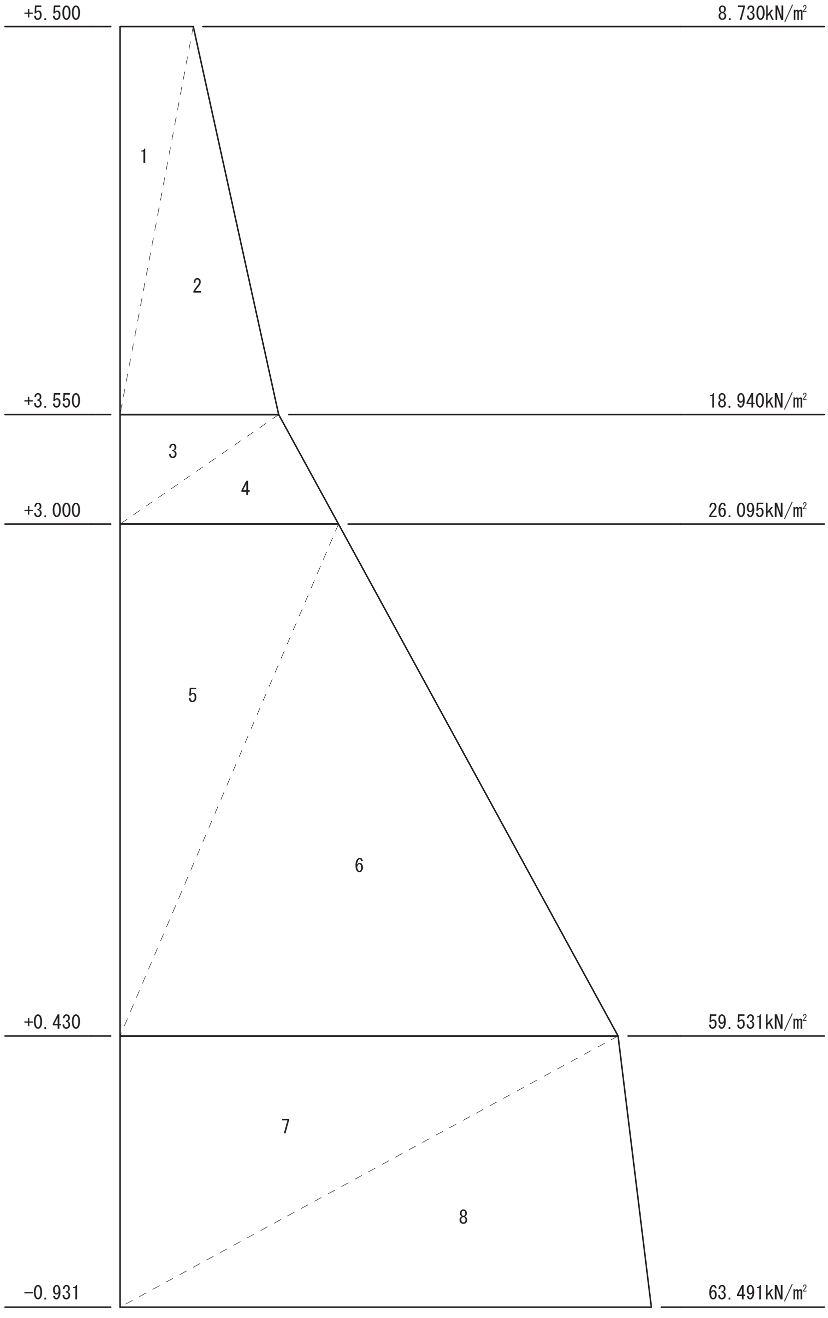
where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

7) Maximum bending moment

- Distance of the shear zero point to the tie setting point
  h = 3.000 – (-0.931) = 3.931 m

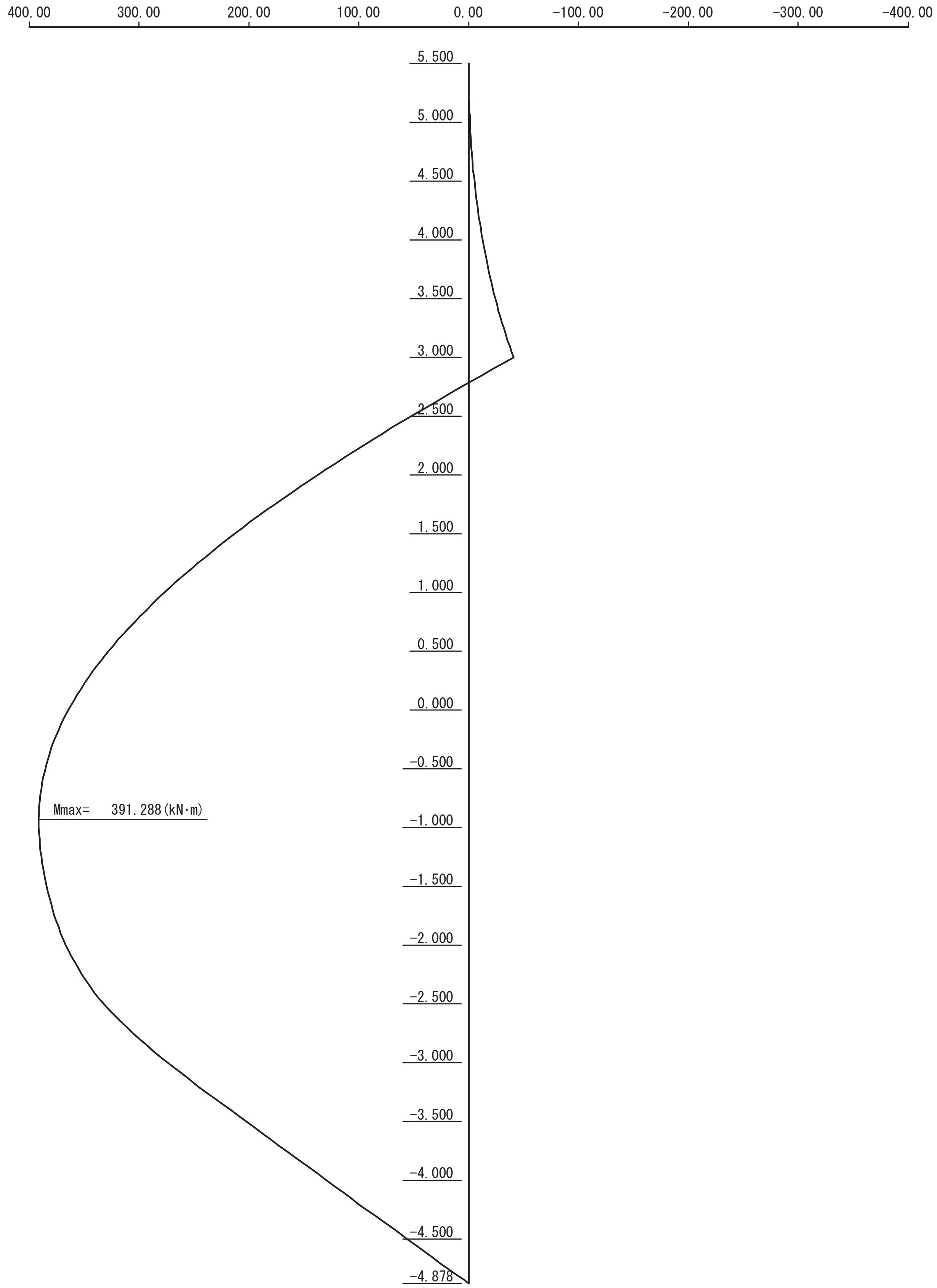
- Maximum bending moment
  $M_{max} = A_p \times h + \sum M = 233.085 \times 3.931 - 524.969 = 391.288$ kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type	: ϕ800 × t10 (P-T joint)
Modulus of elasticity	: E = 200.0 kN/mm^2
Moment of inertia	: I = 193647 cm^4
Section modulus	: Z = 4841 cm^3

Section property (per 1m) before corrosion

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 197599 cm^4/m
- Section modulus : Z = 4940 cm^3/m

Section property (per 1m) after corrosion

- Design life time : 50 years
- Effect of cathodic protection : 90%
- Corrosion rate : 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance : t = 0.030 × 50 years = 1.50 mm

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 166997 cm^4/m
- Section modulus : Z = 4191 cm^3/m

(2) Embedded depth of pipe wall

Toe level of the pipe wall is obtained as follows:

- Deflection curve method : -13.094 m --- adopted
- Free earth support method : -9.097 m

Therefore, the minimum length of the pipe wall is;

L = 3.500 – (-13.094) = 16.594m → 17.000 m

Accordingly the design toe level of the pipe wall is;

EL = +3.500 – 17.000 = -13.500 m

(3) Stress on pipe wall section

Maximum bending moment on the pipe wall is as follows:

- Deflection curve method : 457.146 kN-m/m --- adopted
- Free earth support method : 391.288 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{457.146\times10^6}{4191\times10^3} = 109.1MPa \quad \leq \quad \sigma_a = 140MPa \;\; .... \; OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

T	is the tension force on tie wire (kN/wire)
A_p	is the reaction force of the pipe wall at tie setting point (kN/m)
L	is the spacing of the tie wire (m)
θ_1	is the vertical angle of the tie wire to horizontal (deg.)
θ_2	is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 249.166 kN-m/m --- adopted
- Free earth support method : 233.085 kN-m/m

T = 249.166 × 1.960 × sec(0.000) × sec (0.000) = 488.365 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 488.365 × 3.8 = 1855.787 kN/wire

Tie wire shall have minimum tensile strength of <u>1856 kN</u>.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max} is the maximum bending moment on the waling beam (kN-m)
T is the tension force on tie wire (kN/wire)
L is the spacing of the tie wire (m)

$$M_{maz} = \frac{488.365 \times 1.960}{10.0} = 95.720 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[250×90×11.0×14.5

Steel grade : SS400
Section modulus : Z = 374.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \leq \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{95.720 \times 10^6}{2 \times 374.0 \times 10^3} = 128.0 MPa \quad \leq \quad \sigma_a = 140 MPa \quad .... \ OK$$

Output of Design Software for Anchor Wall (After Completion) – Revetment Block b

1. Design Conditions

1-1 Dimensions

Ground elevation	+5.50 m
Top of cope concrete	+5.50 m
Top of pipe wall	+3.50 m
Tie elevation	+3.00 m
Seabed elevation	-1.00 m
Angle of seabed slope	18.4°

1-2 Tide Levels

H.W.L	+3.55 m
L.W.L	+0.43 m

1-3 Residual Water Level

R.W.L	+3.55 m

1-4 Base Elevation of Cohesion Increment +0.00 m (not used)

1-5 Surcharge Load	(Active side)	30 kPa
	(Passive side)	0 kPa

1-6 Unit Weight of Water 10.10 kN/m^3

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

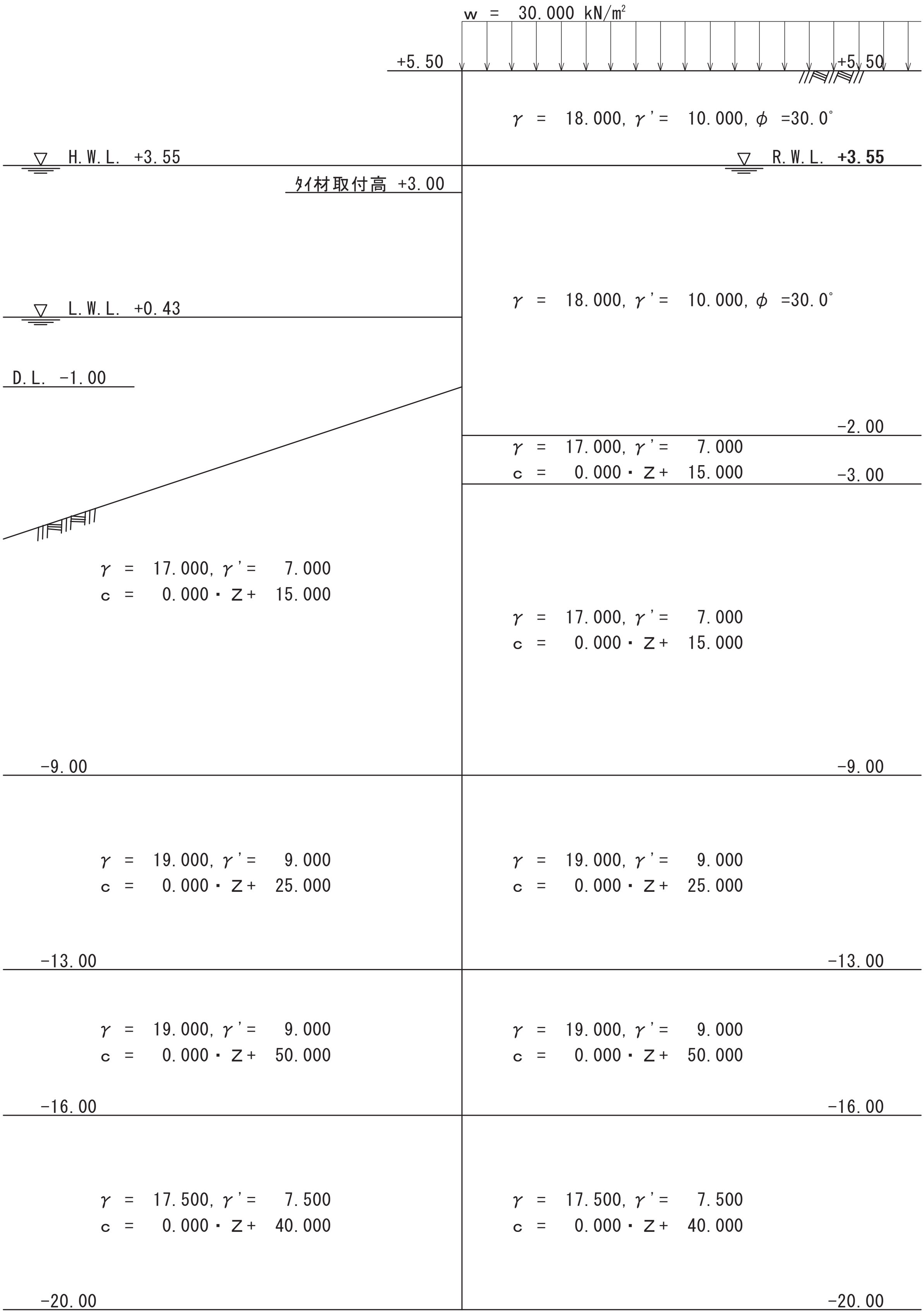
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	:	Deflection Curve Method
Calculation Method 2	:	Free Earth Support Method
Factor of Safety	:	FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
5.50 3.55	1.95	8.730 18.940
3.55 3.00	0.55	18.940 20.540
3.00 -2.00	5.00	20.540 35.090
-2.00 -3.00	1.00	90.600 97.600
-3.00 -9.00	6.00	7.000 7.000
-9.00 -11.00	2.00	7.000 7.000
-11.00 -13.00	2.00	7.000 7.000
-13.00 -16.00	3.00	7.000 7.000
-16.00 -20.00	4.00	7.000 7.000

(2) Residual water pressure

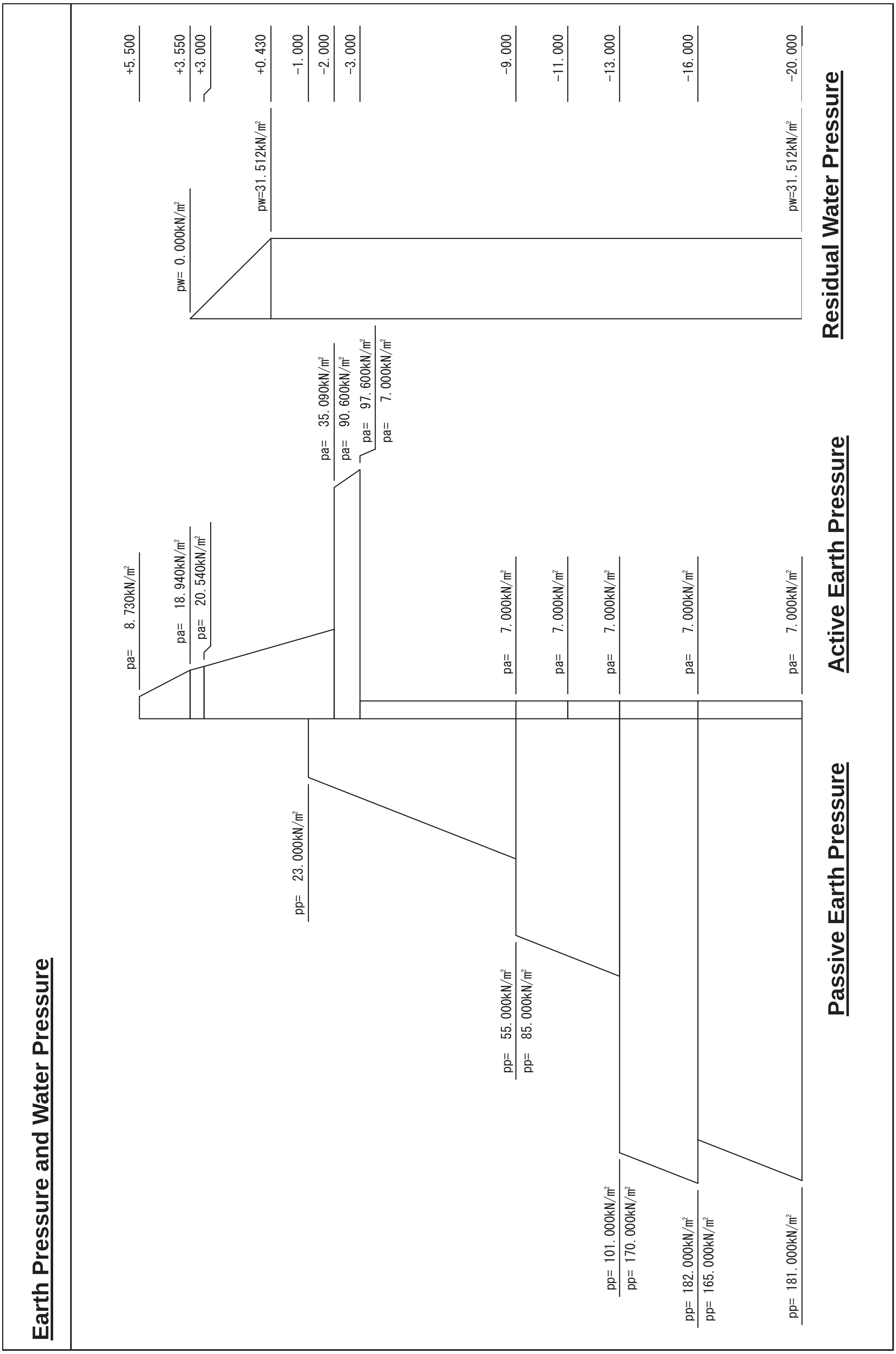
$p_w = \gamma_w \times h_w$

where; p_w is the residual water pressure (kPa)
h_w is the height of the tidal lag (m)
γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-1.00 -9.00	8.00	23.000 55.000
-9.00 -13.00	4.00	85.000 101.000
-13.00 -16.00	3.00	170.000 182.000
-16.00 -20.00	4.00	165.000 181.000


Earth Pressure and Water Pressure
+5.500
+3.550
+3.000
+0.430
-1.000
-2.000
-3.000
-9.000
-11.000
-13.000
-16.000
-20.000
pw= 0.000kN/m²
pw=31.512kN/m²
pw=31.512kN/m²
pa= 8.730kN/m²
pa= 18.940kN/m²
pa= 20.540kN/m²
pa= 35.090kN/m²
pa= 90.600kN/m²
pa= 97.600kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pp= 23.000kN/m²
pp= 55.000kN/m²
pp= 85.000kN/m²
pp= 101.000kN/m²
pp= 170.000kN/m²
pp= 182.000kN/m²
pp= 165.000kN/m²
pp= 181.000kN/m²
Residual Water Pressure
Active Earth Pressure
Passive Earth Pressure

(4) Summary of Forces on the Wall

Elev	Active side (kPa)	Passive side(kPa)
(m)	$P_a + P_w$	P_p
5.50	8.730+ 0.000= 8.730	—
3.55	18.940+ 0.000= 18.940	—
3.55	18.940+ 0.000= 18.940	—
3.00	20.540+ 5.555= 26.095	—
3.00	20.540+ 5.555= 26.095	—
0.43	28.019+ 31.512= 59.531	—
0.43	28.019+ 31.512= 59.531	—
-1.00	32.180+ 31.512= 63.692	—
-1.00	32.180+ 31.512= 63.692	23.000
-2.00	35.090+ 31.512= 66.602	27.000
-2.00	90.600+ 31.512= 122.112	27.000
-3.00	97.600+ 31.512= 129.112	31.000
-3.00	7.000+ 31.512= 38.512	31.000
-9.00	7.000+ 31.512= 38.512	55.000
-9.00	7.000+ 31.512= 38.512	85.000
-11.00	7.000+ 31.512= 38.512	93.000
-11.00	7.000+ 31.512= 38.512	93.000
-13.00	7.000+ 31.512= 38.512	101.000
-13.00	7.000+ 31.512= 38.512	170.000
-16.00	7.000+ 31.512= 38.512	182.000
-16.00	7.000+ 31.512= 38.512	165.000
-20.00	7.000+ 31.512= 38.512	181.000

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -1.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
-1.000	-111.249	135.301	102.195
-2.000	-238.845	159.773	117.870
-3.000	-459.920	187.427	186.828
-4.000	-747.349	214.558	165.209
-5.000	-1017.829	235.345	145.934
-6.000	-1269.787	251.459	127.332
-7.000	-1496.898	263.902	108.401
-8.000	-1689.275	273.308	88.507
-9.000	-1834.063	280.109	67.218
-10.000	-1855.666	283.441	15.398
-11.000	-1674.978	282.689	-36.338
-12.000	-1268.930	278.406	-88.543
-13.000	-610.981	271.003	-141.628
-14.000	512.658	258.765	-262.878

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -13.00 and -14.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-13.614	0.000	264.266	-216.393

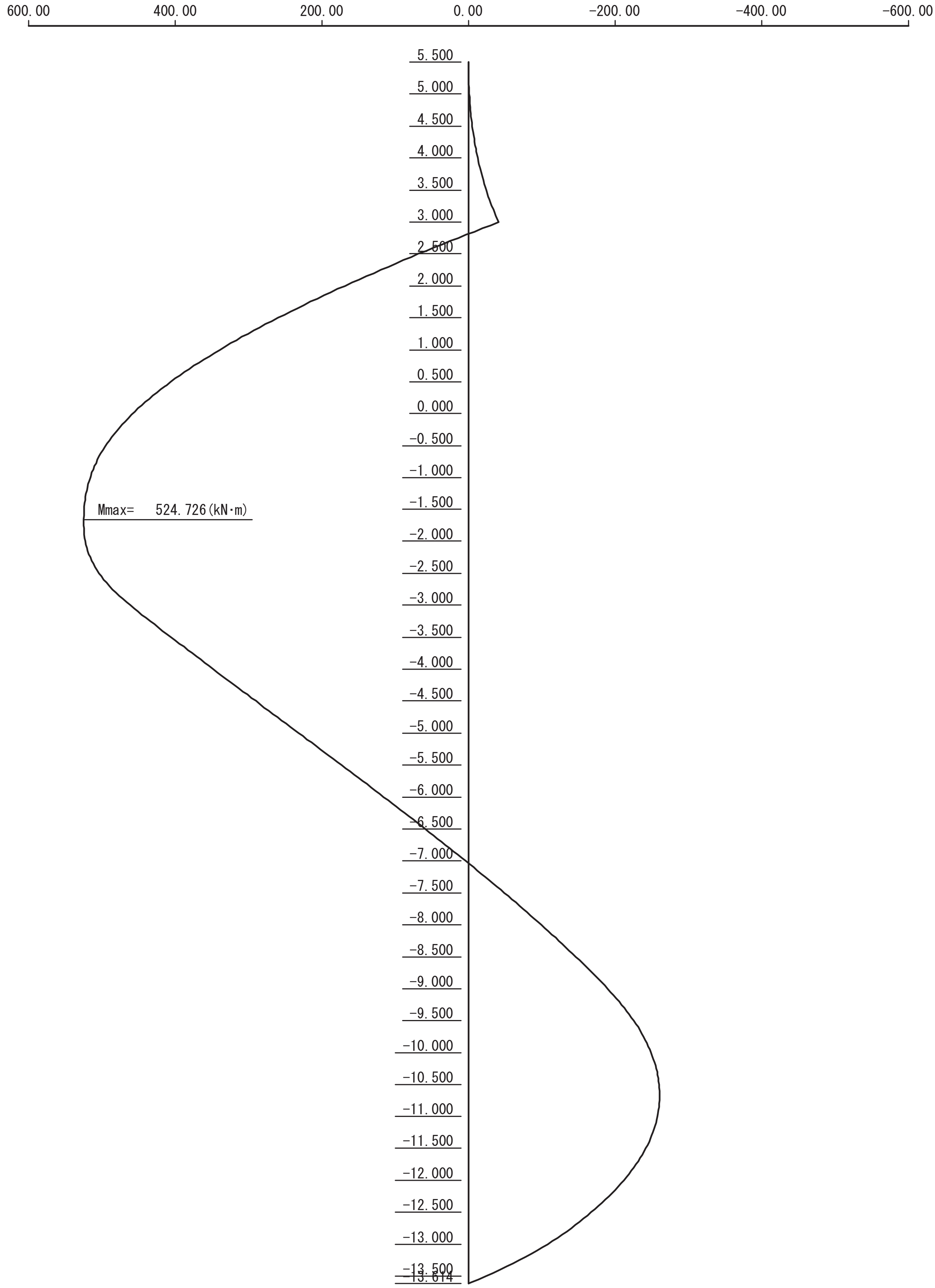
Embedded length of the pipe wall : L = 1.2 × (-1.000 + 13.614) = 15.137 m
Toe elevation : D = -1.000 – 15.137 = -16.137 m
Reaction force at tie setting point : 264.266 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	-1.200	-5.019
4.500	-5.238	-11.348
4.000	-12.766	-18.985
3.550	-23.069	-26.978
3.050	-39.196	-38.074
3.000	-41.132	-39.363
2.500	67.787	210.229
2.000	168.555	192.303
1.500	259.548	171.124
1.000	339.137	146.693
0.500	405.698	119.009
0.430	413.885	114.874
-0.070	463.820	84.744
-0.570	498.508	53.888
-1.000	515.869	26.769
-1.500	524.189	6.560
-1.600	524.645	2.550
-2.000	522.473	-13.378
-2.500	503.833	-61.309
-2.600	497.219	-70.985
-3.000	461.040	-109.990
-3.500	405.189	-113.246
-4.000	347.961	-115.502
-4.500	289.854	-116.758
-5.000	231.370	-117.014
-5.500	173.007	-116.270
-6.000	115.267	-114.526
-6.500	58.648	-111.782
-7.000	3.652	-108.038
-7.500	-49.223	-103.294
-8.000	-99.476	-97.550
-8.500	-146.606	-90.806
-9.000	-190.115	-83.062
-9.500	-225.751	-59.318
-10.000	-249.266	-34.574
-10.500	-260.158	-8.830
-11.000	-257.929	17.914
-11.500	-242.077	45.658
-12.000	-212.104	74.402
-12.500	-167.508	104.146
-13.000	-107.791	134.890
-13.500	-23.826	201.134
-13.614	0.000	216.393

Maximum bending moment : 524.726 kN-m/m
Elevation of maximum bending moment : -1.664 m
Depth of 1st steady point (moment=0) : -7.034 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

M_p = FOS×M_a

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of FOS×M_a

NO	Elev (m)	Calculation			S (kN/m)	L (m)	M (kN-m/m)	FOS×M_a (kN-m/m)
1	5.50	1/2x	8.730x	1.950	8.512	-1.850	-15.747	
2	3.55	1/2x	18.940x	1.950	18.466	-1.200	-22.159	-45.487
3	3.55	1/2x	18.940x	0.550	5.208	-0.367	-1.911	
4	3.00	1/2x	26.095x	0.550	7.176	-0.183	-1.313	-49.356
5	3.00	1/2x	26.095x	2.570	33.532	0.857	28.737	
6	0.43	1/2x	59.531x	2.570	76.497	1.713	131.039	142.375
7	0.43	1/2x	59.531x	1.430	42.565	3.047	129.696	
8	-1.00	1/2x	63.692x	1.430	45.540	3.523	160.437	490.535
9	-1.00	1/2x	63.692x	1.000	31.846	4.333	137.989	
10	-2.00	1/2x	66.602x	1.000	33.301	4.667	155.416	842.621
11	-2.00	1/2x	122.112x	1.000	61.056	5.333	325.612	
12	-3.00	1/2x	129.112x	1.000	64.556	5.667	365.839	1672.362
13	-3.00	1/2x	38.512x	6.000	115.536	8.000	924.288	
14	-9.00	1/2x	38.512x	6.000	115.536	10.000	1155.360	4167.940
15	-9.00	1/2x	38.512x	2.000	38.512	12.667	487.832	
16	-11.00	1/2x	38.512x	2.000	38.512	13.333	513.480	5369.514
17	-11.00	1/2x	38.512x	2.000	38.512	14.667	564.856	
18	-13.00	1/2x	38.512x	2.000	38.512	15.333	590.504	6755.946
19	-13.00	1/2x	38.512x	3.000	57.768	17.000	982.056	
20	-16.00	1/2x	38.512x	3.000	57.768	18.000	1039.824	9182.202
21	-16.00	1/2x	38.512x	4.000	77.024	20.333	1566.129	
22	-20.00	1/2x	38.512x	4.000	77.024	21.667	1668.879	13064.212

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

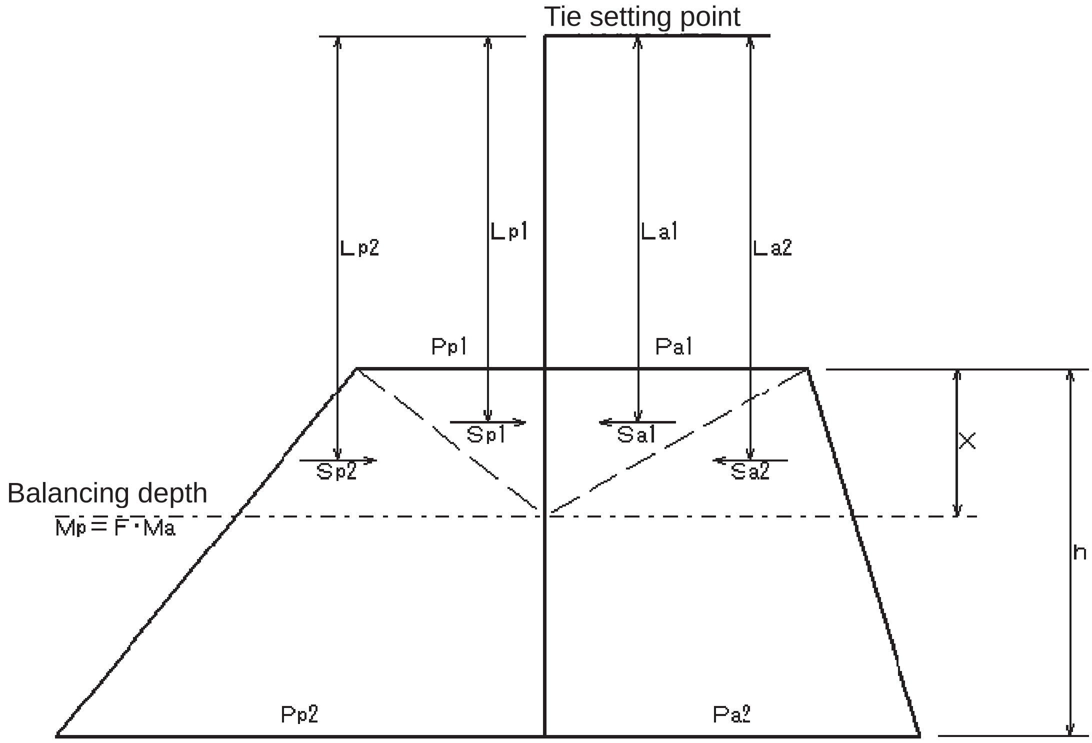
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-1.00	1/2x 23.000x 1.000	11.500	4.333	49.830	
2	-2.00	1/2x 27.000x 1.000	13.500	4.667	63.004	112.834
3	-2.00	1/2x 27.000x 1.000	13.500	5.333	71.996	
4	-3.00	1/2x 31.000x 1.000	15.500	5.667	87.838	272.668
5	-3.00	1/2x 31.000x 6.000	93.000	8.000	744.000	
6	-9.00	1/2x 55.000x 6.000	165.000	10.000	1650.000	2666.668
7	-9.00	1/2x 85.000x 2.000	85.000	12.667	1076.695	
8	-11.00	1/2x 93.000x 2.000	93.000	13.333	1239.969	4983.332
9	-11.00	1/2x 93.000x 2.000	93.000	14.667	1364.031	
10	-13.00	1/2x 101.000x 2.000	101.000	15.333	1548.633	7895.996
11	-13.00	1/2x 170.000x 3.000	255.000	17.000	4335.000	
12	-16.00	1/2x 182.000x 3.000	273.000	18.000	4914.000	17144.996
13	-16.00	1/2x 165.000x 4.000	330.000	20.333	6709.890	
14	-20.00	1/2x 181.000x 4.000	362.000	21.667	7843.454	31698.340

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1}X}{2}, \quad L_{a(p)1} = L + \frac{1}{3}X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \frac{P_{a(p)2} - P_{a(p)1}}{h} X \right] X}{2} \;,\quad L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

$M_{a(p)}$	: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)
$M_{a(p)1}$	: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)
$M_{a(p)1'}$	: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$M_{a(p)2'}$	: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$S_{a(p)1}$	: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$S_{a(p)2}$	: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$L_{a(p)1}$	: the arm length of $S_{a(p)1}$ from the tie setting point (m)
$L_{a(p)2}$	: the arm length of $S_{a(p)2}$ from the tie setting point (m)
$P_{a(p)1}$	: the active (passive) side pressure at the top elevation of the soil layer (kPa)
$P_{a(p)1}$	: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)
h	: the thickness of the soil layer (m)
L	: the vertical distance from the tie setting point to the top elevation of the soil layer (m)
X	: the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -11.00 m	FOS×M_{a1} = 5369.514	> M_{p1} = 4983.332
at -13.00 m	FOS×M_{a2} = 6755.946	< M_{p2} = 7895.996

[Moment on active side]

$$S_{a1} = \frac{38.512X}{2} = 19.256X \ , \quad L_{a1} = 14.000 + \frac{1}{3}X$$

$$M_{a1'} = 6.419X^2 + 269.584X$$

$$S_{a2} = \frac{\left[38.512 + \frac{38.512 - 38.512}{2.000}X\right]X}{2} = 0.000X^2 + 19.256X \ , \quad L_{a2} = 14.000 + \frac{2}{3}X$$

$$M_{a2'} = 0.000X^3 + 12.837X^2 + 269.584X$$

$$M_a = 0.000X^3 + 19.256X^2 + 539.168X + 4474.595$$

[Moment on passive side]

$$S_{p1} = \frac{93.000X}{2} = 46.500X \ , \quad L_{p1} = 14.000 + \frac{1}{3}X$$

$$M_{p1'} = 15.500X^2 + 651.000X$$

$$S_{p2} = \frac{\left[93.000 + \frac{101.000 - 93.000}{2.000}X\right]X}{2} = 2.000X^2 + 46.500X \ , \quad L_{p2} = 14.000 + \frac{2}{3}X$$

$$M_{p2'} = 1.333X^3 + 59.000X^2 + 651.000X$$

$$M_p = 1.333X^3 + 74.500X^2 + 1302.000X + 4983.332$$

[Balancing depth]

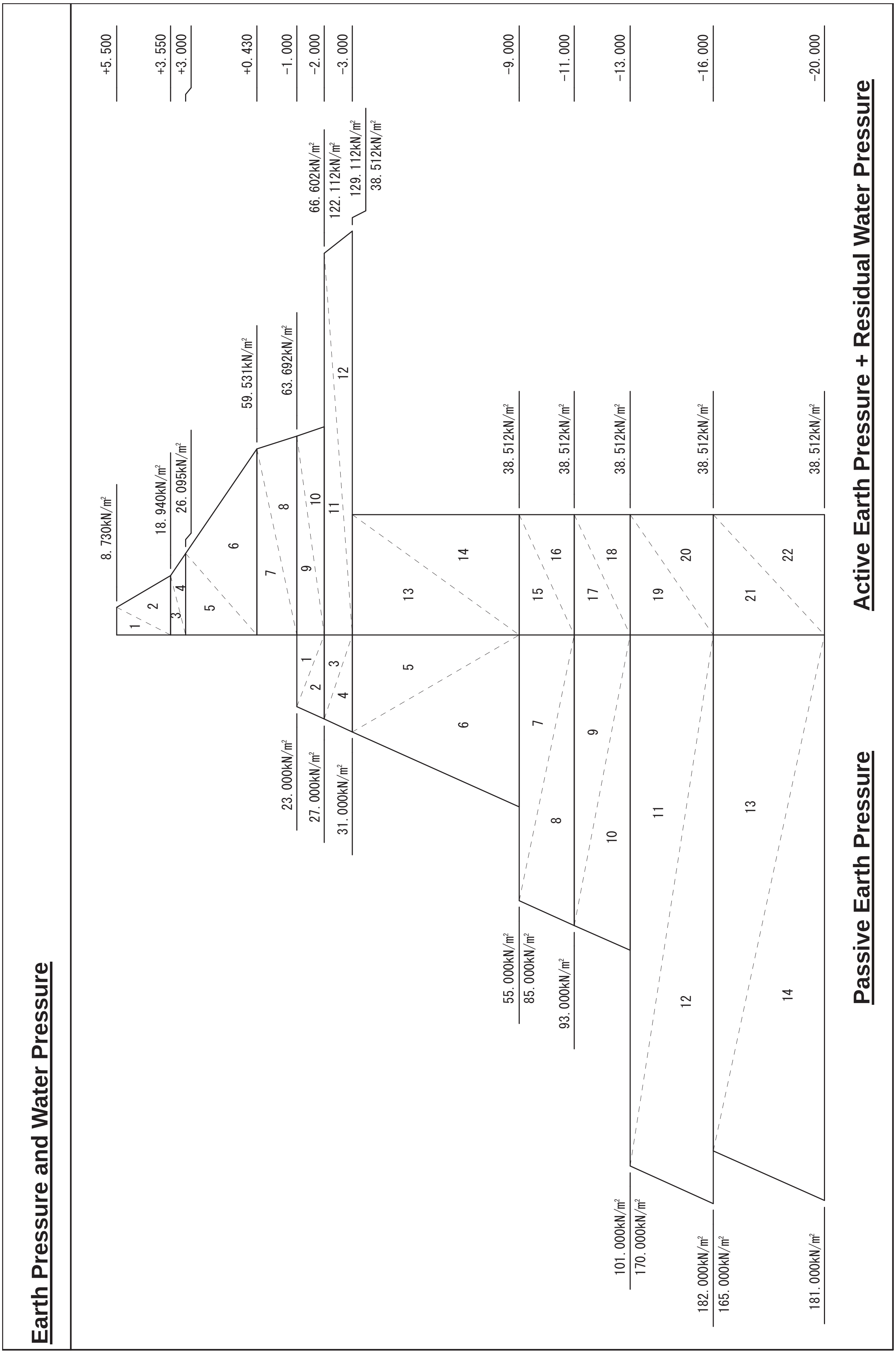
$$FOS \cdot M_a = M_p$$

$$1.2 \times (0.000X^3 + 19.256X^2 + 539.168X + 4474.595)$$

$$= 1.333X^3 + 74.500X^2 + 1302.000X + 4983.332$$

X= 0.564 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -11.000 – 0.564 = -11.564 m


Earth Pressure and Water Pressure
Active Earth Pressure + Residual Water Pressure
Passive Earth Pressure
+5.500
+3.550
+3.000
+0.430
-1.000
-2.000
-3.000
-9.000
-11.000
-13.000
-16.000
-20.000
8.730kN/m²
18.940kN/m²
26.095kN/m²
59.531kN/m²
63.692kN/m²
66.602kN/m²
122.112kN/m²
129.112kN/m²
38.512kN/m²
23.000kN/m²
27.000kN/m²
31.000kN/m²
55.000kN/m²
85.000kN/m²
93.000kN/m²
101.000kN/m²
170.000kN/m²
182.000kN/m²
165.000kN/m²
181.000kN/m²

(2) Calculation of maximum bending moment

1) External forces

Elev (m)	P_a+P_w (kN/m^2)	P_p (kN/m^2)	P_a-P_p (kN/m^2)
5.50 3.55	8.730 18.940	——— ———	8.730 18.940
3.55 3.00	18.940 26.095	——— ———	18.940 26.095
3.00 0.43	26.095 59.531	——— ———	26.095 59.531
0.43 -1.00	59.531 63.692	——— ———	59.531 63.692
-1.00 -2.00	63.692 66.602	23.000 27.000	40.692 39.602
-2.00 -3.00	122.112 129.112	27.000 31.000	95.112 98.112
-3.00 -9.00	38.512 38.512	31.000 55.000	7.512 -16.488
-9.00 -11.00	38.512 38.512	85.000 93.000	-46.488 -54.488
-11.00 -13.00	38.512 38.512	93.000 101.000	-54.488 -62.488
-13.00 -16.00	38.512 38.512	170.000 182.000	-131.488 -143.488
-16.00 -20.00	38.512 38.512	165.000 181.000	-126.488 -142.488

2) Virtual seabed level
The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -3.00 m P_{a1} = 38.512 > P_{p1} = 31.000
at -9.00 m P_{a2} = 38.512 < P_{p2} = 55.000

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

EL_{top} : the top elevation of the soil layer in question (m)

P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)

P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)

P_{p1} : the passive earth pressure at the top of the soil layer (kPa)

P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)

h : the thickness of the soil layer (m)

$$X = -3.00 - \frac{6.00 \times (31.000 - 38.512)}{(38.512 - 38.512) - (55.000 - 31.000)} = -4.878m$$

Accordingly, the virtual seabed level is obtained as -4.878m.

3) Moment about tie setting point

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	8.730x	1.950	8.512	-1.850	-15.747
2	1/2x	18.940x	1.950	18.466	-1.200	-22.159
3	1/2x	18.940x	0.550	5.208	-0.367	-1.911
4	1/2x	26.095x	0.550	7.176	-0.183	-1.313
5	1/2x	26.095x	2.570	33.532	0.857	28.737
6	1/2x	59.531x	2.570	76.497	1.713	131.039
7	1/2x	59.531x	1.430	42.565	3.047	129.696
8	1/2x	63.692x	1.430	45.540	3.523	160.437
9	1/2x	40.692x	1.000	20.346	4.333	88.159
10	1/2x	39.602x	1.000	19.801	4.667	92.411
11	1/2x	95.112x	1.000	47.556	5.333	253.616
12	1/2x	98.112x	1.000	49.056	5.667	278.000
13	1/2x	7.512x	1.878	7.054	6.626	46.740
Total				381.309	———	1167.705

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

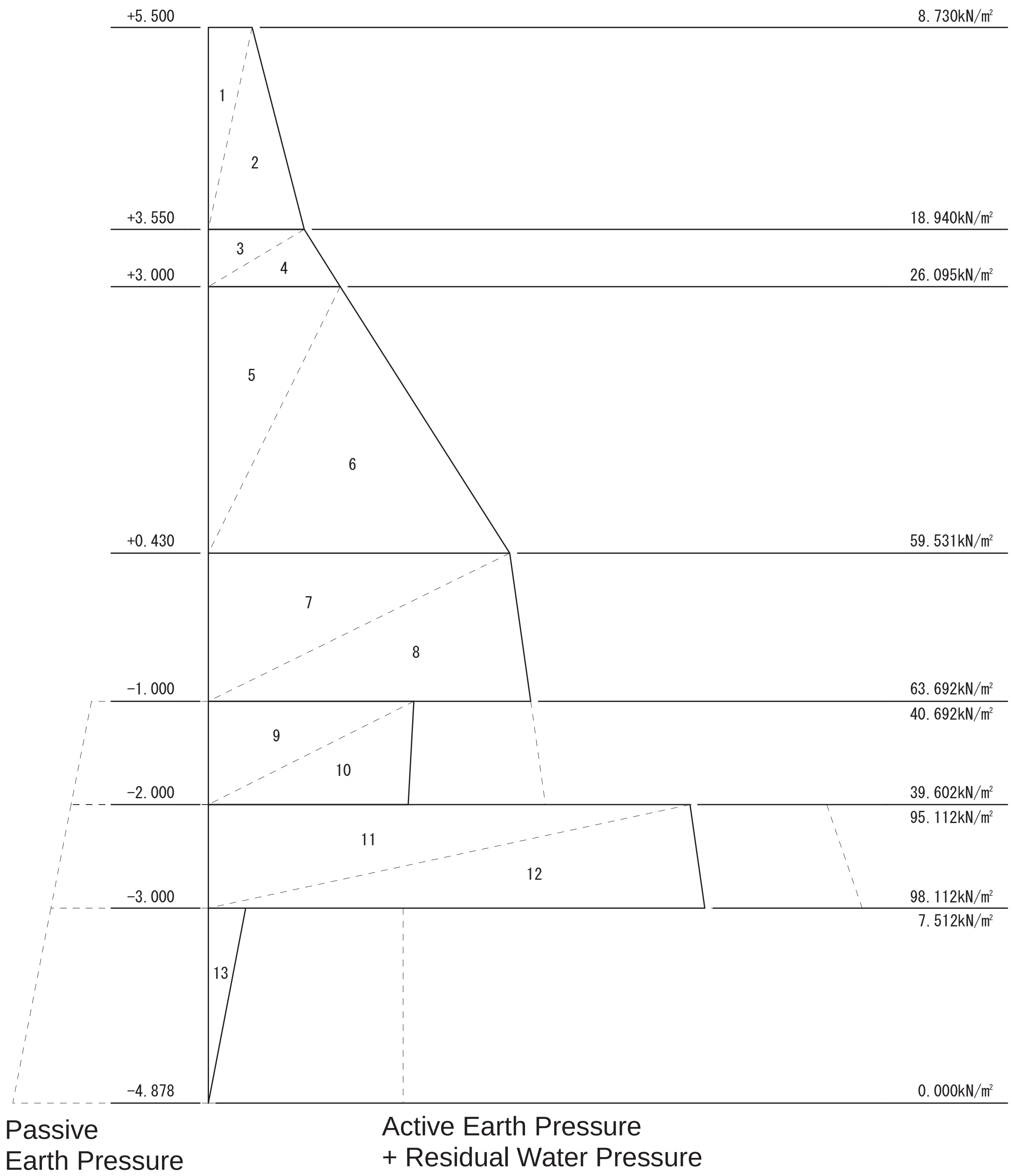
4) Reaction forces

Distance between supports : L_T = 3.000 – (-4.878) = 7.878 m

Reaction at virtual seabed : $R_0 = \frac{\Sigma M}{L_T} = \frac{1167.706}{7.878} = 148.224 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 381.309 - 148.224 = 233.085 kN/m$

External Force Diagram



5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 3.55	8.512 18.466	26.978		-26.978
3.55 3.00	5.208 7.176	39.362	233.085	193.723
3.00 0.43	33.532 76.497	149.391	233.085	83.694
0.43 -1.00	42.565 45.540	237.496	233.085	-4.411
-1.00 -2.00	20.346 19.801	277.643	233.085	-44.558
-2.00 -3.00	47.556 49.056	374.255	233.085	-141.170
-3.00 -4.88	7.054 0.000	381.309	233.085	-148.224

Shear force Q = A_p - ∑S

The above table suggests that the shear force zero point exists in between 0.430m and -1.000m.

$$Q = 83.694 - \frac{[59.531 + (59.531 + 2.910X)]X}{2} = 0$$

X = 1.361 m

Shear force zero point : DL = +0.43 – 1.361 = -0.931m

6) Calculation of moment

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	8.730x	1.950	-8.512	5.781	-49.208
2	1/2x	18.940x	1.950	-18.466	5.131	-94.749
3	1/2x	18.940x	0.550	-5.208	4.298	-22.384
4	1/2x	26.095x	0.550	-7.176	4.114	-29.522
5	1/2x	26.095x	2.570	-33.532	3.074	-103.077
6	1/2x	59.531x	2.570	-76.497	2.218	-169.670
7	1/2x	59.531x	1.361	-40.511	0.907	-36.743
8	1/2x	63.491x	1.361	-43.206	0.454	-19.616
Total				———	———	-524.969

where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

7) Maximum bending moment

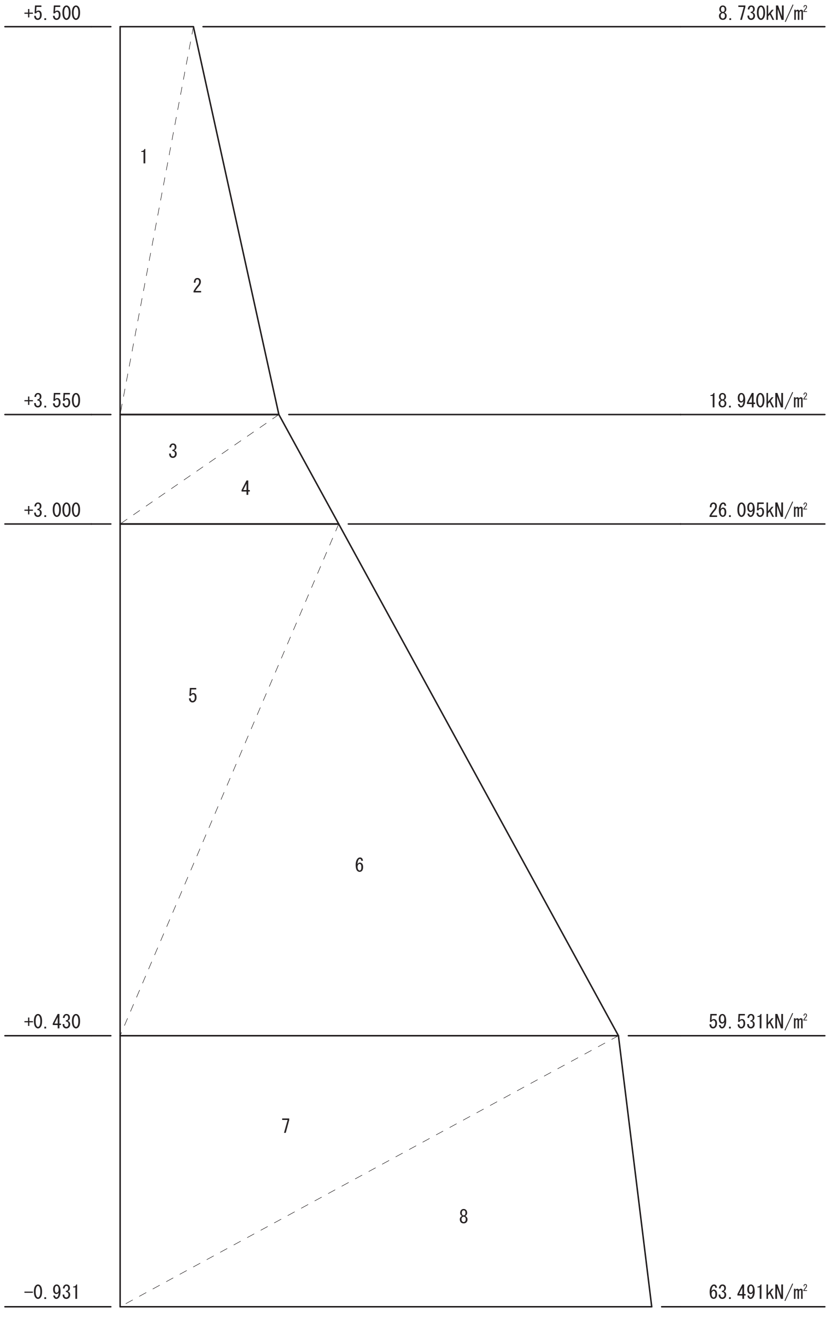
- Distance of the shear zero point to the tie setting point

  h = 3.000 – (-0.931) = 3.931 m

- Maximum bending moment

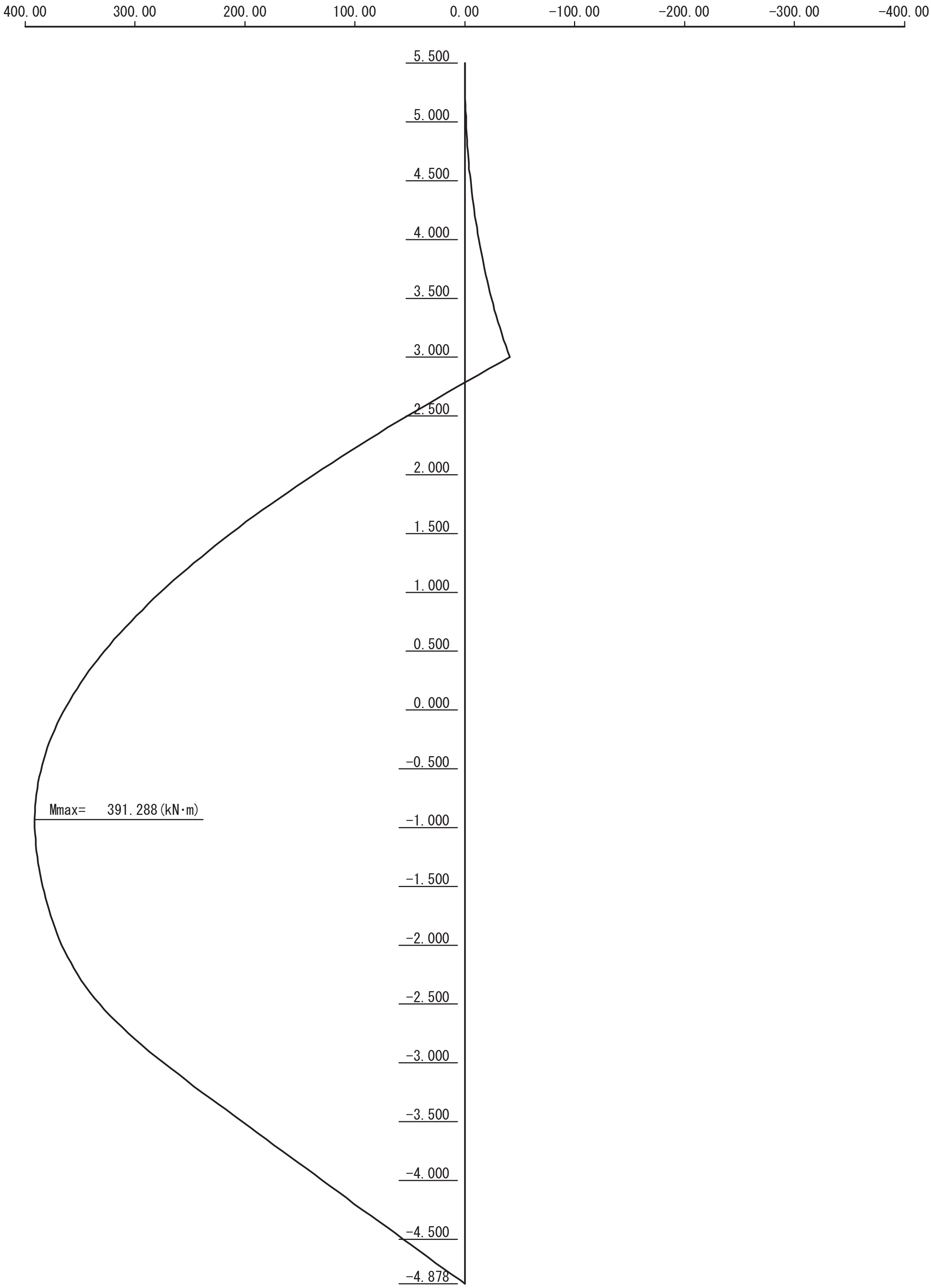
  $M_{max} = A_p \times h + \sum M = 233.085 \times 3.931 - 524.969 = 391.288$ kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type : ϕ800 × t10 (P-T joint)

Modulus of elasticity : E = 200.0 kN/mm^2
Moment of inertia : I = 193647 cm^4
Section modulus : Z = 4841 cm^3

Section property (per 1m) before corrosion
- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 197599 cm^4/m
- Section modulus : Z = 4940 cm^3/m

Section property (per 1m) after corrosion
- Design life time : 50 years
- Effect of cathodic protection : 90%
- Corrosion rate : 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance : t = 0.030 × 50 years = 1.50 mm

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 166997 cm^4/m
- Section modulus : Z = 4191 cm^3/m

(2) Embedded depth of pipe wall
Toe level of the pipe wall is obtained as follows:
- Deflection curve method : -16.137 m --- adopted
- Free earth support method : -11.564 m

Therefore, the minimum length of the pipe wall is;
L = 3.500 – (-16.137) = 19.637m → 20.000 m

Accordingly the design toe level of the pipe wall is;
EL = +3.500 – 20.000 = -16.500 m

(3) Stress on pipe wall section
Maximum bending moment on the pipe wall is as follows:
- Deflection curve method : 524.726 kN-m/m --- adopted
- Free earth support method : 391.288 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{524.726\times10^6}{4191\times10^3} = 125.2MPa \quad \leq \quad \sigma_a = 140MPa \ \ .... \ OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

T	is the tension force on tie wire (kN/wire)
A_p	is the reaction force of the pipe wall at tie setting point (kN/m)
L	is the spacing of the tie wire (m)
θ_1	is the vertical angle of the tie wire to horizontal (deg.)
θ_2	is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 264.266 kN-m/m --- adopted
- Free earth support method : 233.085 kN-m/m

T = 264.266 × 1.960 × sec(0.000) × sec (0.000) = 517.961 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 517.961 × 3.8 = 1968.252 kN/wire

Tie wire shall have minimum tensile strength of 1969 kN.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max} is the maximum bending moment on the waling beam (kN-m)
T is the tension force on tie wire (kN/wire)
L is the spacing of the tie wire (m)

$$M_{maz} = \frac{517.961 \times 1.960}{10.0} = 101.520 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[250×90×11.0×14.5

Steel grade : SS400
Section modulus : Z = 374.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \ \leq \ \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{101.520 \times 10^6}{2 \times 374.0 \times 10^3} = 135.7 MPa \quad \leq \quad \sigma_a = 140 MPa \ \text{.... } OK$$

Output of Design Software for Anchor Wall (After Completion)
– Revetment Block c

1. Design Conditions

1-1 Dimensions

Ground elevation	+5.50 m
Top of cope concrete	+5.50 m
Top of pile wall	+3.50 m
Tie elevation	+3.00 m
Seabed elevation	-1.00 m
Angle of seabed slope	18.4°

1-2 Tide Levels

H.W.L	+3.55 m
L.W.L	+0.43 m

1-3 Residual Water Level

R.W.L	+3.55 m

1-4 Base Elevation of Cohesion Increment +0.00 m (not used)

1-5 Surcharge Load	(Active side)	30 kPa
	(Passive side)	0 kPa

1-6 Unit Weight of Water $10.10\ kN/m^3$

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

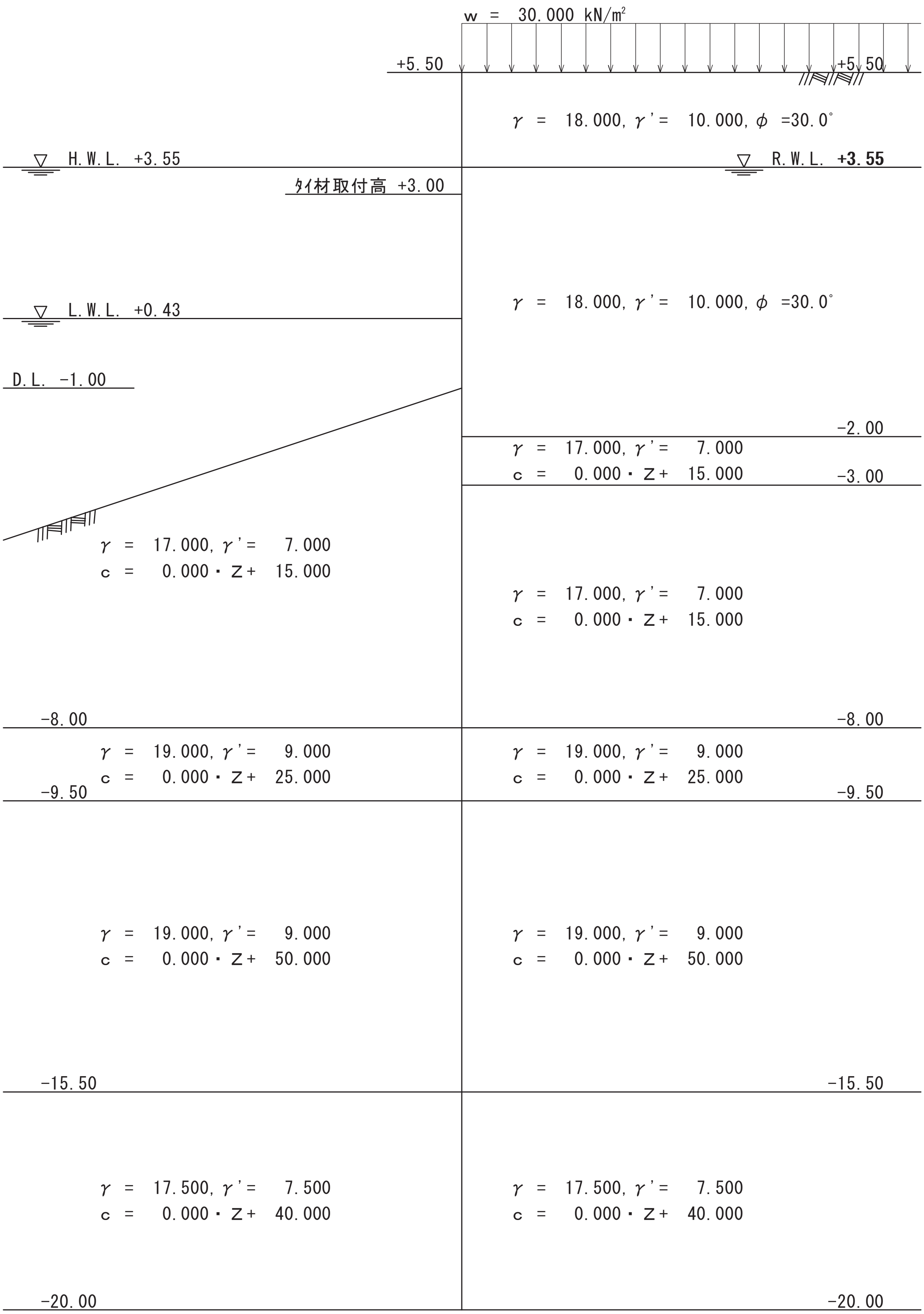
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	:	Deflection Curve Method
Calculation Method 2	:	Free Earth Support Method
Factor of Safety	:	FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
5.50 3.55	1.95	8.730 18.940
3.55 3.00	0.55	18.940 20.540
3.00 -2.00	5.00	20.540 35.090
-2.00 -3.00	1.00	90.600 97.600
-3.00 -8.00	5.00	7.000 7.000
-8.00 -9.50	1.50	7.000 7.000
-9.50 -11.00	1.50	7.000 7.000
-11.00 -15.50	4.50	7.000 7.000
-15.50 -20.00	4.50	7.000 7.000

(2) Residual water pressure

$p_w = \gamma_w \times h_w$

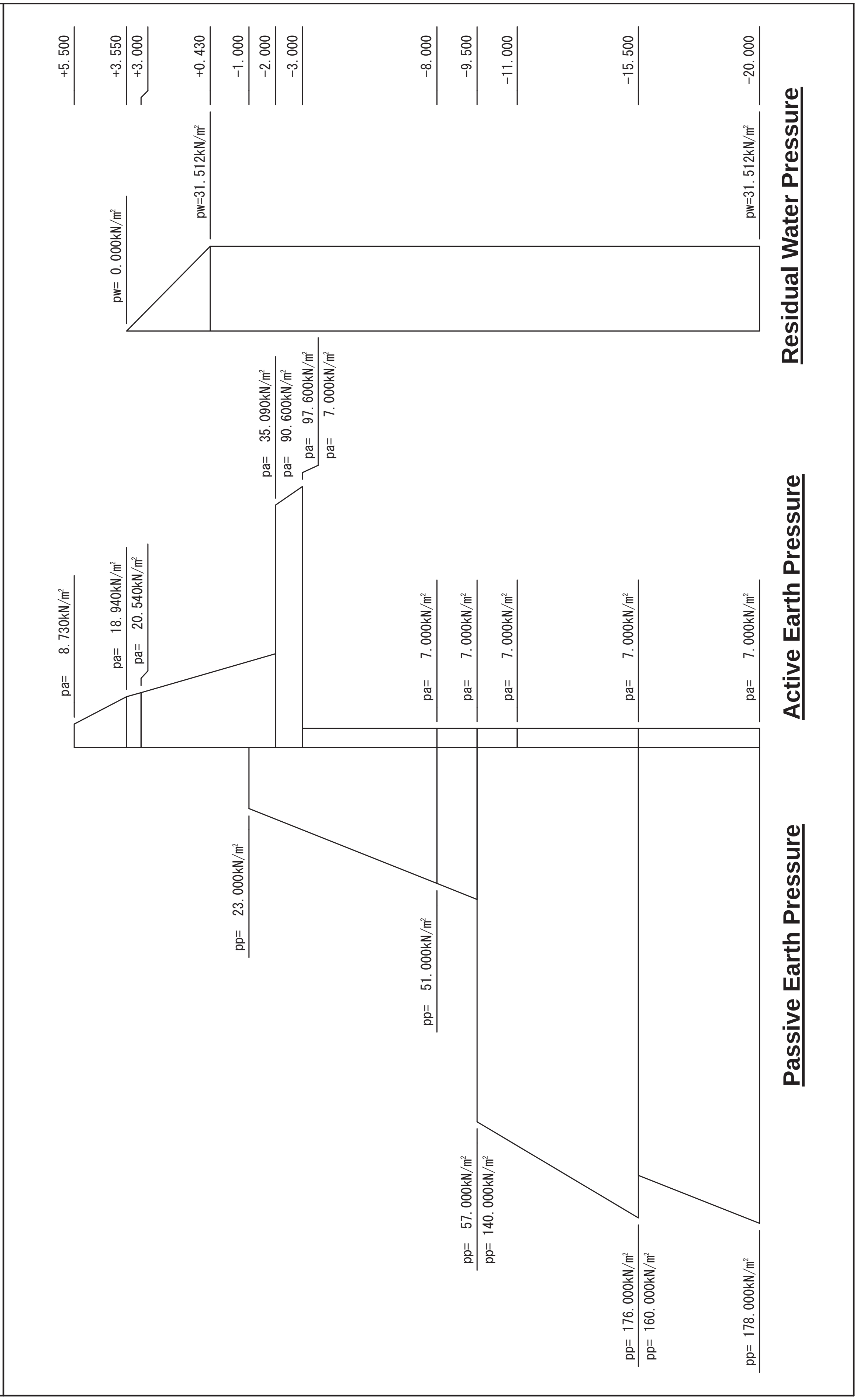
where; p_w is the residual water pressure (kPa)
h_w is the height of the tidal lag (m)
γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-1.00 -8.00	7.00	23.000 51.000
-8.00 -9.50	1.50	51.000 57.000
-9.50 -15.50	6.00	140.000 176.000
-15.50 -20.00	4.50	160.000 178.000

Earth Pressure and Water Pressure



(4) Summary of Forces on the Wall

Elev (m)	Active side (kPa) $P_a + P_w$	Passive side(kPa) P_p
5.50 3.55	8.730+ 0.000= 8.730 18.940+ 0.000= 18.940	——— ———
3.55 3.00	18.940+ 0.000= 18.940 20.540+ 5.555= 26.095	——— ———
3.00 0.43	20.540+ 5.555= 26.095 28.019+ 31.512= 59.531	——— ———
0.43 -1.00	28.019+ 31.512= 59.531 32.180+ 31.512= 63.692	——— ———
-1.00 -2.00	32.180+ 31.512= 63.692 35.090+ 31.512= 66.602	23.000 27.000
-2.00 -3.00	90.600+ 31.512= 122.112 97.600+ 31.512= 129.112	27.000 31.000
-3.00 -8.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	31.000 51.000
-8.00 -9.50	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	51.000 57.000
-9.50 -11.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	140.000 149.000
-11.00 -15.50	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	149.000 176.000
-15.50 -20.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	160.000 178.000

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -1.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
-1.000	-111.249	135.301	102.195
-2.000	-238.845	159.773	117.870
-3.000	-459.920	187.428	186.827
-4.000	-747.349	214.559	165.208
-5.000	-1017.829	235.345	145.934
-6.000	-1269.787	251.459	127.332
-7.000	-1496.898	263.902	108.400
-8.000	-1689.275	273.308	88.507
-9.000	-1834.063	280.108	67.219
-10.000	-1872.340	283.792	3.297
-11.000	-1521.256	280.224	-100.623
-12.000	-703.050	269.766	-203.653
-13.000	623.948	253.335	-306.710

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -12.00 and -13.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-12.579	0.000	260.932	-263.241

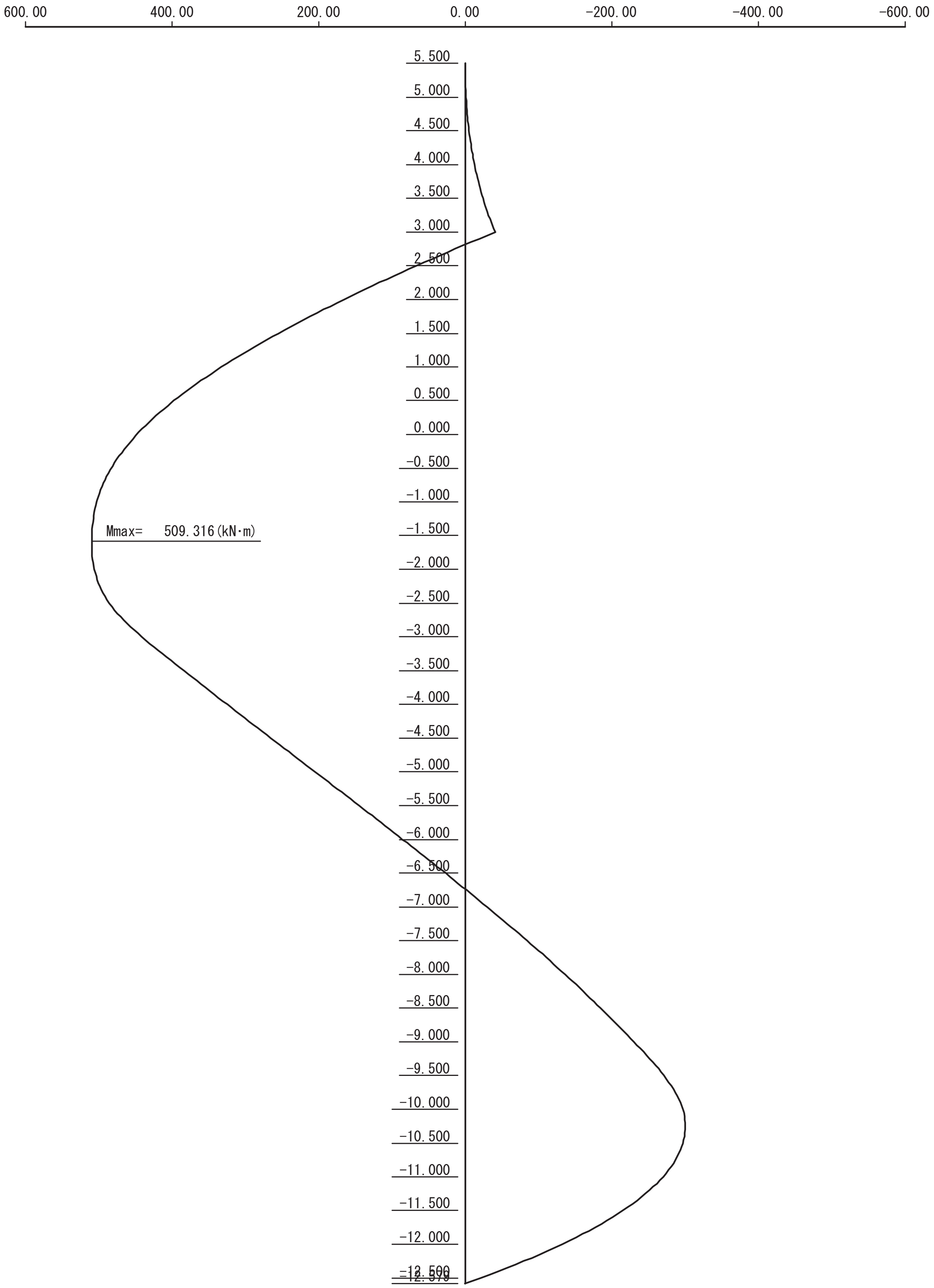
Embedded length of the pipe wall : L = 1.2 × (-1.000 + 12.579) = 13.895 m
Toe elevation : D = -1.000 – 13.895 = -14.895 m
Reaction force at tie setting point : 260.931 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	-1.200	-5.019
4.500	-5.238	-11.348
4.000	-12.766	-18.985
3.550	-23.069	-26.978
3.050	-39.196	-38.074
3.000	-41.132	-39.363
2.500	66.120	206.895
2.000	165.221	188.969
1.500	254.547	167.790
1.000	332.469	143.359
0.500	397.363	115.675
0.430	405.316	111.540
-0.070	453.584	81.410
-0.570	486.606	50.554
-1.000	502.533	23.435
-1.500	509.186	3.226
-2.000	505.803	-16.712
-2.500	485.496	-64.643
-3.000	441.036	-113.324
-3.500	383.518	-116.580
-4.000	324.623	-118.836
-4.500	264.849	-120.092
-5.000	204.698	-120.348
-5.500	144.668	-119.604
-6.000	85.261	-117.860
-6.500	26.975	-115.116
-7.000	-29.688	-111.372
-7.500	-84.230	-106.628
-8.000	-136.150	-100.884
-8.500	-184.947	-94.140
-9.000	-230.123	-86.396
-9.500	-271.176	-77.652
-10.000	-297.191	-26.158
-10.500	-297.084	26.836
-11.000	-270.105	81.330
-11.500	-215.504	137.324
-12.000	-132.530	194.818
-12.500	-20.435	253.812
-12.579	0.000	263.241

Maximum bending moment : 509.316 kN-m/m
Elevation of maximum bending moment : -1.580 m
Depth of 1st steady point (moment=0) : -6.736 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

$$M_p = FOS \times M_a$$

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of $FOS \times M_a$

NO	Elev (m)	Calculation			S (kN/m)	L (m)	M (kN-m/m)	$FOS \times M_a$ (kN-m/m)
1	5.50	1/2x	8.730x	1.950	8.512	-1.850	-15.747	
2	3.55	1/2x	18.940x	1.950	18.466	-1.200	-22.159	-45.487
3	3.55	1/2x	18.940x	0.550	5.208	-0.367	-1.911	
4	3.00	1/2x	26.095x	0.550	7.176	-0.183	-1.313	-49.356
5	3.00	1/2x	26.095x	2.570	33.532	0.857	28.737	
6	0.43	1/2x	59.531x	2.570	76.497	1.713	131.039	142.375
7	0.43	1/2x	59.531x	1.430	42.565	3.047	129.696	
8	-1.00	1/2x	63.692x	1.430	45.540	3.523	160.437	490.535
9	-1.00	1/2x	63.692x	1.000	31.846	4.333	137.989	
10	-2.00	1/2x	66.602x	1.000	33.301	4.667	155.416	842.621
11	-2.00	1/2x	122.112x	1.000	61.056	5.333	325.612	
12	-3.00	1/2x	129.112x	1.000	64.556	5.667	365.839	1672.362
13	-3.00	1/2x	38.512x	5.000	96.280	7.667	738.179	
14	-8.00	1/2x	38.512x	5.000	96.280	9.333	898.581	3636.474
15	-8.00	1/2x	38.512x	1.500	28.884	11.500	332.166	
16	-9.50	1/2x	38.512x	1.500	28.884	12.000	346.608	4451.003
17	-9.50	1/2x	38.512x	1.500	28.884	13.000	375.492	
18	-11.00	1/2x	38.512x	1.500	28.884	13.500	389.934	5369.514
19	-11.00	1/2x	38.512x	4.500	86.652	15.500	1343.106	
20	-15.50	1/2x	38.512x	4.500	86.652	17.000	1473.084	8748.942
21	-15.50	1/2x	38.512x	4.500	86.652	20.000	1733.040	
22	-20.00	1/2x	38.512x	4.500	86.652	21.500	1863.018	13064.212

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

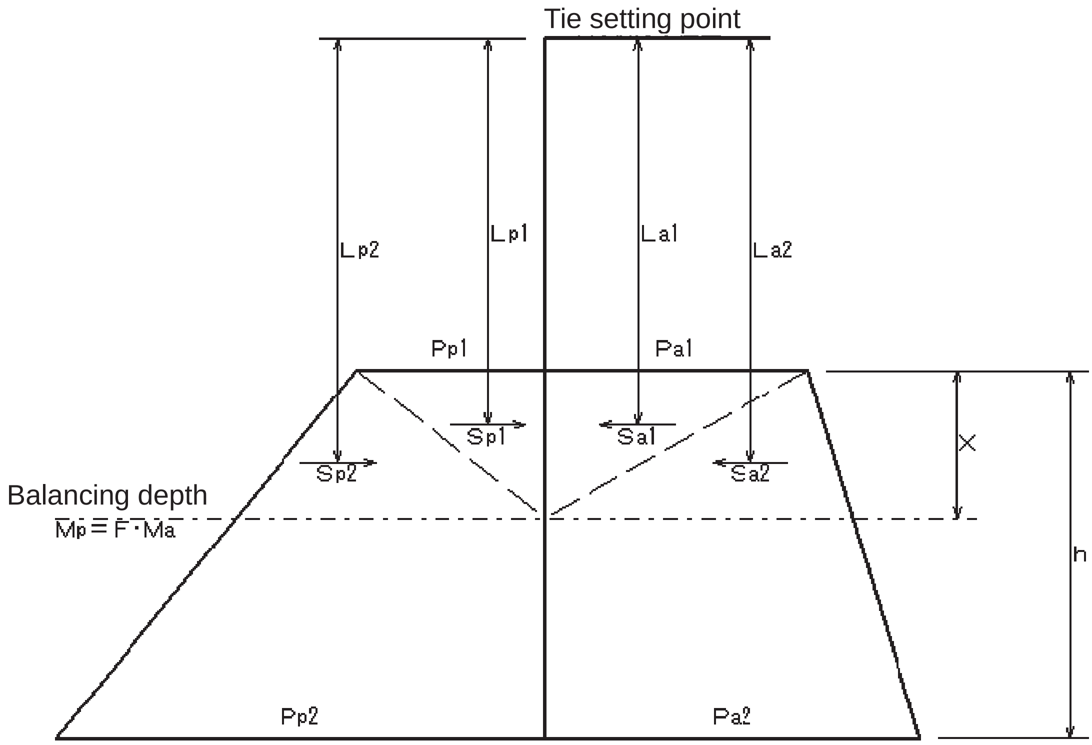
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation			S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-1.00	1/2x	23.000x	1.000	11.500	4.333	49.830	
2	-2.00	1/2x	27.000x	1.000	13.500	4.667	63.004	112.834
3	-2.00	1/2x	27.000x	1.000	13.500	5.333	71.996	
4	-3.00	1/2x	31.000x	1.000	15.500	5.667	87.838	272.668
5	-3.00	1/2x	31.000x	5.000	77.500	7.667	594.192	
6	-8.00	1/2x	51.000x	5.000	127.500	9.333	1189.958	2056.818
7	-8.00	1/2x	51.000x	1.500	38.250	11.500	439.875	
8	-9.50	1/2x	57.000x	1.500	42.750	12.000	513.000	3009.693
9	-9.50	1/2x	140.000x	1.500	105.000	13.000	1365.000	
10	-11.00	1/2x	149.000x	1.500	111.750	13.500	1508.625	5883.318
11	-11.00	1/2x	149.000x	4.500	335.250	15.500	5196.375	
12	-15.50	1/2x	176.000x	4.500	396.000	17.000	6732.000	17811.693
13	-15.50	1/2x	160.000x	4.500	360.000	20.000	7200.000	
14	-20.00	1/2x	178.000x	4.500	400.500	21.500	8610.750	33622.443

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1}X}{2}, \quad L_{a(p)1} = L + \frac{1}{3}X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \frac{P_{a(p)2} - P_{a(p)1}}{h} X\right] X}{2}, \quad L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

- $M_{a(p)}$: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)
- $M_{a(p)1}$: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)
- $M_{a(p)1'}$: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
- $M_{a(p)2'}$: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
- $S_{a(p)1}$: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
- $S_{a(p)2}$: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
- $L_{a(p)1}$: the arm length of $S_{a(p)1}$ from the tie setting point (m)
- $L_{a(p)2}$: the arm length of $S_{a(p)2}$ from the tie setting point (m)
- $P_{a(p)1}$: the active (passive) side pressure at the top elevation of the soil layer (kPa)
- $P_{a(p)1}$: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)
- h : the thickness of the soil layer (m)
- L : the vertical distance from the tie setting point to the top elevation of the soil layer (m)
- X : the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -9.50 m	FOS×M_{a1} = 4451.003	> M_{p1} = 3009.693
at -11.00 m	FOS×M_{a2} = 5369.514	< M_{p2} = 5883.318

[Moment on active side]

$$S_{a1} = \frac{38.512X}{2} = 19.256X \ , \quad L_{a1} = 12.500 + \frac{1}{3}X$$

$$M_{a1'} = 6.419X^2 + 240.700X$$

$$S_{a2} = \frac{\left[38.512 + \frac{38.512 - 38.512}{1.500}X\right]X}{2} = 0.000X^2 + 19.256X \ , \quad L_{a2} = 12.500 + \frac{2}{3}X$$

$$M_{a2'} = 0.000X^3 + 12.837X^2 + 240.700X$$

$$M_a = 0.000X^3 + 19.256X^2 + 481.400X + 3709.169$$

[Moment on passive side]

$$S_{p1} = \frac{140.000X}{2} = 70.000X \ , \quad L_{p1} = 12.500 + \frac{1}{3}X$$

$$M_{p1'} = 23.333X^2 + 875.000X$$

$$S_{p2} = \frac{\left[140.000 + \frac{149.000 - 140.000}{1.500}X\right]X}{2} = 3.000X^2 + 70.000X \ , \quad L_{p2} = 12.500 + \frac{2}{3}X$$

$$M_{p2'} = 2.000X^3 + 84.167X^2 + 875.000X$$

$$M_p = 2.000X^3 + 107.500X^2 + 1750.000X + 3009.693$$

[Balancing depth]

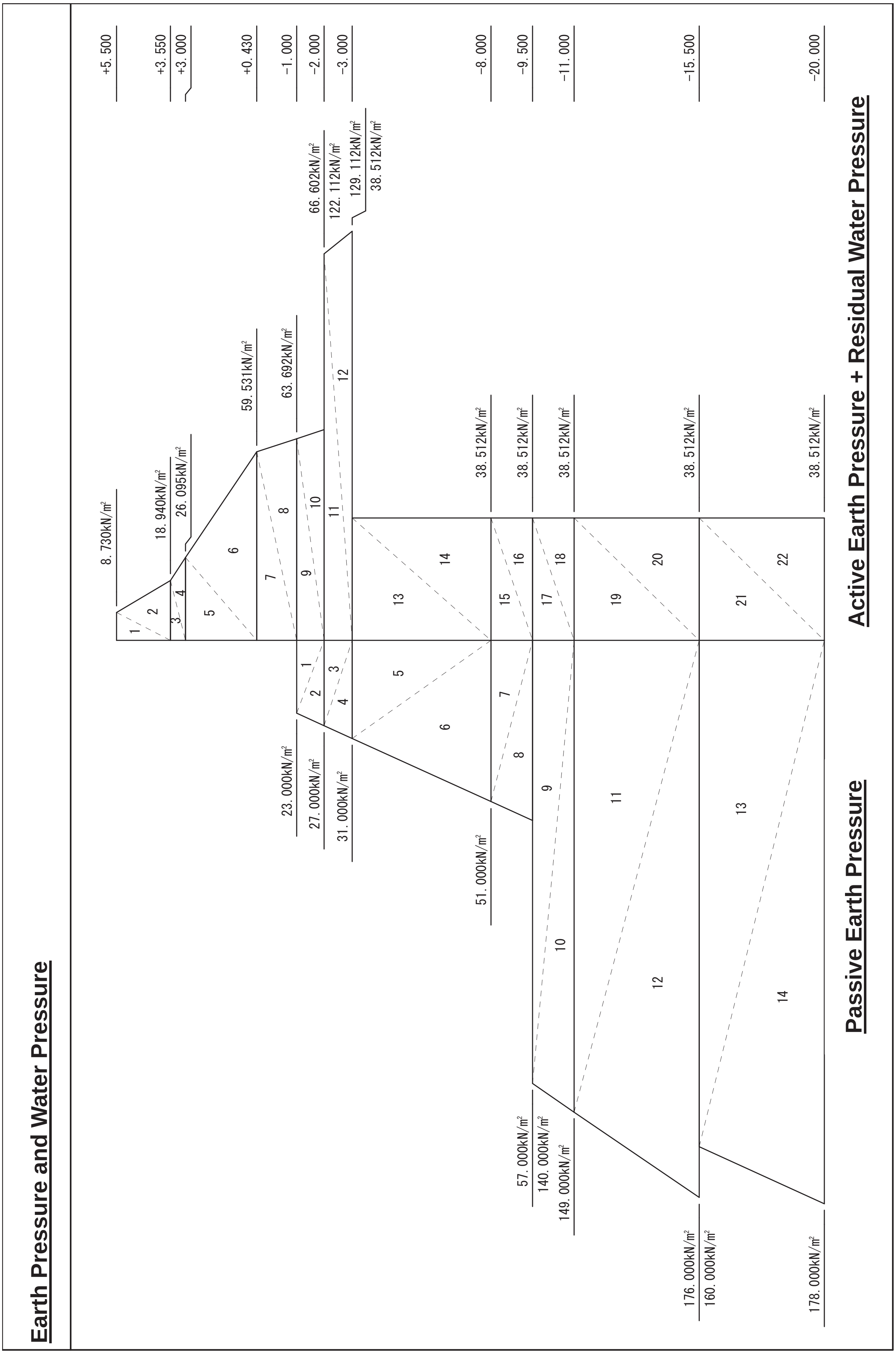
$$FOS \cdot M_a = M_p$$

$$1.2 \times (0.000X^3 + 19.256X^2 + 481.400X + 3709.169)$$

$$= 2.000X^3 + 107.500X^2 + 1750.000X + 3009.693$$

X= 1.134 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -9.500 – 1.134 = -10.634 m


Earth Pressure and Water Pressure
Active Earth Pressure + Residual Water Pressure
Passive Earth Pressure
+5. 500
+3. 550
+3. 000
+0. 430
-1. 000
-2. 000
-3. 000
-8. 000
-9. 500
-11. 000
-15. 500
-20. 000
8. 730kN/m²
18. 940kN/m²
26. 095kN/m²
59. 531kN/m²
63. 692kN/m²
66. 602kN/m²
122. 112kN/m²
129. 112kN/m²
38. 512kN/m²
23. 000kN/m²
27. 000kN/m²
31. 000kN/m²
51. 000kN/m²
57. 000kN/m²
140. 000kN/m²
149. 000kN/m²
176. 000kN/m²
160. 000kN/m²
178. 000kN/m²

(2) Calculation of maximum bending moment

1) External forces

Elev (m)	$P_a + P_w$ (kN/m^2)	P_p (kN/m^2)	$P_a - P_p$ (kN/m^2)
5.50 3.55	8.730 18.940	——— ———	8.730 18.940
3.55 3.00	18.940 26.095	——— ———	18.940 26.095
3.00 0.43	26.095 59.531	——— ———	26.095 59.531
0.43 -1.00	59.531 63.692	——— ———	59.531 63.692
-1.00 -2.00	63.692 66.602	23.000 27.000	40.692 39.602
-2.00 -3.00	122.112 129.112	27.000 31.000	95.112 98.112
-3.00 -8.00	38.512 38.512	31.000 51.000	7.512 -12.488
-8.00 -9.50	38.512 38.512	51.000 57.000	-12.488 -18.488
-9.50 -11.00	38.512 38.512	140.000 149.000	-101.488 -110.488
-11.00 -15.50	38.512 38.512	149.000 176.000	-110.488 -137.488
-15.50 -20.00	38.512 38.512	160.000 178.000	-121.488 -139.488

2) Virtual seabed level
The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -3.00 m $P_{a1} = 38.512 > P_{p1} = 31.000$
at -8.00 m $P_{a2} = 38.512 < P_{p2} = 51.000$

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

EL_{top} : the top elevation of the soil layer in question (m)

P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)

P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)

P_{p1} : the passive earth pressure at the top of the soil layer (kPa)

P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)

h : the thickness of the soil layer (m)

$$X = -3.00 - \frac{5.00 \times (31.000 - 38.512)}{(38.512 - 38.512) - (51.000 - 31.000)} = -4.878m$$

Accordingly, the virtual seabed level is obtained as -4.878m.

3) Moment about tie setting point

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	8.730x	1.950	8.512	-1.850	-15.747
2	1/2x	18.940x	1.950	18.466	-1.200	-22.159
3	1/2x	18.940x	0.550	5.208	-0.367	-1.911
4	1/2x	26.095x	0.550	7.176	-0.183	-1.313
5	1/2x	26.095x	2.570	33.532	0.857	28.737
6	1/2x	59.531x	2.570	76.497	1.713	131.039
7	1/2x	59.531x	1.430	42.565	3.047	129.696
8	1/2x	63.692x	1.430	45.540	3.523	160.437
9	1/2x	40.692x	1.000	20.346	4.333	88.159
10	1/2x	39.602x	1.000	19.801	4.667	92.411
11	1/2x	95.112x	1.000	47.556	5.333	253.616
12	1/2x	98.112x	1.000	49.056	5.667	278.000
13	1/2x	7.512x	1.878	7.054	6.626	46.740
Total				381.309	———	1167.705

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

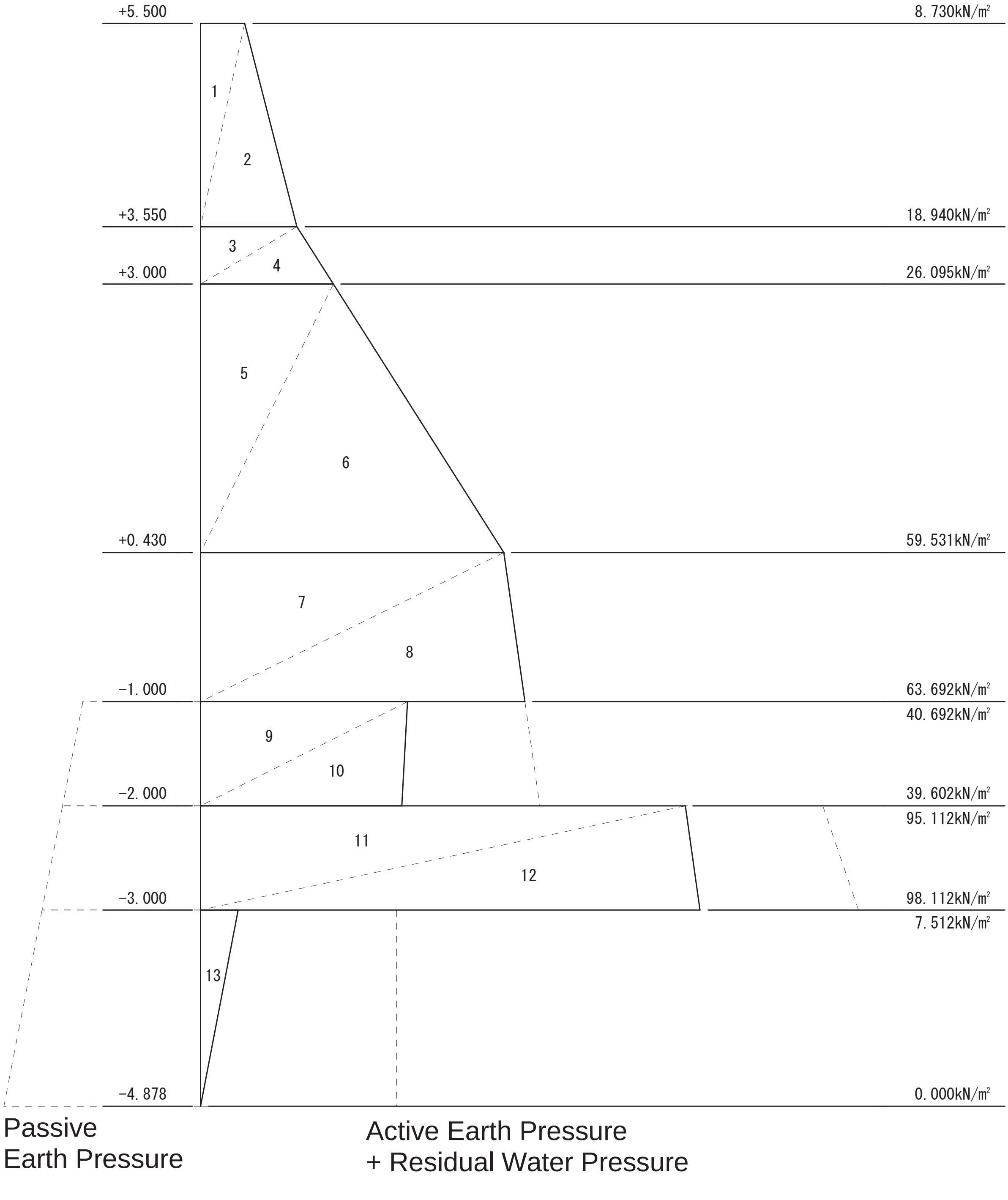
4) Reaction forces

Distance between supports : L_T = 3.000 – (-4.878) = 7.878 m

Reaction at virtual seabed : $R_0 = \frac{\Sigma M}{L_T} = \frac{1167.705}{7.878} = 148.224 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 381.309 - 148.224 = 233.085 kN/m$

External Force Diagram



5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 3.55	8.512 18.466	26.978		-26.978
3.55 3.00	5.208 7.176	39.362	233.085	193.723
3.00 0.43	33.532 76.497	149.391	233.085	83.694
0.43 -1.00	42.565 45.540	237.496	233.085	-4.411
-1.00 -2.00	20.346 19.801	277.643	233.085	-44.558
-2.00 -3.00	47.556 49.056	374.255	233.085	-141.170
-3.00 -4.88	7.054 0.000	381.309	233.085	-148.224

Shear force $Q = A_p - \sum S$

The above table suggests that the shear force zero point exists in between 0.430m and -1.000m.

$$Q = 83.694 - \frac{[59.531 + (59.531 + 2.910X)]X}{2} = 0$$

X = 1.361 m

Shear force zero point : DL = +0.43 – 1.361 = -0.931m

6) Calculation of moment

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	8.730x	1.950	-8.512	5.781	-49.208
2	1/2x	18.940x	1.950	-18.466	5.131	-94.749
3	1/2x	18.940x	0.550	-5.208	4.298	-22.384
4	1/2x	26.095x	0.550	-7.176	4.114	-29.522
5	1/2x	26.095x	2.570	-33.532	3.074	-103.077
6	1/2x	59.531x	2.570	-76.497	2.218	-169.670
7	1/2x	59.531x	1.361	-40.511	0.907	-36.743
8	1/2x	63.491x	1.361	-43.206	0.454	-19.616
Total				———	———	-524.969

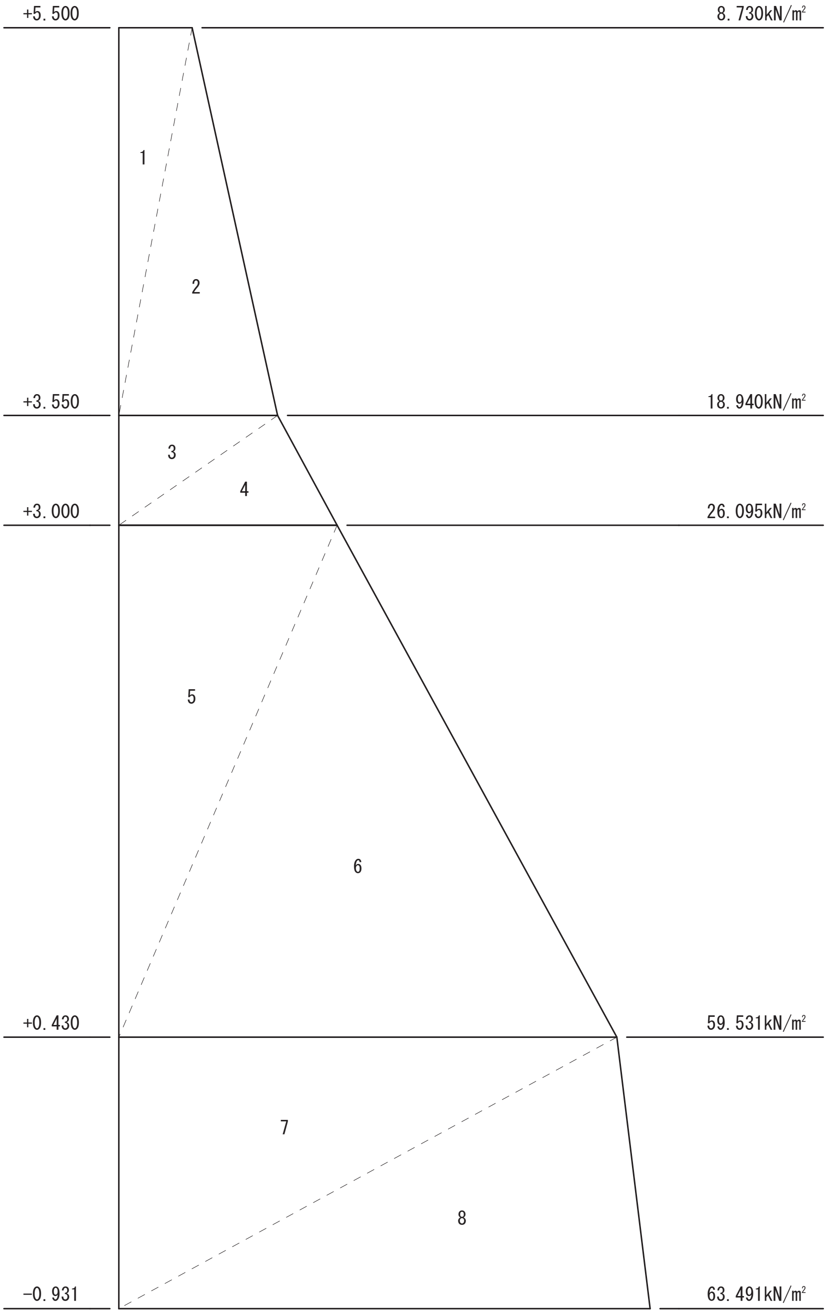
where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

7) Maximum bending moment

- Distance of the shear zero point to the tie setting point
  h = 3.000 – (-0.931) = 3.931 m

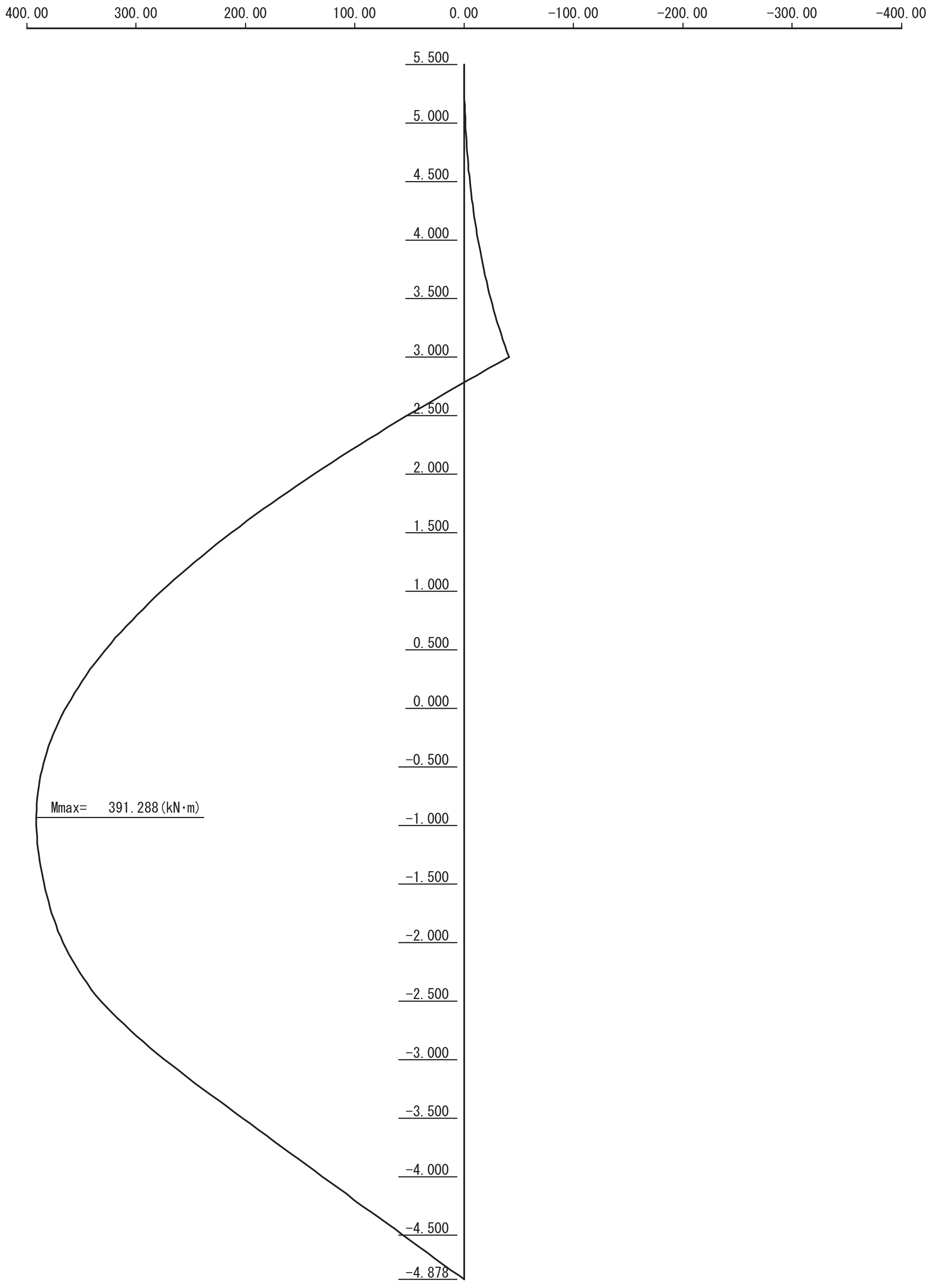
- Maximum bending moment
  $M_{max} = A_p \times h + \sum M$ = 233.085 ×3.931 – 524.969 = 391.288 kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type : ϕ800 × t10 (P-T joint)

Modulus of elasticity : E = 200.0 kN/mm^2
Moment of inertia : I = 193647 cm^4
Section modulus : Z = 4841 cm^3

Section property (per 1m) before corrosion
- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 197599 cm^4/m
- Section modulus : Z = 4940 cm^3/m

Section property (per 1m) after corrosion
- Design life time : 50 years
- Effect of cathodic protection : 90%
- Corrosion rate : 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance : t = 0.030 × 50 years = 1.50 mm

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 166997 cm^4/m
- Section modulus : Z = 4191 cm^3/m

(2) Embedded depth of pipe wall

Toe level of the pipe wall is obtained as follows:
- Deflection curve method : -14.895 m --- adopted
- Free earth support method : -10.634 m

Therefore, the minimum length of the pipe wall is;
L = 3.500 – (-14.895) = 18.395m → 18.500 m

Accordingly the design toe level of the pipe wall is;
EL = +3.500 – 18.500 = -15.000 m

(3) Stress on pipe wall section

Maximum bending moment on the pipe wall is as follows:
- Deflection curve method : 509.316 kN-m/m --- adopted
- Free earth support method : 391.288 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{509.311\times10^6}{4191\times10^3} = 121.5MPa \quad \leq \quad \sigma_a = 140MPa \quad .... \ OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

- T is the tension force on tie wire (kN/wire)
- A_p is the reaction force of the pipe wall at tie setting point (kN/m)
- L is the spacing of the tie wire (m)
- θ_1 is the vertical angle of the tie wire to horizontal (deg.)
- θ_2 is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 260.931 kN-m/m --- adopted
- Free earth support method : 233.085 kN-m/m

T = 260.931 × 1.960 × sec(0.000) × sec (0.000) = 511.425 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 511.425 × 3.8 = 1943.415 kN/wire

Tie wire shall have minimum tensile strength of <u>1944 kN</u>.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max} is the maximum bending moment on the waling beam (kN-m)
T is the tension force on tie wire (kN/wire)
L is the spacing of the tie wire (m)

$$M_{maz} = \frac{511.425 \times 1.960}{10.0} = 100.239 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[250×90×11.0×14.5

Steel grade : SS400
Section modulus : Z = 374.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \le \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{100.239 \times 10^6}{2 \times 374.0 \times 10^3} = 134.0 MPa \quad \le \quad \sigma_a = 140 MPa \text{ .... } OK$$

Output of Design Software for Anchor Wall (After Completion) – Revetment Block d

1. Design Conditions

1-1 Dimensions

Ground elevation	+5.50 m
Top of cope concrete	+5.50 m
Top of pipe wall	+3.50 m
Tie elevation	+3.00 m
Seabed elevation	-1.00 m
Angle of seabed slope	18.4°

1-2 Tide Levels

H.W.L	+3.55 m
L.W.L	+0.43 m

1-3 Residual Water Level

R.W.L	+3.55 m

1-4 Base Elevation of Cohesion Increment +0.00 m (not used)

1-5 Surcharge Load	(Active side)	30 kPa
	(Passive side)	0 kPa

1-6 Unit Weight of Water 10.10 kN/m^3

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

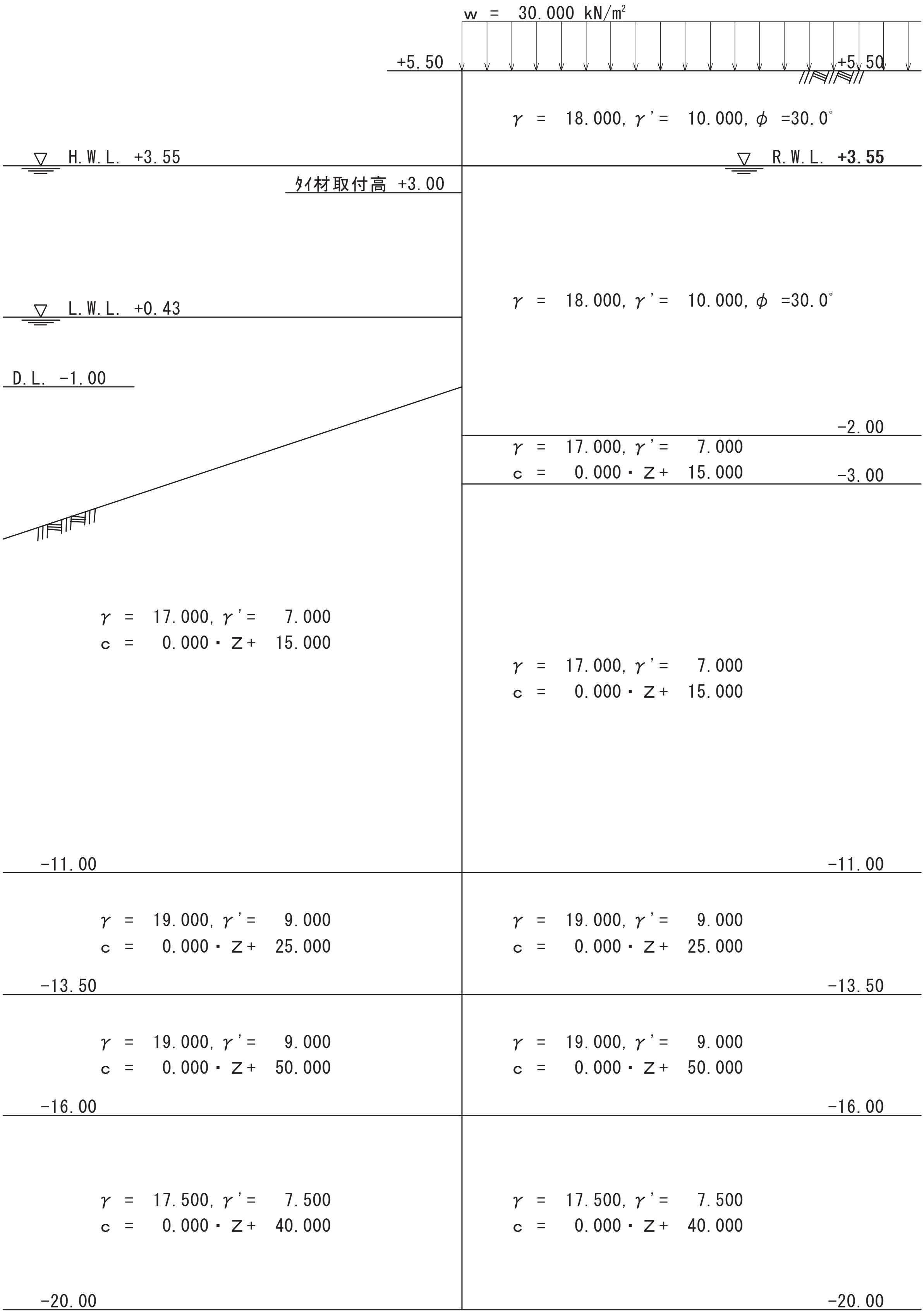
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	:	Deflection Curve Method
Calculation Method 2	:	Free Earth Support Method
Factor of Safety	:	FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
5.50 3.55	1.95	8.730 18.940
3.55 3.00	0.55	18.940 20.540
3.00 -2.00	5.00	20.540 35.090
-2.00 -3.00	1.00	90.600 97.600
-3.00 -11.00	8.00	7.000 7.000
-11.00 -13.50	2.50	7.000 7.000
-13.50 -16.00	2.50	7.000 7.000
-16.00 -20.00	4.00	7.000 7.000

(2) Residual water pressure

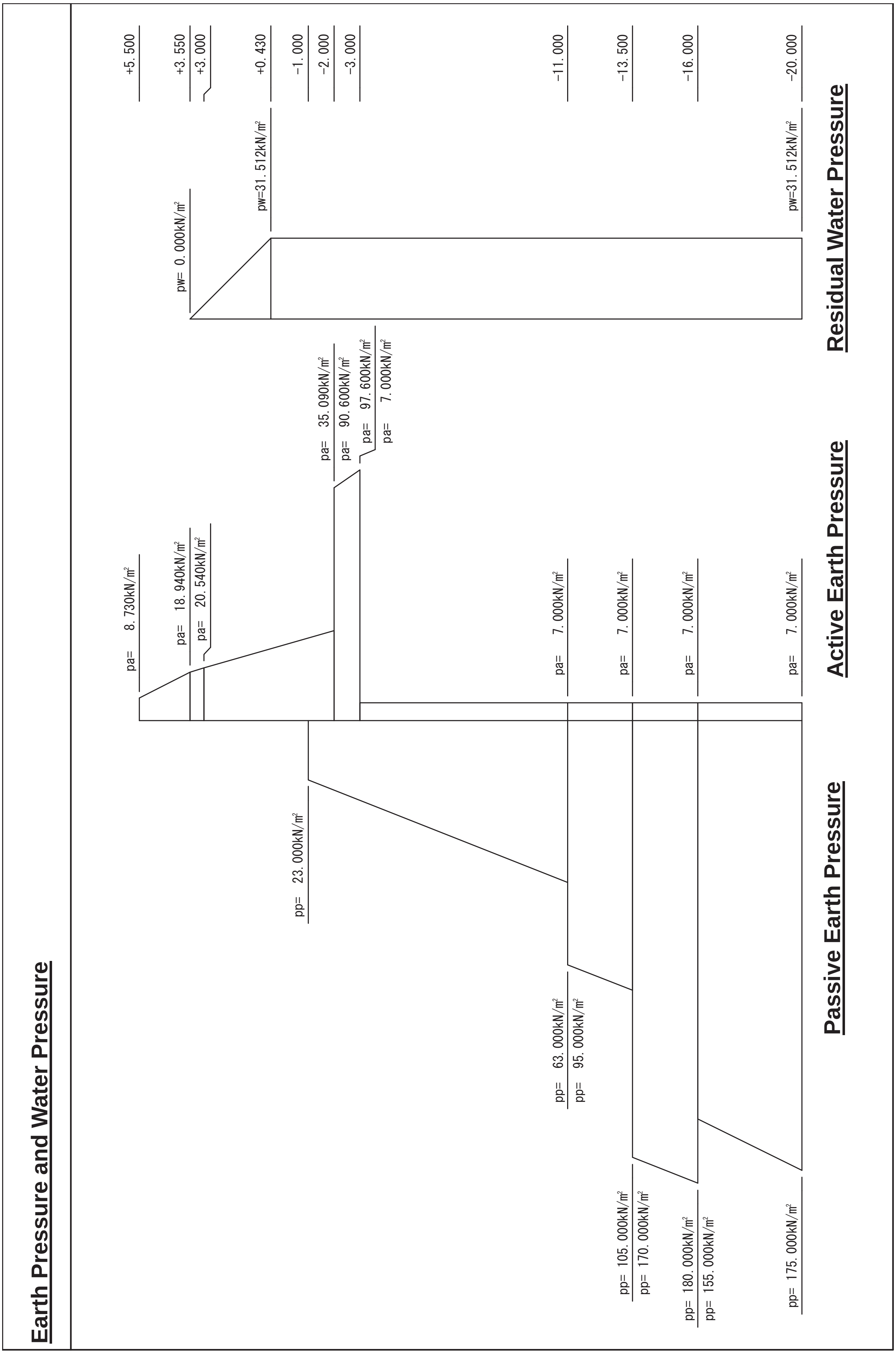
$p_w = \gamma_w \times h_w$

where; p_w is the residual water pressure (kPa)
h_w is the height of the tidal lag (m)
γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-1.00 -11.00	10.00	23.000 63.000
-11.00 -13.50	2.50	95.000 105.000
-13.50 -16.00	2.50	170.000 180.000
-16.00 -20.00	4.00	155.000 175.000


Earth Pressure and Water Pressure
+5.500
+3.550
+3.000
+0.430
−1.000
−2.000
−3.000
−11.000
−13.500
−16.000
−20.000
pw= 0.000kN/m²
pw=31.512kN/m²
pw=31.512kN/m²
pa= 8.730kN/m²
pa= 18.940kN/m²
pa= 20.540kN/m²
pa= 35.090kN/m²
pa= 90.600kN/m²
pa= 97.600kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pp= 23.000kN/m²
pp= 63.000kN/m²
pp= 95.000kN/m²
pp= 105.000kN/m²
pp= 170.000kN/m²
pp= 180.000kN/m²
pp= 155.000kN/m²
pp= 175.000kN/m²
Residual Water Pressure
Active Earth Pressure
Passive Earth Pressure

(4) Summary of Forces on the Wall

Elev (m)	Active side (kPa) $P_a + P_w$	Passive side(kPa) P_p
5.50 3.55	8.730+ 0.000= 8.730 18.940+ 0.000= 18.940	——— ———
3.55 3.00	18.940+ 0.000= 18.940 20.540+ 5.555= 26.095	——— ———
3.00 0.43	20.540+ 5.555= 26.095 28.019+ 31.512= 59.531	——— ———
0.43 -1.00	28.019+ 31.512= 59.531 32.180+ 31.512= 63.692	——— ———
-1.00 -2.00	32.180+ 31.512= 63.692 35.090+ 31.512= 66.602	23.000 27.000
-2.00 -3.00	90.600+ 31.512= 122.112 97.600+ 31.512= 129.112	27.000 31.000
-3.00 -11.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	31.000 63.000
-11.00 -13.50	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	95.000 105.000
-13.50 -16.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	170.000 180.000
-16.00 -20.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	155.000 175.000

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -1.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
-1.000	-111.249	135.301	102.195
-2.000	-238.845	159.773	117.870
-3.000	-459.920	187.428	186.827
-4.000	-747.349	214.559	165.208
-5.000	-1017.829	235.345	145.934
-6.000	-1269.787	251.459	127.332
-7.000	-1496.898	263.902	108.400
-8.000	-1689.275	273.308	88.507
-9.000	-1834.063	280.109	67.218
-10.000	-1915.762	284.597	44.242
-11.000	-1916.406	286.972	19.379
-12.000	-1740.925	286.337	-38.474
-13.000	-1290.981	282.000	-96.625
-14.000	-494.416	273.903	-187.516
-15.000	948.493	259.740	-308.841

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -14.00 and -15.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-14.402	0.000	268.956	-236.494

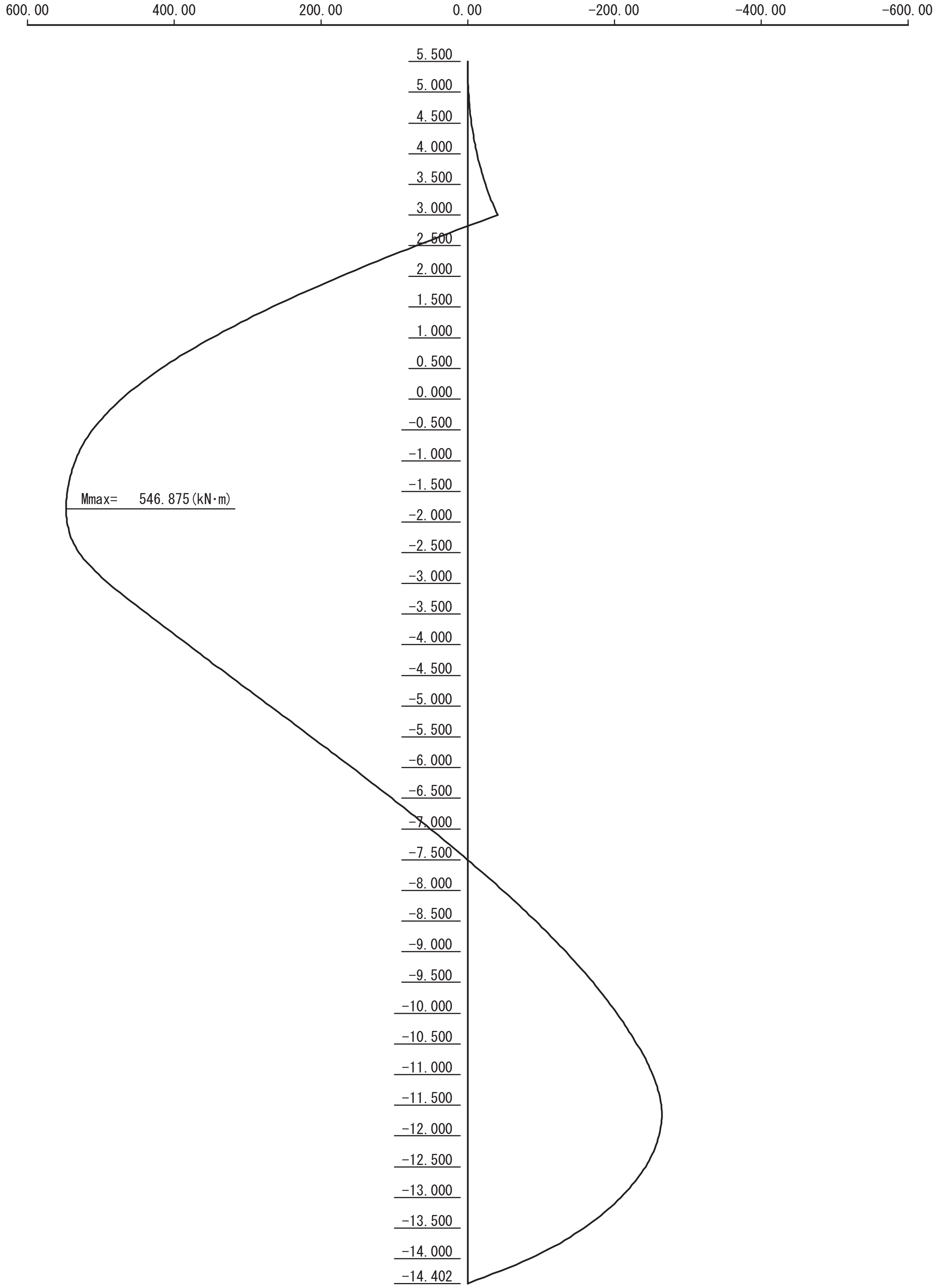
Embedded length of the pipe wall : L = 1.2 × (-1.000 + 14.402) = 16.082 m
Toe elevation : D = -1.000 – 16.082 = -17.082 m
Reaction force at tie setting point : 268.956 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	-1.200	-5.019
4.500	-5.238	-11.348
4.000	-12.766	-18.985
3.550	-23.069	-26.978
3.050	-39.196	-38.074
3.000	-41.132	-39.363
2.500	70.132	214.919
2.000	173.245	196.993
1.500	266.583	175.814
1.000	348.517	151.383
0.500	417.423	123.699
0.430	425.938	119.564
-0.070	478.218	89.434
-0.570	515.251	58.578
-1.000	534.629	31.459
-1.500	545.294	11.250
-2.000	545.923	-8.688
-2.500	529.628	-56.619
-3.000	489.180	-105.300
-3.500	435.674	-108.556
-4.000	380.791	-110.812
-4.500	325.029	-112.068
-5.000	268.890	-112.324
-5.500	212.872	-111.580
-6.000	157.477	-109.836
-6.500	103.203	-107.092
-7.000	50.552	-103.348
-7.500	0.022	-98.604
-8.000	-47.886	-92.860
-8.500	-92.671	-86.116
-9.000	-133.835	-78.372
-9.500	-170.876	-69.628
-10.000	-203.296	-59.884
-10.500	-230.593	-49.140
-11.000	-252.269	-37.396
-11.500	-263.822	-8.652
-12.000	-260.754	21.092
-12.500	-242.563	51.836
-13.000	-208.751	83.580
-13.500	-158.816	116.324
-14.000	-84.135	182.568
-14.402	0.000	236.494

Maximum bending moment : 546.875 kN-m/m
Elevation of maximum bending moment : -1.781 m
Depth of 1st steady point (moment=0) : -7.500 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

M_p = FOS×M_a

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of FOS×M_a

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_a (kN-m/m)
1	5.50	1/2x 8.730x 1.950	8.512	-1.850	-15.747	
2	3.55	1/2x 18.940x 1.950	18.466	-1.200	-22.159	-45.487
3	3.55	1/2x 18.940x 0.550	5.208	-0.367	-1.911	
4	3.00	1/2x 26.095x 0.550	7.176	-0.183	-1.313	-49.356
5	3.00	1/2x 26.095x 2.570	33.532	0.857	28.737	
6	0.43	1/2x 59.531x 2.570	76.497	1.713	131.039	142.375
7	0.43	1/2x 59.531x 1.430	42.565	3.047	129.696	
8	-1.00	1/2x 63.692x 1.430	45.540	3.523	160.437	490.535
9	-1.00	1/2x 63.692x 1.000	31.846	4.333	137.989	
10	-2.00	1/2x 66.602x 1.000	33.301	4.667	155.416	842.621
11	-2.00	1/2x 122.112x 1.000	61.056	5.333	325.612	
12	-3.00	1/2x 129.112x 1.000	64.556	5.667	365.839	1672.362
13	-3.00	1/2x 38.512x 8.000	154.048	8.667	1335.134	
14	-11.00	1/2x 38.512x 8.000	154.048	11.333	1745.826	5369.514
15	-11.00	1/2x 38.512x 2.500	48.140	14.833	714.061	
16	-13.50	1/2x 38.512x 2.500	48.140	15.667	754.209	7131.438
17	-13.50	1/2x 38.512x 2.500	48.140	17.333	834.411	
18	-16.00	1/2x 38.512x 2.500	48.140	18.167	874.559	9182.202
19	-16.00	1/2x 38.512x 4.000	77.024	20.333	1566.129	
20	-20.00	1/2x 38.512x 4.000	77.024	21.667	1668.879	13064.212

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

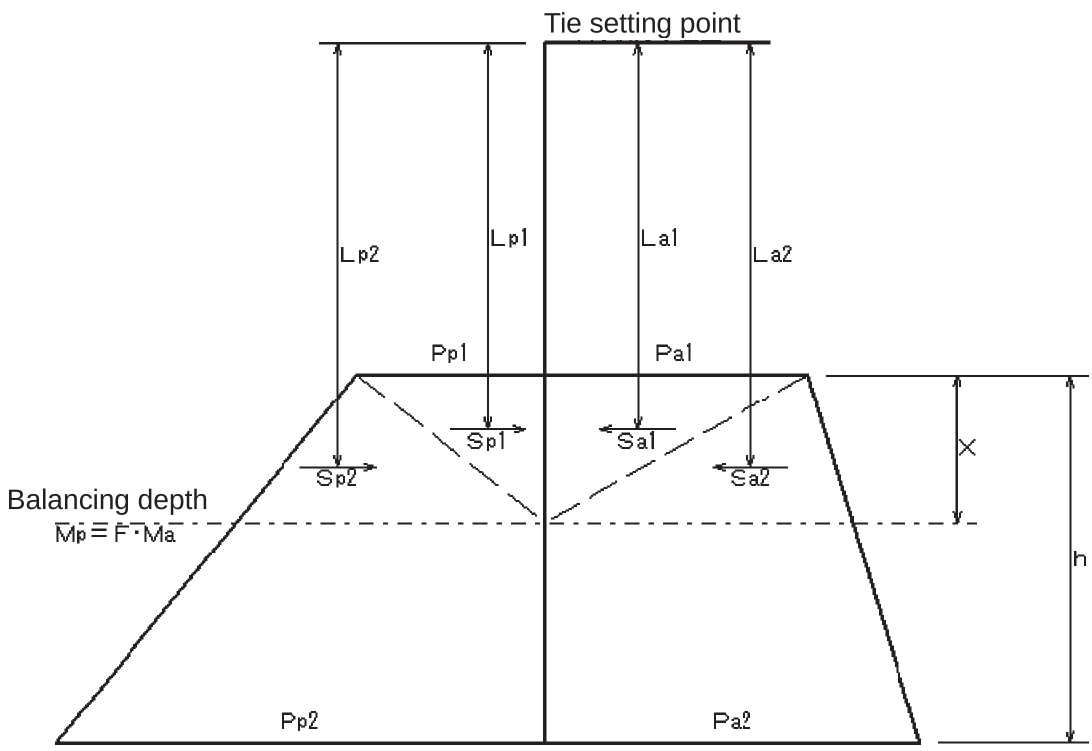
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-1.00	1/2x 23.000x 1.000	11.500	4.333	49.830	
2	-2.00	1/2x 27.000x 1.000	13.500	4.667	63.004	112.834
3	-2.00	1/2x 27.000x 1.000	13.500	5.333	71.996	
4	-3.00	1/2x 31.000x 1.000	15.500	5.667	87.838	272.668
5	-3.00	1/2x 31.000x 8.000	124.000	8.667	1074.708	
6	-11.00	1/2x 63.000x 8.000	252.000	11.333	2855.916	4203.292
7	-11.00	1/2x 95.000x 2.500	118.750	14.833	1761.419	
8	-13.50	1/2x 105.000x 2.500	131.250	15.667	2056.294	8021.005
9	-13.50	1/2x 170.000x 2.500	212.500	17.333	3683.262	
10	-16.00	1/2x 180.000x 2.500	225.000	18.167	4087.575	15791.842
11	-16.00	1/2x 155.000x 4.000	310.000	20.333	6303.230	
12	-20.00	1/2x 175.000x 4.000	350.000	21.667	7583.450	29678.522

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1}X}{2}, \quad L_{a(p)1} = L + \frac{1}{3}X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \frac{P_{a(p)2} - P_{a(p)1}}{h} X \right] X}{2}, \quad L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

$M_{a(p)}$	: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)
$M_{a(p)1}$	: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)
$M_{a(p)1'}$	: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$M_{a(p)2'}$	: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$S_{a(p)1}$	: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$S_{a(p)2}$	: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$L_{a(p)1}$	: the arm length of $S_{a(p)1}$ from the tie setting point (m)
$L_{a(p)2}$	: the arm length of $S_{a(p)2}$ from the tie setting point (m)
$P_{a(p)1}$	: the active (passive) side pressure at the top elevation of the soil layer (kPa)
$P_{a(p)1}$	: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)
h	: the thickness of the soil layer (m)
L	: the vertical distance from the tie setting point to the top elevation of the soil layer (m)
X	: the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -11.00 m FOS×M_{a1} = 5369.514 > M_{p1} = 4203.292
at -13.50 m FOS×M_{a2} = 7131.438 > M_{p2} = 8021.005

[Moment on active side]

$S_{a1} = \dfrac{38.512X}{2} = 19.256X$, $L_{a1} = 14.000 + \dfrac{1}{3}X$

$M_{a1'} = 6.419X^2 + 269.584X$

$S_{a2} = \dfrac{\left[38.512 + \dfrac{38.512 - 38.512}{2.500}X\right]X}{2} = 0.000X^2 + 19.256X$, $L_{a2} = 14.000 + \dfrac{2}{3}X$

$M_{a2'} = 0.000X^3 + 12.837X^2 + 269.584X$

$M_a = 0.000X^3 + 19.256X^2 + 539.168X + 4474.595$

[Moment on passive side]

$S_{p1} = \dfrac{95.000X}{2} = 47.500X$, $L_{p1} = 14.000 + \dfrac{1}{3}X$

$M_{p1'} = 15.833X^2 + 665.000X$

$S_{p2} = \dfrac{\left[95.000 + \dfrac{105.000 - 95.000}{2.500}X\right]X}{2} = 2.000X^2 + 47.500X$, $L_{p2} = 14.000 + \dfrac{2}{3}X$

$M_{p2'} = 1.333X^3 + 59.667X^2 + 665.000X$

$M_p = 1.333X^3 + 75.500X^2 + 1330.000X + 4203.292$

[Balancing depth]

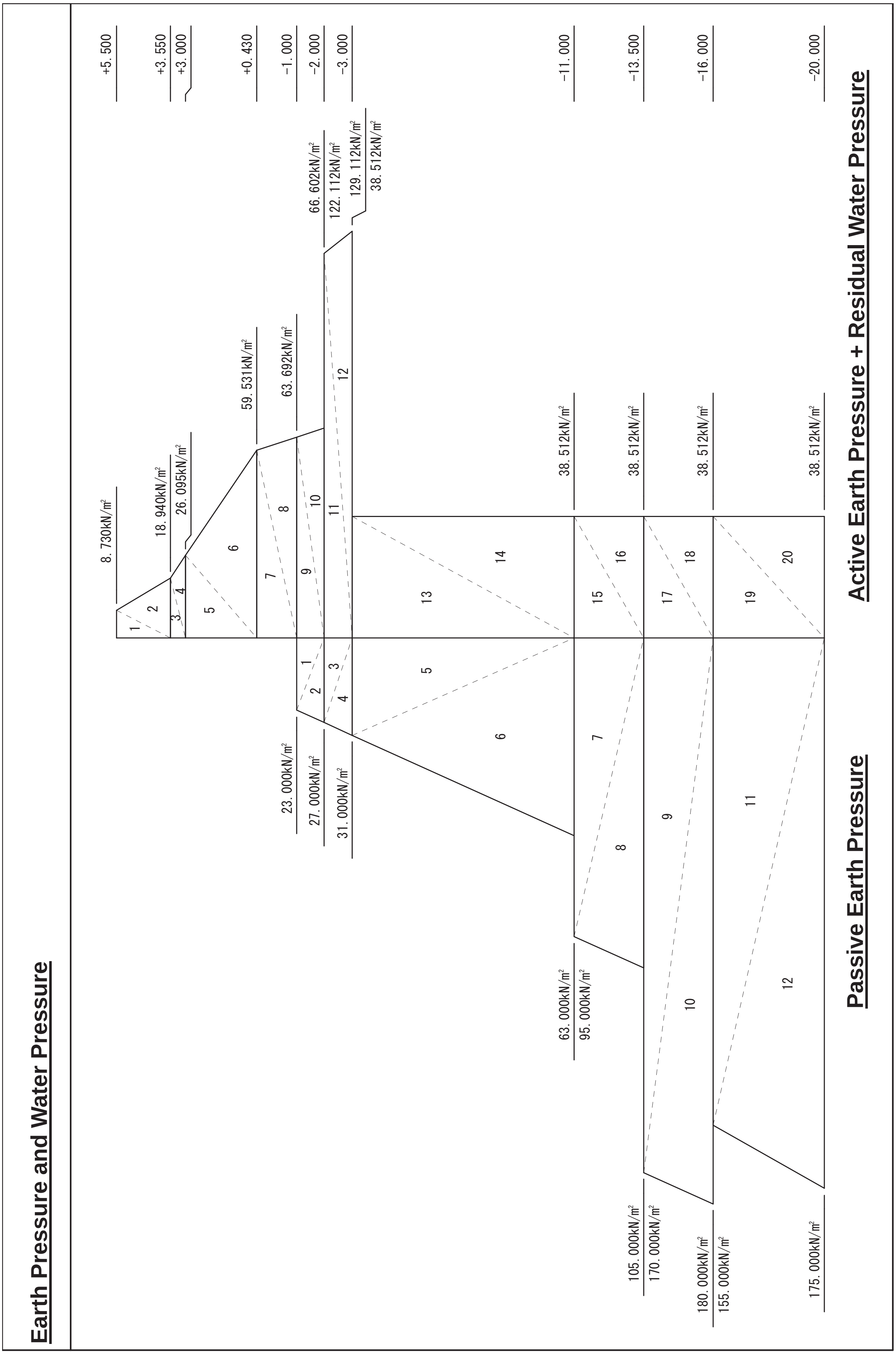
$FOS \cdot M_a = M_p$

$1.2 \times (0.000X^3 + 19.256X^2 + 539.168X + 4474.595)$

$= 1.333X^3 + 75.500X^2 + 1330.000X + 4203.292$

X= 1.523 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -11.000 – 1.523 = -12.523 m


Earth Pressure and Water Pressure
Active Earth Pressure + Residual Water Pressure
Passive Earth Pressure
+5.500
+3.550
+3.000
+0.430
-1.000
-2.000
-3.000
-11.000
-13.500
-16.000
-20.000
8.730kN/m²
18.940kN/m²
26.095kN/m²
59.531kN/m²
63.692kN/m²
66.602kN/m²
122.112kN/m²
129.112kN/m²
38.512kN/m²
38.512kN/m²
38.512kN/m²
38.512kN/m²
38.512kN/m²
23.000kN/m²
27.000kN/m²
31.000kN/m²
63.000kN/m²
95.000kN/m²
105.000kN/m²
170.000kN/m²
180.000kN/m²
155.000kN/m²
175.000kN/m²

(2) Calculation of maximum bending moment

1) External forces

Elev (m)	$P_a + P_w$ (kN/m^2)	P_p (kN/m^2)	$P_a - P_p$ (kN/m^2)
5.50 3.55	8.730 18.940	——— ———	8.730 18.940
3.55 3.00	18.940 26.095	——— ———	18.940 26.095
3.00 0.43	26.095 59.531	——— ———	26.095 59.531
0.43 -1.00	59.531 63.692	——— ———	59.531 63.692
-1.00 -2.00	63.692 66.602	23.000 27.000	40.692 39.602
-2.00 -3.00	122.112 129.112	27.000 31.000	95.112 98.112
-3.00 -11.00	38.512 38.512	31.000 63.000	7.512 -24.488
-11.00 -13.50	38.512 38.512	95.000 105.000	-56.488 -66.488
-13.50 -16.00	38.512 38.512	170.000 180.000	-131.488 -141.488
-16.00 -20.00	38.512 38.512	155.000 175.000	-116.488 -136.488

2) Virtual seabed level

The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -3.00 m $\quad P_{a1} = 38.512 \quad > \quad P_{p1} = 31.000$
at -11.00 m $\quad P_{a2} = 38.512 \quad < \quad P_{p2} = 63.000$

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

EL_{top} : the top elevation of the soil layer in question (m)

P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)

P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)

P_{p1} : the passive earth pressure at the top of the soil layer (kPa)

P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)

h : the thickness of the soil layer (m)

$$X = -3.00 - \frac{8.00 \times (31.000 - 38.512)}{(38.512 - 38.512) - (63.000 - 31.000)} = -4.878m$$

Accordingly, the virtual seabed level is obtained as -4.878m.

3) Moment about tie setting point

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	8.730x	1.950	8.512	-1.850	-15.747
2	1/2x	18.940x	1.950	18.466	-1.200	-22.159
3	1/2x	18.940x	0.550	5.208	-0.367	-1.911
4	1/2x	26.095x	0.550	7.176	-0.183	-1.313
5	1/2x	26.095x	2.570	33.532	0.857	28.737
6	1/2x	59.531x	2.570	76.497	1.713	131.039
7	1/2x	59.531x	1.430	42.565	3.047	129.696
8	1/2x	63.692x	1.430	45.540	3.523	160.437
9	1/2x	40.692x	1.000	20.346	4.333	88.159
10	1/2x	39.602x	1.000	19.801	4.667	92.411
11	1/2x	95.112x	1.000	47.556	5.333	253.616
12	1/2x	98.112x	1.000	49.056	5.667	278.000
13	1/2x	7.512x	1.878	7.054	6.626	46.740
Total				381.309	———	1167.705

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

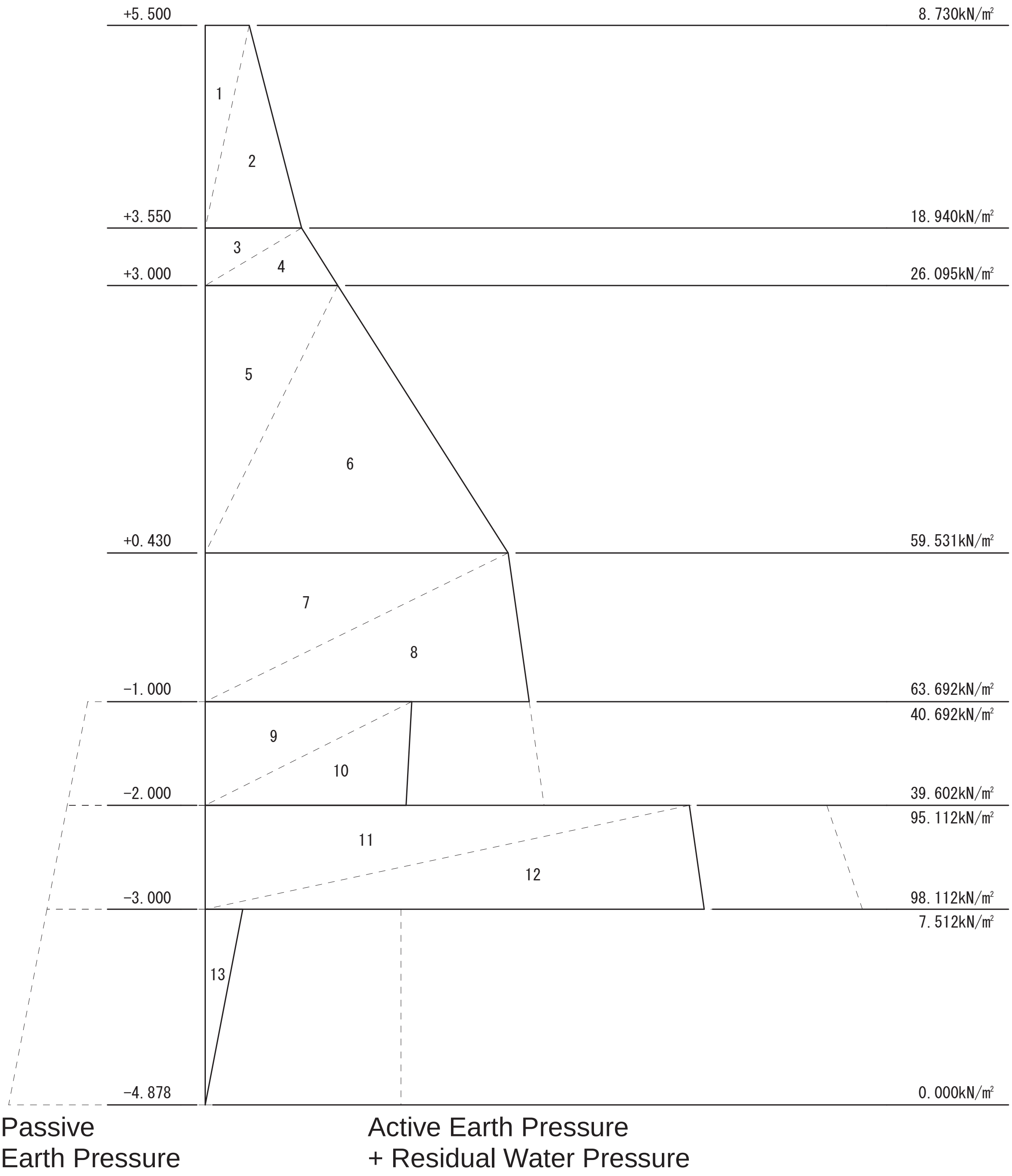
4) Reaction forces

Distance between supports : L_T = 3.000 – (-4.878) = 7.878 m

Reaction at virtual seabed : $R_0 = \frac{\Sigma M}{L_T} = \frac{1167.705}{7.878} = 148.224 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 381.309 - 148.224 = 233.085 kN/m$

External Force Diagram



5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 3.55	8.512 18.466	26.978		-26.978
3.55 3.00	5.208 7.176	39.362	233.085	193.723
3.00 0.43	33.532 76.497	149.391	233.085	83.694
0.43 -1.00	42.565 45.540	237.496	233.085	-4.411
-1.00 -2.00	20.346 19.801	277.643	233.085	-44.558
-2.00 -3.00	47.556 49.056	374.255	233.085	-141.170
-3.00 -4.88	7.054 0.000	381.309	233.085	-148.224

Shear force Q = A_p - ∑S

The above table suggests that the shear force zero point exists in between 0.430m and -1.000m.

$$Q = 83.694 - \frac{[59.531 + (59.531 + 2.910X)]X}{2} = 0$$

X = 1.361 m

Shear force zero point : DL = 0.430 – 1.361 = -0.931m

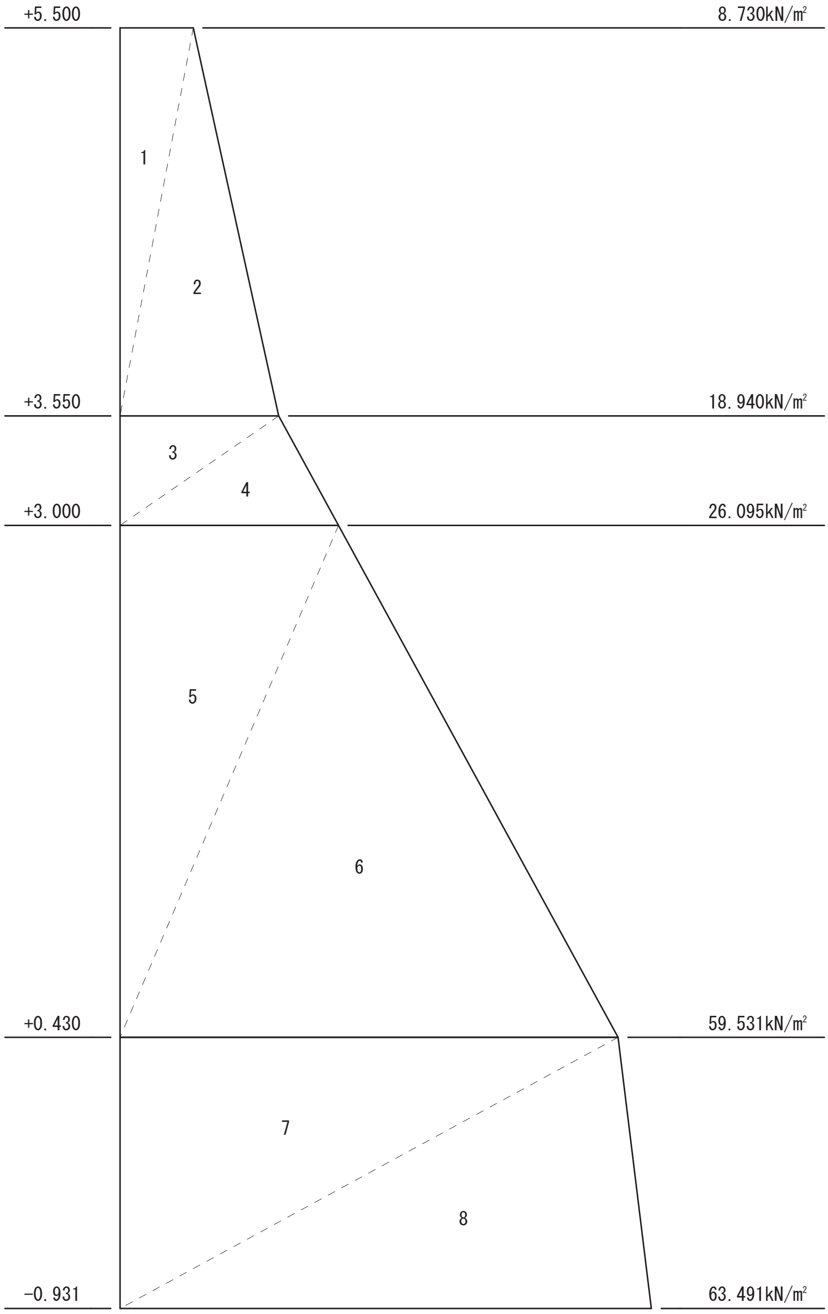
6) Calculation of moment

No	Calculation	S (kN/m)	L (m)	M (kN-m/m)
1	1/2x 8.730x 1.950	-8.512	5.781	-49.208
2	1/2x 18.940x 1.950	-18.466	5.131	-94.749
3	1/2x 18.940x 0.550	-5.208	4.298	-22.384
4	1/2x 26.095x 0.550	-7.176	4.114	-29.522
5	1/2x 26.095x 2.570	-33.532	3.074	-103.077
6	1/2x 59.531x 2.570	-76.497	2.218	-169.670
7	1/2x 59.531x 1.361	-40.511	0.907	-36.743
8	1/2x 63.491x 1.361	-43.206	0.454	-19.616
Total		———	———	-524.969

where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

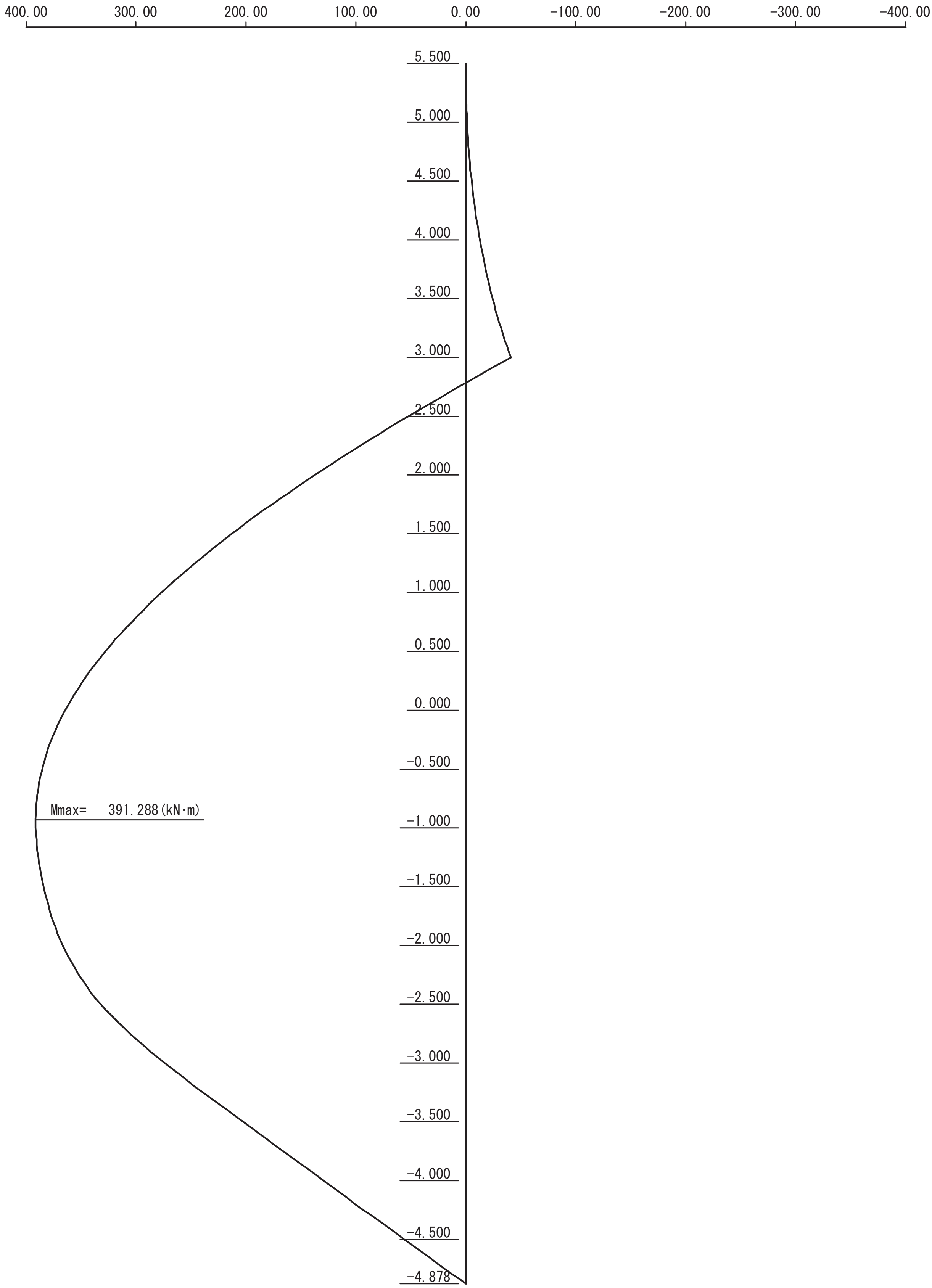
7) Maximum bending moment
- Distance of the shear zero point to the tie setting point
  h = 3.000 – (-0.931) = 3.931 m
- Maximum bending moment
  $M_{max} = A_p \times h + \sum M$ = 233.085 ×3.931 – 524.969 = 391.288 kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type : ϕ800 × t10 (P-T joint)

Modulus of elasticity : E = 200.0 kN/mm^2
Moment of inertia : I = 193647 cm^4
Section modulus : Z = 4841 cm^3

Section property (per 1m) before corrosion
- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 197599 cm^4/m
- Section modulus : Z = 4940 cm^3/m

Section property (per 1m) after corrosion
- Design life time : 50 years
- Effect of cathodic protection : 90%
- Corrosion rate : 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance : t = 0.030 × 50 years = 1.50 mm

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 166997 cm^4/m
- Section modulus : Z = 4191 cm^3/m

(2) Embedded depth of pipe wall

Toe level of the pipe wall is obtained as follows:
- Deflection curve method : -17.082 m --- adopted
- Free earth support method : -12.523 m

Therefore, the minimum length of the pipe wall is;
L = 3.500 – (-17.082) = 20.582m → 21.000 m

Accordingly the design toe level of the pipe wall is;
EL = +3.500 – 21.000 = -17.500 m

(3) Stress on pipe wall section

Maximum bending moment on the pipe wall is as follows:
- Deflection curve method : 546.875 kN-m/m --- adopted
- Free earth support method : 391.288 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{546.875 \times 10^6}{4191 \times 10^3} = 130.5 MPa \quad \leq \quad \sigma_a = 140 MPa \quad .... \ OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

T	is the tension force on tie wire (kN/wire)
A_p	is the reaction force of the pipe wall at tie setting point (kN/m)
L	is the spacing of the tie wire (m)
θ_1	is the vertical angle of the tie wire to horizontal (deg.)
θ_2	is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 268.956 kN-m/m --- adopted
- Free earth support method : 233.085 kN-m/m

T = 268.956 × 1.96 × sec(0.000) × sec (0.000) = 527.154 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 527.154 × 3.8 = 2003.185 kN/wire

Tie wire shall have minimum tensile strength of 2004 kN.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max} is the maximum bending moment on the waling beam (kN-m)
T is the tension force on tie wire (kN/wire)
L is the spacing of the tie wire (m)

$$M_{maz} = \frac{527.154 \times 1.960}{10.0} = 103.322 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[250×90×11.0×14.5

Steel grade : SS400
Section modulus : Z = 374.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \leq \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{103.322 \times 10^6}{2 \times 374.0 \times 10^3} = 138.1 MPa \quad \leq \quad \sigma_a = 140 MPa \ \ .... \ OK$$

Phụ lục 7-8

Kết quả tính toán tường cọc ván thép (trong khi thi công)

Output of Design Software for Anchor Wall (During Construction)
– Junction to Service Berth

1. Design Conditions

1-1 Dimensions

Ground elevation	+4.50 m
Top of cope concrete	+5.50 m
Top of pipe wall	+3.50 m
Tie elevation	+3.00 m
Seabed elevation	-5.00 m
Angle of seabed slope	0.0˚

1-2 Tide Levels

H.W.L	+3.55 m
L.W.L	+0.43 m

1-3 Residual Water Level

R.W.L	+3.55 m

1-4 Base Elevation of Cohesion Increment +0.00 m (not used)

1-5 Surcharge Load	(Active side)	20 kPa
	(Passive side)	0 kPa

1-6 Unit Weight of Water 10.10 kN/m^3

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

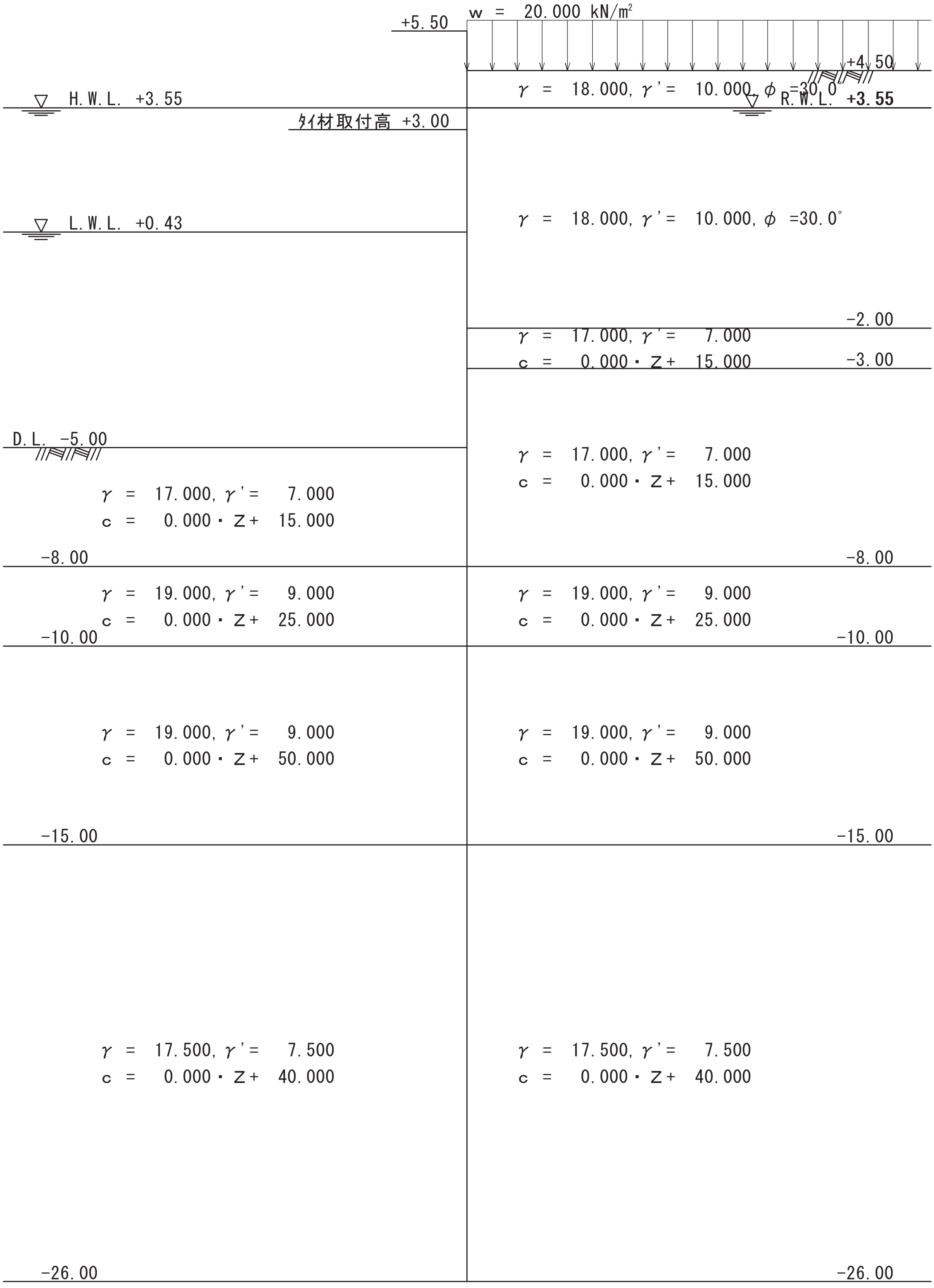
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	:	Deflection Curve Method
Calculation Method 2	:	Free Earth Support Method
Factor of Safety	:	FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
4.50 3.55	0.95	5.820 10.800
3.55 3.00	0.55	10.800 12.400
3.00 -2.00	5.00	12.400 26.950
-2.00 -3.00	1.00	62.600 69.600
-3.00 -8.00	5.00	7.000 7.000
-8.00 -10.00	2.00	7.000 7.000
-10.00 -15.00	5.00	7.000 7.000
-15.00 -26.00	11.00	7.000 7.000

(2) Residual water pressure

$p_w = \gamma_w \times h_w$

where; p_w is the residual water pressure (kPa)

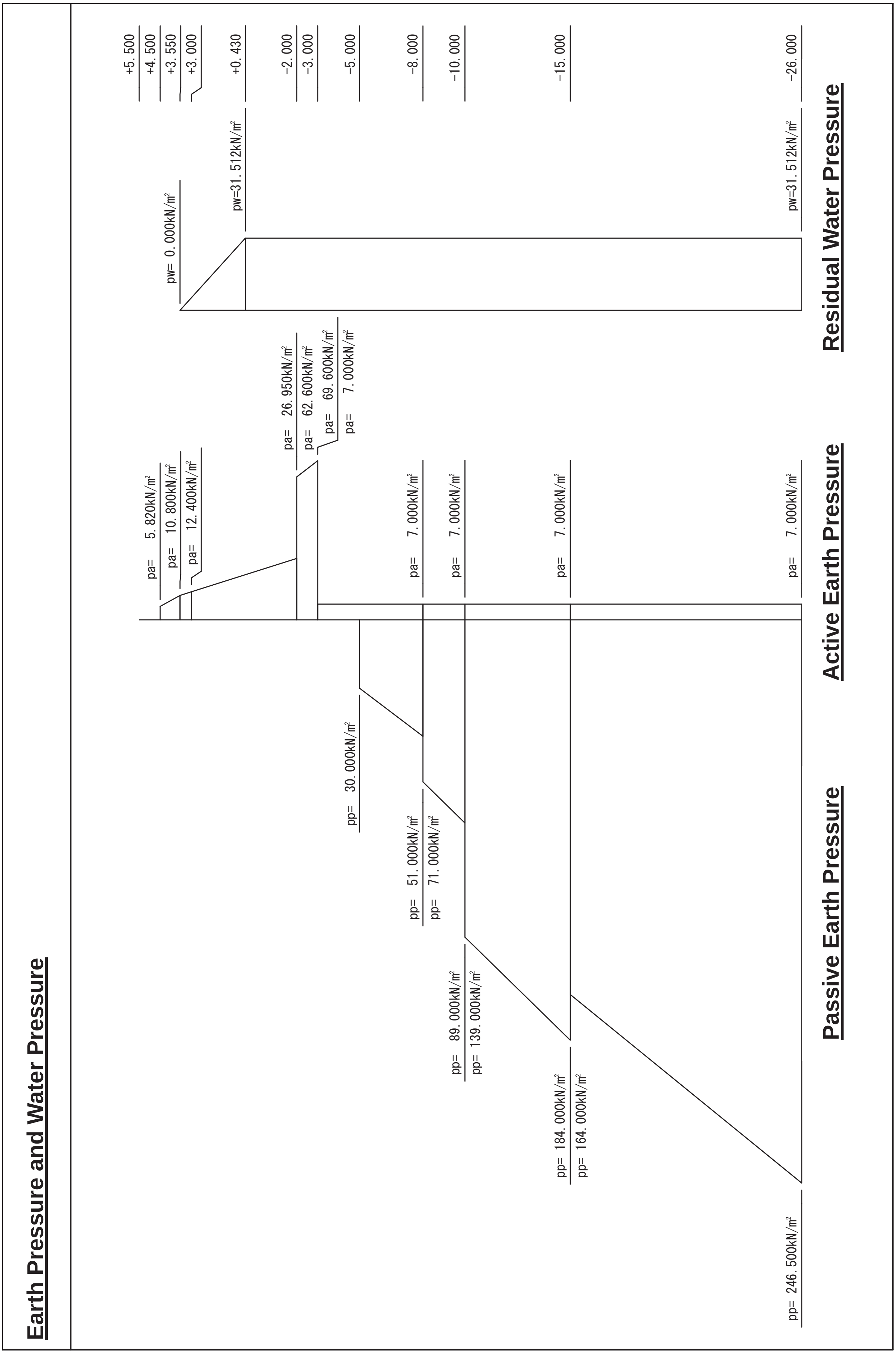
h_w is the height of the tidal lag (m)

γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-5.00 -8.00	3.00	30.000 51.000
-8.00 -10.00	2.00	71.000 89.000
-10.00 -15.00	5.00	139.000 184.000
-15.00 -26.00	11.00	164.000 246.500


Earth Pressure and Water Pressure
+5.500
+4.500
+3.550
+3.000
+0.430
-2.000
-3.000
-5.000
-8.000
-10.000
-15.000
-26.000
pw= 0.000kN/m²
pw=31.512kN/m²
pw=31.512kN/m²
Residual Water Pressure
pa= 5.820kN/m²
pa= 10.800kN/m²
pa= 12.400kN/m²
pa= 26.950kN/m²
pa= 62.600kN/m²
pa= 69.600kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
pa= 7.000kN/m²
Active Earth Pressure
pp= 30.000kN/m²
pp= 51.000kN/m²
pp= 71.000kN/m²
pp= 89.000kN/m²
pp= 139.000kN/m²
pp= 184.000kN/m²
pp= 164.000kN/m²
pp= 246.500kN/m²
Passive Earth Pressure

(4) Summary of Forces on the Wall

Elev (m)	Active side (kPa) $P_a + P_w$	Passive side(kPa) P_p
5.50 4.50	0.000+ 0.000= 0.000 0.000+ 0.000= 0.000	―――― ――――
4.50 3.55	5.820+ 0.000= 5.820 10.800+ 0.000= 10.800	―――― ――――
3.55 3.00	10.800+ 0.000= 10.800 12.400+ 5.555= 17.955	―――― ――――
3.00 0.43	12.400+ 5.555= 17.955 19.879+ 31.512= 51.391	―――― ――――
0.43 -2.00	19.879+ 31.512= 51.391 26.950+ 31.512= 58.462	―――― ――――
-2.00 -3.00	62.600+ 31.512= 94.112 69.600+ 31.512= 101.112	―――― ――――
-3.00 -5.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	―――― ――――
-5.00 -8.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	30.000 51.000
-8.00 -10.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	71.000 89.000
-10.00 -15.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	139.000 184.000
-15.00 -26.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	164.000 246.500

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -5.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
−5.000	−1194.453	199.459	213.559
−6.000	−1607.766	223.532	194.498
−7.000	−1999.986	242.940	173.102
−8.000	−2355.793	258.321	148.733
−9.000	−2616.807	269.237	100.829
−10.000	−2714.084	275.282	48.796
−11.000	−2499.470	275.071	−55.981
−12.000	−1817.399	267.589	−162.487
−13.000	−612.608	253.637	−271.523
−14.000	1177.367	233.829	−383.703

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -13.00 and -14.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-13.383	0.000	246.716	-314.076

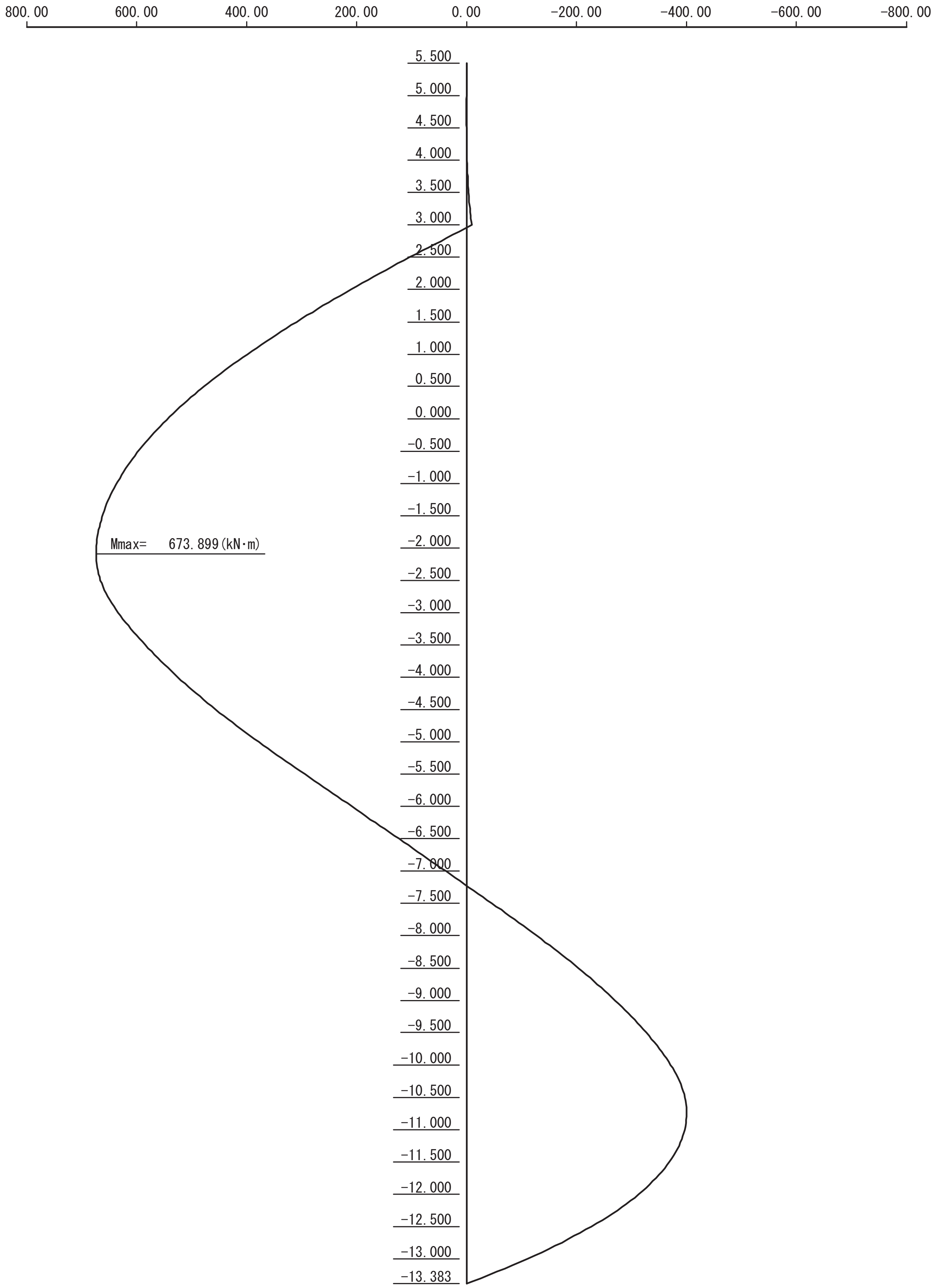
Embedded length of the pipe wall : L = 1.2 × (-5.000 + 13.383) = 10.060 m
Toe elevation : D = -5.000 – 10.060 = -15.060 m
Reaction force at tie setting point : 246.716 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	0.000	0.000
4.500	0.000	0.000
4.000	-0.837	-3.565
3.550	-3.375	-7.894
3.050	-8.944	-14.921
3.000	-9.712	-15.802
2.500	103.230	220.310
2.000	210.056	206.454
1.500	309.142	189.345
1.000	398.859	168.984
0.500	477.583	145.370
0.430	487.635	141.804
-0.070	552.052	115.745
-0.570	603.258	88.958
-1.070	640.889	61.444
-1.570	664.581	33.203
-2.000	673.531	8.333
-2.500	665.787	-39.598
-3.000	633.641	-89.279
-3.500	584.187	-108.535
-4.000	525.106	-127.791
-4.500	456.396	-147.047
-5.000	378.059	-166.303
-5.500	293.989	-169.684
-6.000	208.666	-171.315
-6.500	122.966	-171.196
-7.000	37.762	-169.327
-7.500	-46.070	-165.708
-8.000	-127.655	-160.339
-8.500	-203.576	-142.970
-9.000	-270.250	-123.351
-9.500	-326.552	-101.482
-10.000	-371.357	-77.363
-10.500	-397.290	-25.994
-11.000	-396.976	27.625
-11.500	-369.290	83.494
-12.000	-313.107	141.613
-12.500	-227.302	201.982
-13.000	-110.750	264.601
-13.383	0.000	314.076

Maximum bending moment : 673.899 kN-m/m
Elevation of maximum bending moment : -2.088 m
Depth of 1st steady point (moment=0) : -7.224 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

M_p = FOS×M_a

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of FOS×M_a

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_a (kN-m/m)
─	5.50	1/2x 0.000x 1.000	0.000	-2.167	0.000	
─	4.50	1/2x 0.000x 1.000	0.000	-1.833	0.000	0.000
1	4.50	1/2x 5.820x 0.950	2.764	-1.183	-3.270	
2	3.55	1/2x 10.800x 0.950	5.130	-0.867	-4.448	-9.262
3	3.55	1/2x 10.800x 0.550	2.970	-0.367	-1.090	
4	3.00	1/2x 17.955x 0.550	4.938	-0.183	-0.904	-11.655
5	3.00	1/2x 17.955x 2.570	23.072	0.857	19.773	
6	0.43	1/2x 51.391x 2.570	66.037	1.713	113.121	147.818
7	0.43	1/2x 51.391x 2.430	62.440	3.380	211.047	
8	-2.00	1/2x 58.462x 2.430	71.031	4.190	297.620	758.218
9	-2.00	1/2x 94.112x 1.000	47.056	5.333	250.950	
10	-3.00	1/2x 101.112x 1.000	50.556	5.667	286.501	1403.159
11	-3.00	1/2x 38.512x 2.000	38.512	6.667	256.760	
12	-5.00	1/2x 38.512x 2.000	38.512	7.333	282.408	2050.161
13	-5.00	1/2x 38.512x 3.000	57.768	9.000	519.912	
14	-8.00	1/2x 38.512x 3.000	57.768	10.000	577.680	3367.271
15	-8.00	1/2x 38.512x 2.000	38.512	11.667	449.320	
16	-10.00	1/2x 38.512x 2.000	38.512	12.333	474.968	4476.417
17	-10.00	1/2x 38.512x 5.000	96.280	14.667	1412.139	
18	-15.00	1/2x 38.512x 5.000	96.280	16.333	1572.541	8058.033
19	-15.00	1/2x 38.512x 11.000	211.816	21.667	4589.417	
20	-26.00	1/2x 38.512x 11.000	211.816	25.333	5365.935	20004.455

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

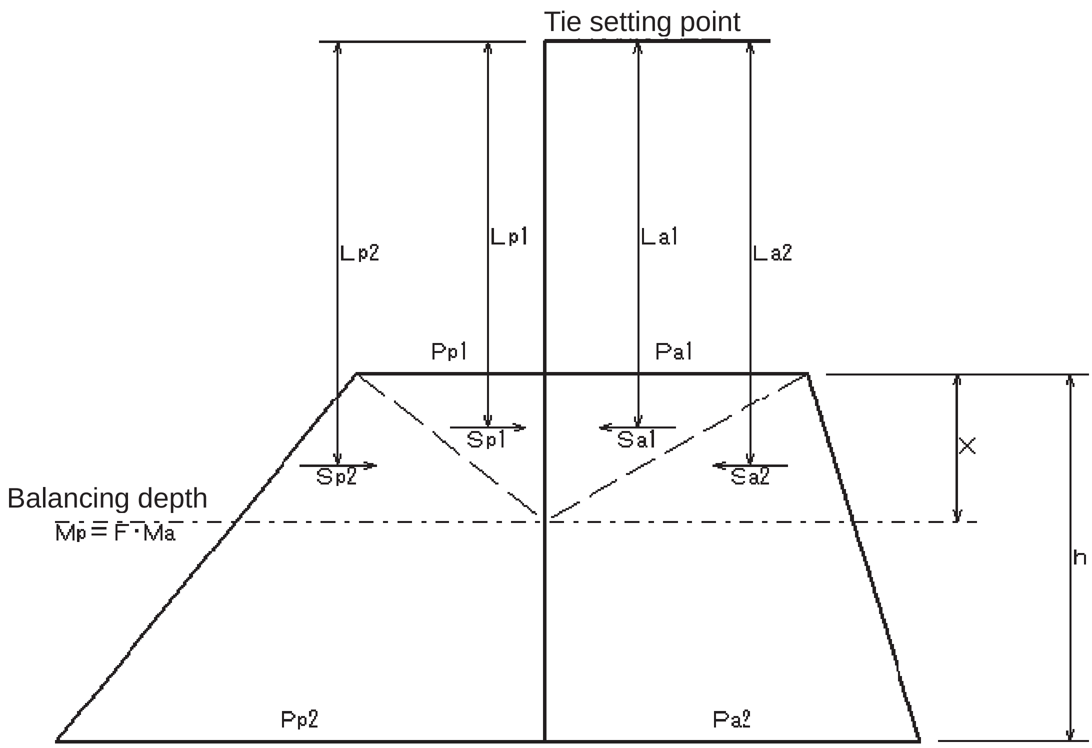
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-5.00	1/2x 30.000x 3.000	45.000	9.000	405.000	
2	-8.00	1/2x 51.000x 3.000	76.500	10.000	765.000	1170.000
3	-8.00	1/2x 71.000x 2.000	71.000	11.667	828.357	
4	-10.00	1/2x 89.000x 2.000	89.000	12.333	1097.637	3095.994
5	-10.00	1/2x 139.000x 5.000	347.500	14.667	5096.782	
6	-15.00	1/2x 184.000x 5.000	460.000	16.333	7513.180	15705.956
7	-15.00	1/2x 164.000x 11.000	902.000	21.667	19543.634	
8	-26.00	1/2x 246.500x 11.000	1355.750	25.333	34345.215	69594.805

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1}X}{2}\ , \quad L_{a(p)1} = L + \frac{1}{3}X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \frac{P_{a(p)2} - P_{a(p)1}}{h} X\right] X}{2}, \quad L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

$M_{a(p)}$: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)

$M_{a(p)1}$: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)

$M_{a(p)1'}$: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)

$M_{a(p)2'}$: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)

$S_{a(p)1}$: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)

$S_{a(p)2}$: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)

$L_{a(p)1}$: the arm length of $S_{a(p)1}$ from the tie setting point (m)

$L_{a(p)2}$: the arm length of $S_{a(p)2}$ from the tie setting point (m)

$P_{a(p)1}$: the active (passive) side pressure at the top elevation of the soil layer (kPa)

$P_{a(p)1}$: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)

h : the thickness of the soil layer (m)

L : the vertical distance from the tie setting point to the top elevation of the soil layer (m)

X : the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -10.00 m FOS×M_{a1} = 4476.417 > M_{p1} = 3095.994
at -15.00 m FOS×M_{a2} = 8058.033 < M_{p2} = 15705.956

[Moment on active side]

$$S_{a1} = \frac{38.512X}{2} = 19.256X \;,\quad L_{a1} = 13.00 + \frac{1}{3}X$$

$$M_{a1'} = 6.419X^2 + 250.328X$$

$$S_{a2} = \frac{\left[38.512 + \frac{38.512 - 38.512}{5.000}X\right]X}{2} = 0.000X^2 + 19.256X \;,\quad L_{a2} = 13.000 + \frac{2}{3}X$$

$$M_{a2'} = 0.000X^3 + 12.837X^2 + 250.328X$$

$$M_a = 0.000X^3 + 19.256X^2 + 500.656X + 3730.348$$

[Moment on passive side]

$$S_{p1} = \frac{139.000X}{2} = 69.500X \;,\quad L_{p1} = 13.000 + \frac{1}{3}X$$

$$M_{p1'} = 23.167X^2 + 903.500X$$

$$S_{p2} = \frac{\left[139.000 + \frac{184.000 - 139.000}{5.000}X\right]X}{2} = 4.500X^2 + 69.500X \;,\quad L_{p2} = 13.000 + \frac{2}{3}X$$

$$M_{p2'} = 3.000X^3 + 104.833X^2 + 903.500X$$

$$M_p = 3.000X^3 + 128.000X^2 + 1807.000X + 3095.994$$

[Balancing depth]

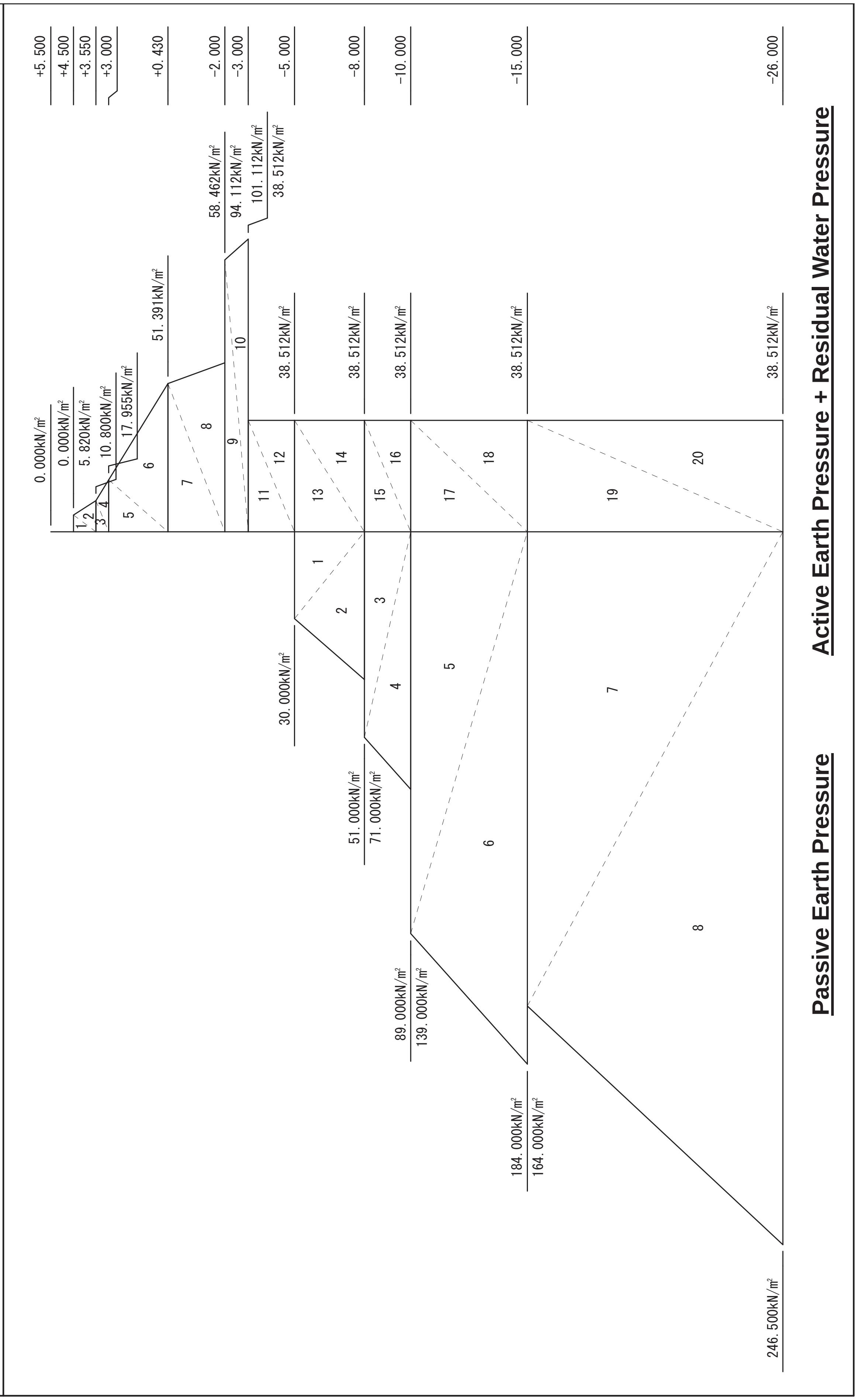
$$FOS \cdot M_a = M_p$$

$$1.2 \times (0.000X^3 + 19.256X^2 + 500.656X + 3730.348)$$
$$= 3.000X^3 + 128.000X^2 + 1807.000X + 3095.994$$

X= 1.046 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -10.000 – 1.046 = -11.046 m

Earth Pressure and Water Pressure



(2) Calculation of maximum bending moment

1) External forces

Elev (m)	$P_a + P_w$ (kN/m^2)	P_p (kN/m^2)	$P_a - P_p$ (kN/m^2)
5.50 4.50	0.000 0.000	——— ———	0.000 0.000
4.50 3.55	5.820 10.800	——— ———	5.820 10.800
3.55 3.00	10.800 17.955	——— ———	10.800 17.955
3.00 0.43	17.955 51.391	——— ———	17.955 51.391
0.43 -2.00	51.391 58.462	——— ———	51.391 58.462
-2.00 -3.00	94.112 101.112	——— ———	94.112 101.112
-3.00 -5.00	38.512 38.512	——— ———	38.512 38.512
-5.00 -8.00	38.512 38.512	30.000 51.000	8.512 -12.488
-8.00 -10.00	38.512 38.512	71.000 89.000	-32.488 -50.488
-10.00 -15.00	38.512 38.512	139.000 184.000	-100.488 -145.488
-15.00 -26.00	38.512 38.512	164.000 246.500	-125.488 -207.988

2) Virtual seabed level

The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -5.00 m $P_{a1} = 38.512 \quad > \quad P_{p1} = 30.000$
at -8.00 m $P_{a2} = 38.512 \quad < \quad P_{p2} = 51.000$

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

- EL_{top} : the top elevation of the soil layer in question (m)
- P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)
- P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)
- P_{p1} : the passive earth pressure at the top of the soil layer (kPa)
- P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)
- h : the thickness of the soil layer (m)

$$X = -5.00 - \frac{3.00 \times (30.000 - 38.512)}{(38.512 - 38.512) - (51.000 - 30.000)} = -6.216m$$

Accordingly, the virtual seabed level is obtained as -6.216m.

3) Moment about tie setting point

No	Calculation	S (kN/m)	L (m)	M (kN-m/m)
1	1/2x 5.820x 0.950	2.764	-1.183	-3.270
2	1/2x 10.800x 0.950	5.130	-0.867	-4.448
3	1/2x 10.800x 0.550	2.970	-0.367	-1.090
4	1/2x 17.955x 0.550	4.938	-0.183	-0.904
5	1/2x 17.955x 2.570	23.072	0.857	19.773
6	1/2x 51.391x 2.570	66.037	1.713	113.121
7	1/2x 51.391x 2.430	62.440	3.380	211.047
8	1/2x 58.462x 2.430	71.031	4.190	297.620
9	1/2x 94.112x 1.000	47.056	5.333	250.950
10	1/2x 101.112x 1.000	50.556	5.667	286.501
11	1/2x 38.512x 2.000	38.512	6.667	256.760
12	1/2x 38.512x 2.000	38.512	7.333	282.408
13	1/2x 8.512x 1.216	5.175	8.405	43.496
Total		418.193	——	1751.964

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

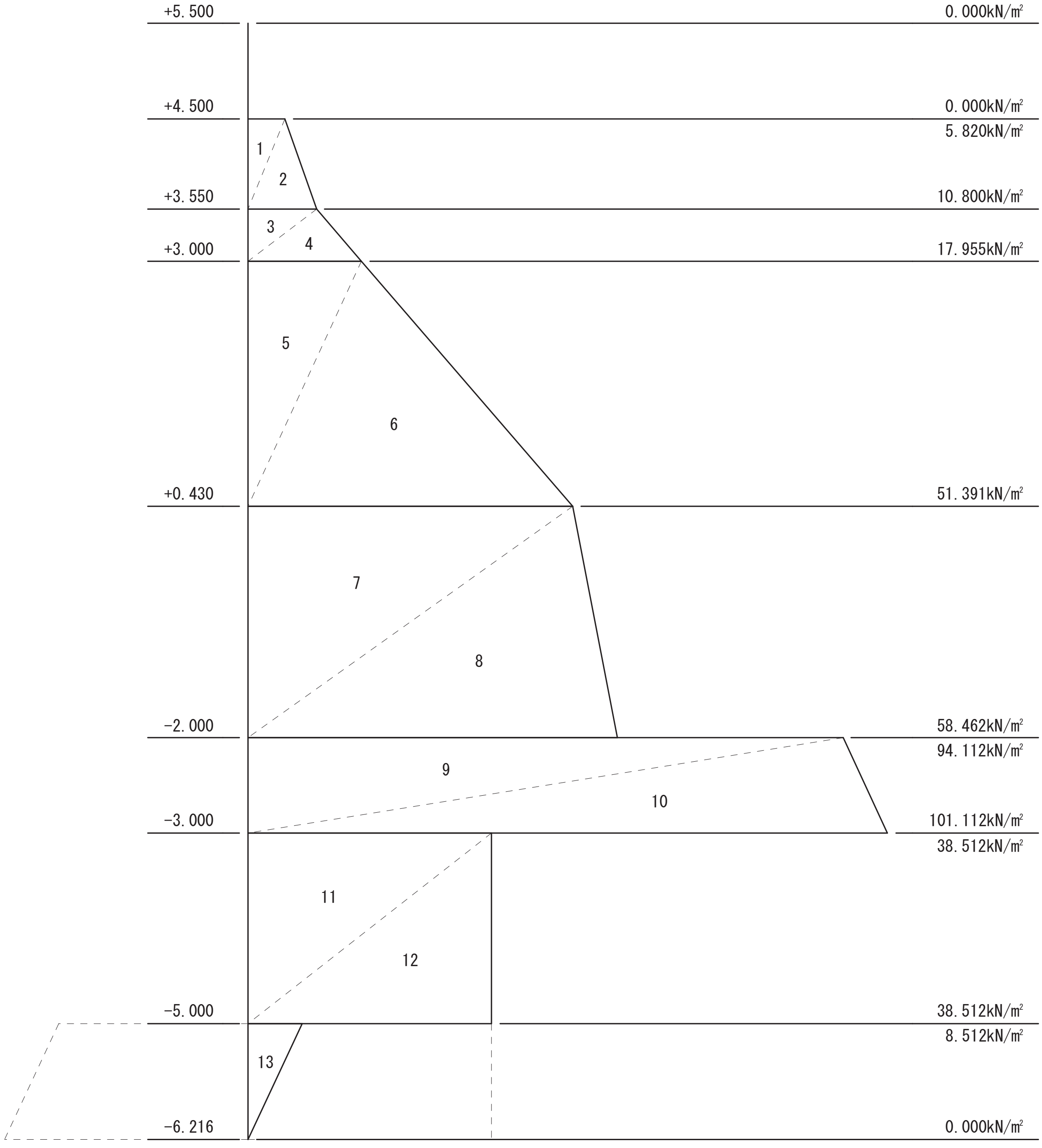
4) Reaction forces

Distance between supports : L_T = 3.000 – (-6.216) = 9.216 m

Reaction at virtual seabed : $R_0 = \frac{\Sigma M}{L_T} = \frac{1751.964}{9.216} = 190.100 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 418.193 - 190.100 = 228.093 kN/m$

External Force Diagram



Passive
Earth Pressure

Active Earth Pressure
+ Residual Water Pressure

5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 4.50	0.000 0.000	0.000		0.000
4.50 3.55	2.764 5.130	7.894		-7.894
3.55 3.00	2.970 4.938	15.802	228.093	212.291
3.00 0.43	23.072 66.037	104.911	228.093	123.182
0.43 -2.00	62.440 71.031	238.382	228.093	-10.289
-2.00 -3.00	47.056 50.556	335.994	228.093	-107.901
-3.00 -5.00	38.512 38.512	413.018	228.093	-184.925
-5.00 -6.22	5.175 0.000	418.193	228.093	-190.100

Shear force Q = A_p - ∑S

The above table suggests that the shear force zero point exists in between 0.430m and -2.000m.

$$Q = 123.182 - \frac{[51.391 + (51.391 + 2.910X)]X}{2} = 0$$

X = 2.253 m

Shear force zero point : DL = 0.430 – 2.253 = -1.823m

6) Calculation of moment

No	Calculation	S (kN/m)	L (m)	M (kN-m/m)
1	1/2x 5.820x 0.950	-2.764	6.006	-16.601
2	1/2x 10.800x 0.950	-5.130	5.690	-29.190
3	1/2x 10.800x 0.550	-2.970	5.190	-15.414
4	1/2x 17.955x 0.550	-4.938	5.006	-24.720
5	1/2x 17.955x 2.570	-23.072	3.966	-91.504
6	1/2x 51.391x 2.570	-66.037	3.110	-205.375
7	1/2x 51.391x 2.253	-57.892	1.502	-86.954
8	1/2x 57.947x 2.253	-65.277	0.751	-49.023
Total		———	———	-518.781

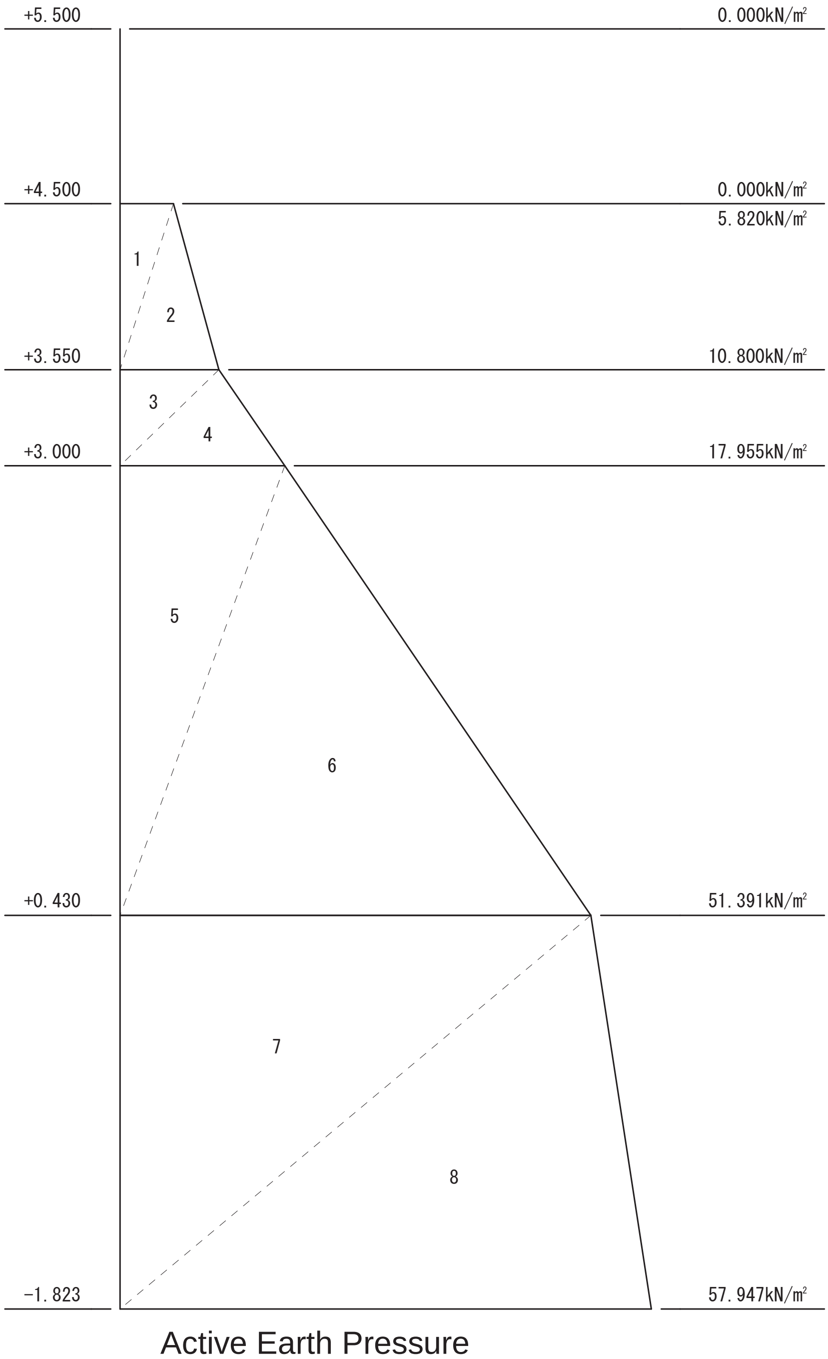
where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

7) Maximum bending moment

- Distance of the shear zero point to the tie setting point
  h = 3.000 – (-1.823) = 4.823 m

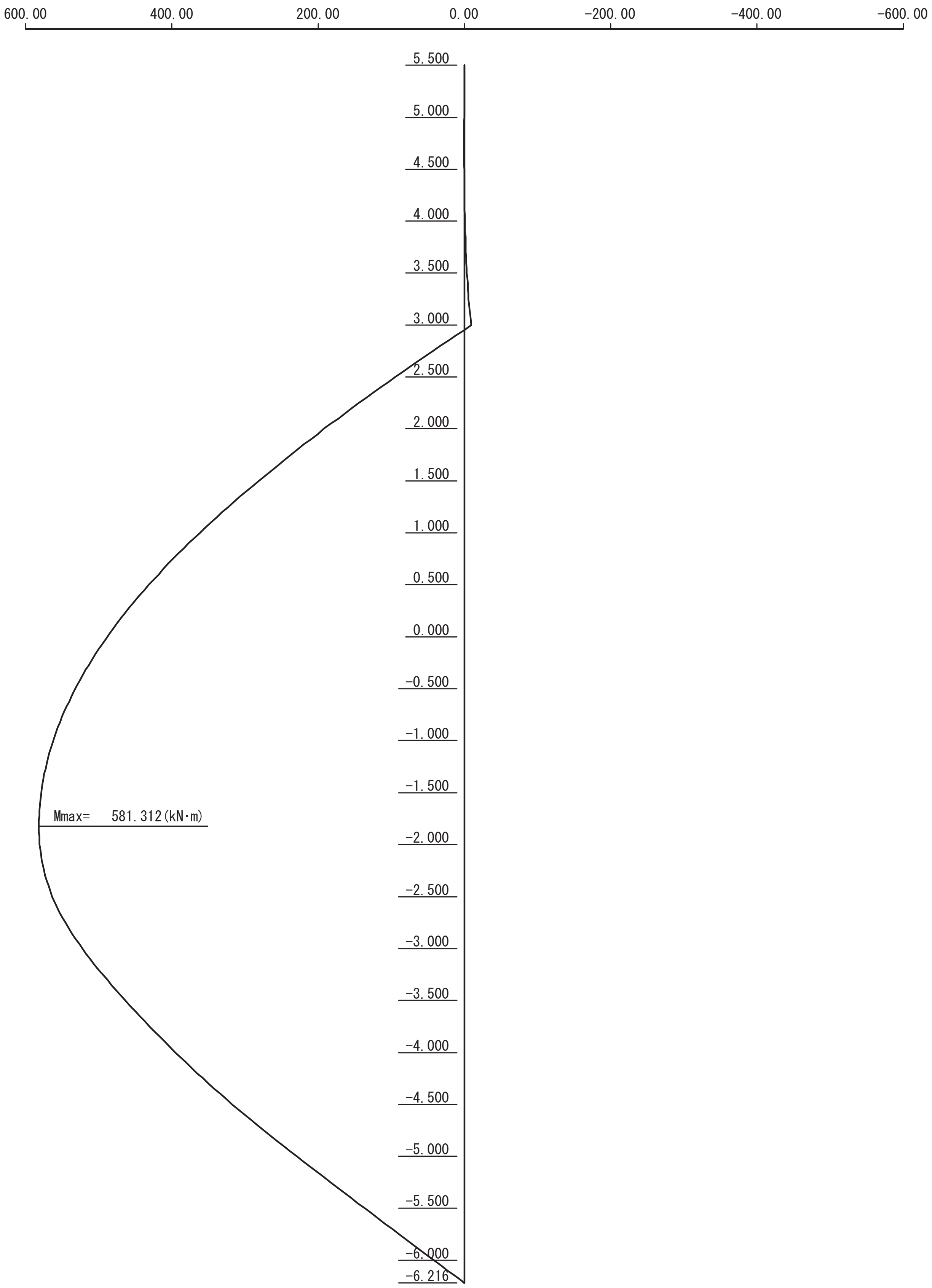
- Maximum bending moment
  $M_{max} = A_p \times h + \sum M = 228.093 \times 4.823 - 518.781 = 581.312$ kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type	: ϕ800 × t14 (P-T joint)
Modulus of elasticity	: E = 200.0 kN/mm^2
Moment of inertia	: I = 267050 cm^4
Section modulus	: Z = 6676 cm^3

Section property (per 1m) before corrosion

- Spacing of pipes	: Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia	: I = 272500 cm^4/m
- Section modulus	: Z = 6812 cm^3/m

Section property (per 1m) after corrosion

- Design life time	: 50 years
- Effect of cathodic protection	: 90%
- Corrosion rate	: 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance	: t = 0.030 × 50 years = 1.50 mm
- Spacing of pipes	: Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia	: I = 241898 cm^4/m
- Section modulus	: Z = 6070 cm^3/m

(2) Embedded depth of pipe wall

Toe level of the pipe wall is obtained as follows:

- Deflection curve method	: -15.060 m --- adopted
- Free earth support method	: -11.046 m

Therefore, the minimum length of the pipe wall is;

L = 3.500 – (-15.060) = 18.560m → 19.000 m

Accordingly the design toe level of the pipe wall is;

EL = +3.500 – 19.000 = -15.500 m

(3) Stress on pipe wall section

Maximum bending moment on the pipe wall is as follows:

- Deflection curve method	: 673.899 kN-m/m --- adopted
- Free earth support method	: 581.312 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{673.899\times10^6}{6070\times10^3} = 111.0MPa \quad \leq \quad \sigma_a = 140MPa \;\; .... \; OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

T	is the tension force on tie wire (kN/wire)
A_p	is the reaction force of the pipe wall at tie setting point (kN/m)
L	is the spacing of the tie wire (m)
θ_1	is the vertical angle of the tie wire to horizontal (deg.)
θ_2	is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 246.716 kN-m/m --- adopted
- Free earth support method : 228.093 kN-m/m

T = 246.716 × 1.960 × sec(0.000) × sec (0.000) = 483.563 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 362.673 × 3.8 = 1837.539 kN/wire

Tie wire shall have minimum tensile strength of 1838 kN.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max} is the maximum bending moment on the waling beam (kN-m)
T is the tension force on tie wire (kN/wire)
L is the spacing of the tie wire (m)

$$M_{maz} = \frac{483.563 \times 1.960}{10.0} = 94.778 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[300×90×10.0×15.5

Steel grade : SS400
Section modulus : Z = 494.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \leq \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{94.778 \times 10^6}{2 \times 494.0 \times 10^3} = 95.9 MPa \quad \leq \quad \sigma_a = 140 MPa \ \ .... \ OK$$

Output of Design Software for Anchor Wall (During Construction) – Revetment Block a

1. Design Conditions

1-1 Dimensions

Ground elevation	+4.50 m
Top of cope concrete	+5.50 m
Top of pipe wall	+3.50 m
Tie elevation	+3.00 m
Seabed elevation	-2.00 m
Angle of seabed slope	18.4°

1-2 Tide Levels

H.W.L	+3.55 m
L.W.L	+0.43 m

1-3 Residual Water Level

R.W.L	+3.55 m

1-4 Base Elevation of Cohesion Increment +0.00 m (not used)

1-5 Surcharge Load

(Active side)	20 kPa
(Passive side)	0 kPa

1-6 Unit Weight of Water 10.10 kN/m^3

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

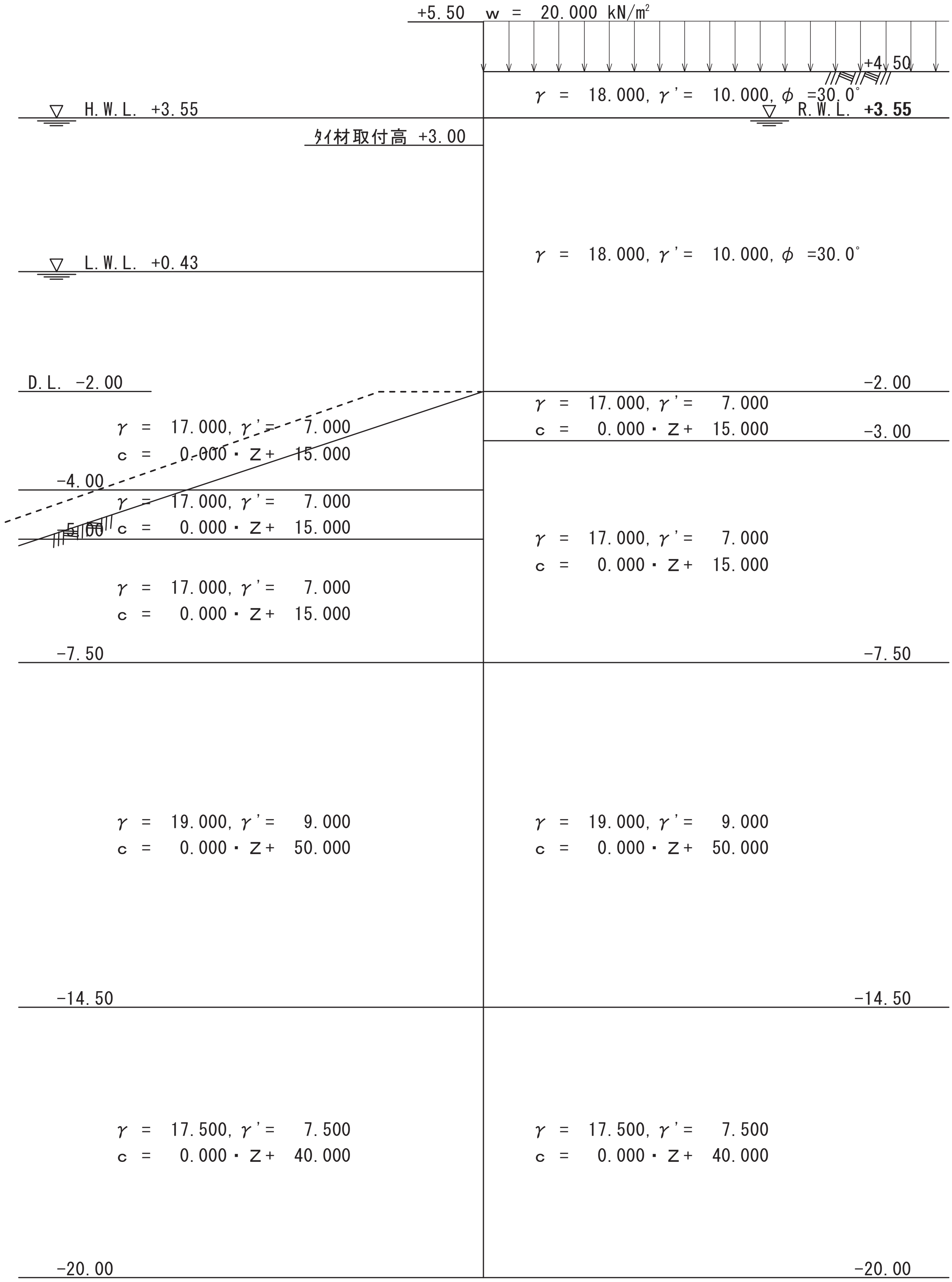
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	:	Deflection Curve Method
Calculation Method 2	:	Free Earth Support Method
Factor of Safety	:	FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
4.50 3.55	0.95	5.820 10.800
3.55 3.00	0.55	10.800 12.400
3.00 -2.00	5.00	12.400 26.950
-2.00 -3.00	1.00	62.600 69.600
-3.00 -7.50	4.50	7.000 7.000
-7.50 -12.00	4.50	7.000 7.000
-12.00 -14.50	2.50	7.000 7.000
-14.50 -20.00	5.50	7.000 7.000

(2) Residual water pressure

$p_w = \gamma_w \times h_w$

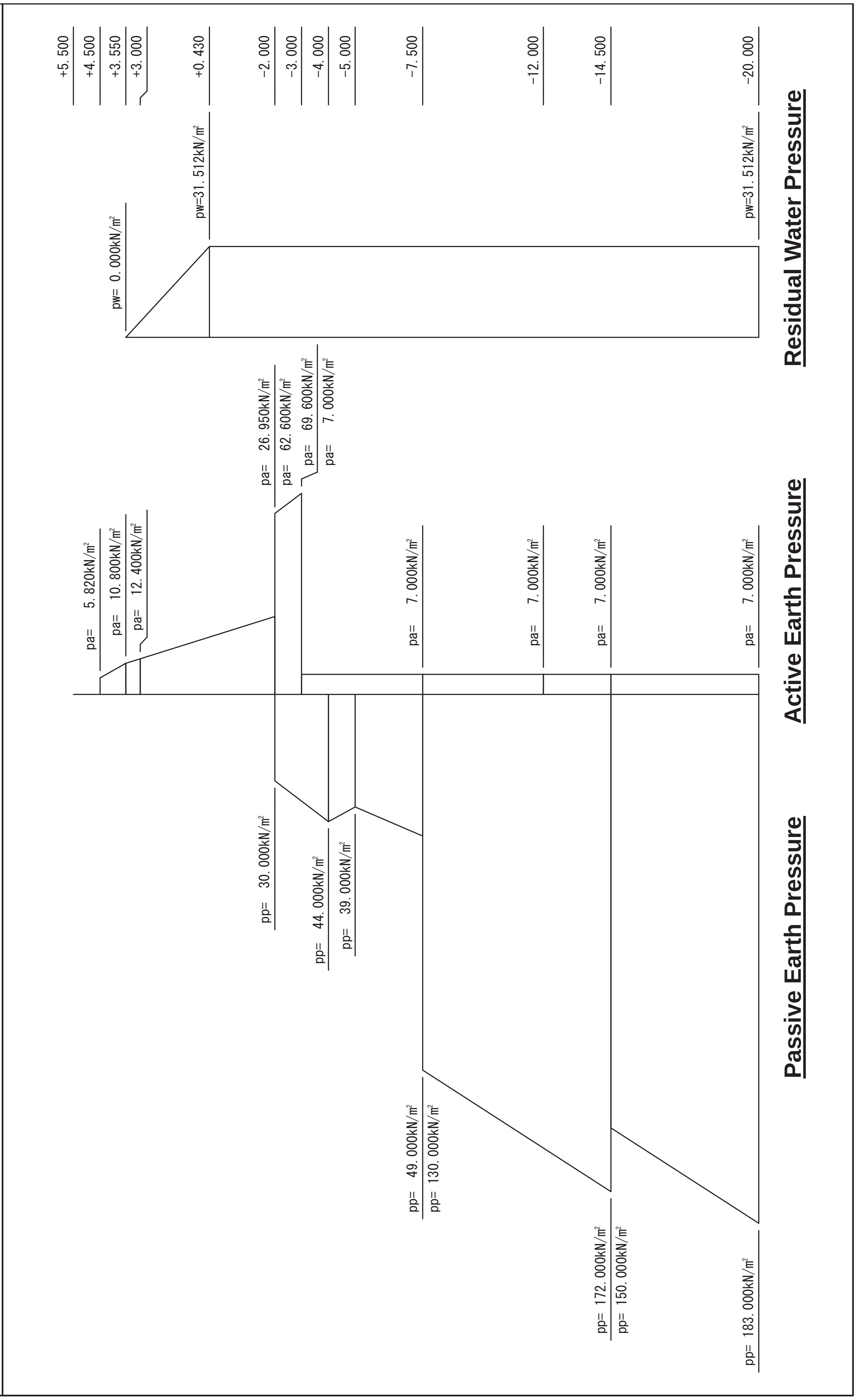
where; p_w is the residual water pressure (kPa)
h_w is the height of the tidal lag (m)
γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-2.00 -4.00	2.00	30.000 44.000
-4.00 -5.00	1.00	44.000 39.000
-5.00 -7.50	2.50	39.000 49.000
-7.50 -14.50	7.00	130.000 172.000
-14.50 -20.00	5.50	150.000 183.000

Earth Pressure and Water Pressure



(4) Summary of Forces on the Wall

Elev (m)	Active side (kPa) $P_a + P_w$	Passive side(kPa) P_p
5.50 4.50	0.000+ 0.000= 0.000 0.000+ 0.000= 0.000	―――― ――――
4.50 3.55	5.820+ 0.000= 5.820 10.800+ 0.000= 10.800	―――― ――――
3.55 3.00	10.800+ 0.000= 10.800 12.400+ 5.555= 17.955	―――― ――――
3.00 0.43	12.400+ 5.555= 17.955 19.879+ 31.512= 51.391	―――― ――――
0.43 -2.00	19.879+ 31.512= 51.391 26.950+ 31.512= 58.462	―――― ――――
-2.00 -3.00	62.600+ 31.512= 94.112 69.600+ 31.512= 101.112	30.000 37.000
-3.00 -4.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	37.000 44.000
-4.00 -5.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	44.000 39.000
-5.00 -7.50	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	39.000 49.000
-7.50 -12.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	130.000 157.000
-12.00 -14.50	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	157.000 172.000
-14.50 -20.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	150.000 183.000

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -2.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
-2.000	-239.109	112.012	126.370
-3.000	-446.199	138.417	164.077
-4.000	-686.260	161.798	138.708
-5.000	-899.495	178.897	118.621
-6.000	-1095.816	191.976	103.054
-7.000	-1271.134	201.990	86.552
-8.000	-1378.909	208.488	28.816
-9.000	-1187.951	206.869	-67.053
-10.000	-633.294	197.770	-161.442
-11.000	321.991	182.363	-255.523

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -10.00 and -11.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-10.709	0.000	187.448	-228.100

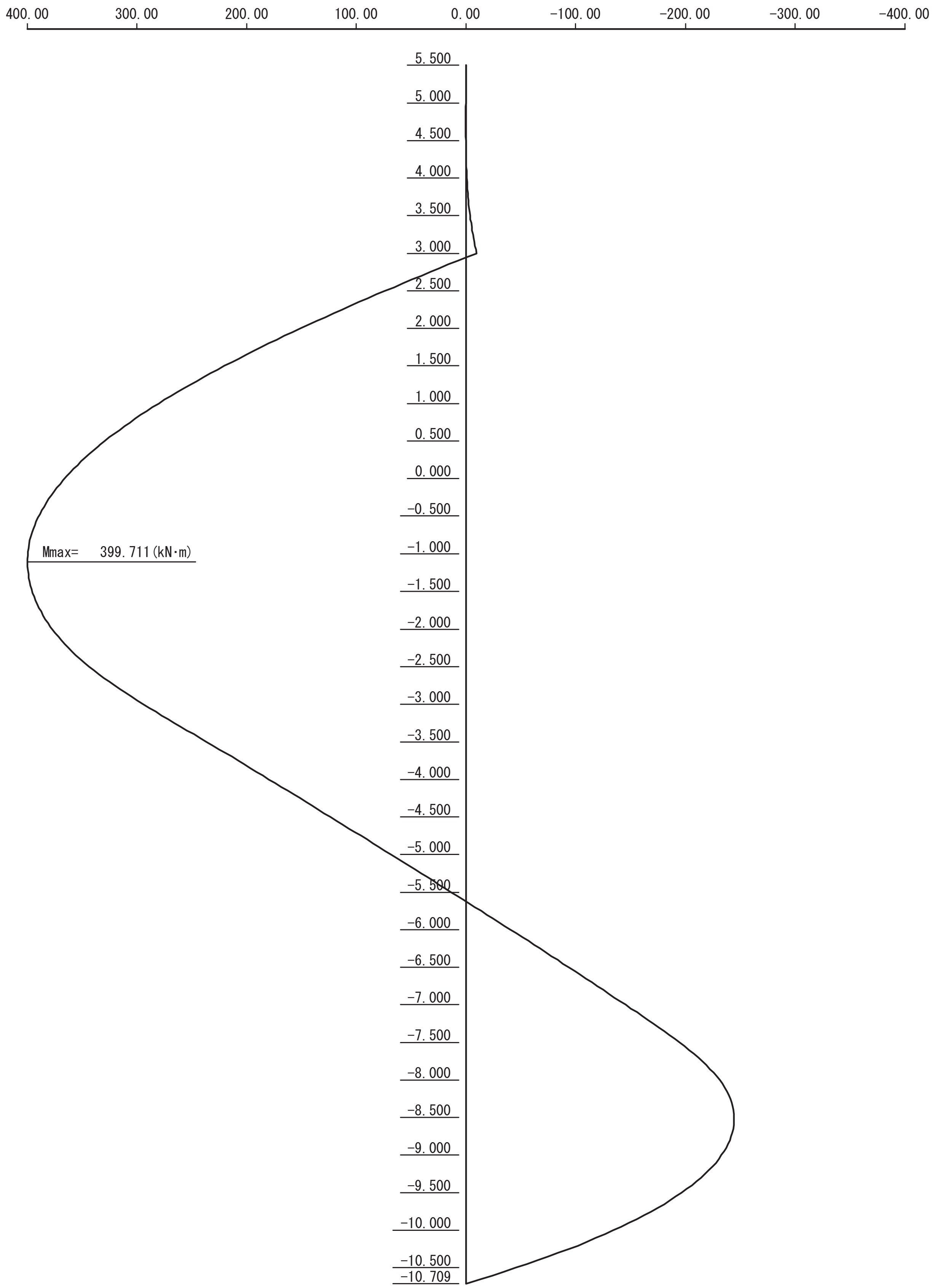
Embedded length of the pipe wall : L = 1.2 × (-2.000 + 10.709) = 10.451 m
Toe elevation : D = -2.000 – 10.451 = -12.451 m
Reaction force at tie setting point : 187.448 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	0.000	0.000
4.500	0.000	0.000
4.000	-0.837	-3.565
3.550	-3.375	-7.894
3.050	-8.944	-14.921
3.000	-9.712	-15.802
2.500	73.596	161.042
2.000	150.788	147.186
1.500	220.240	130.077
1.000	280.323	109.716
0.500	329.413	86.102
0.430	335.316	82.536
-0.070	370.100	56.477
-0.570	391.672	29.690
-1.070	399.669	2.176
-1.570	393.727	-26.065
-2.000	377.191	-50.935
-2.500	343.709	-82.991
-3.000	294.200	-115.047
-3.500	236.633	-114.928
-4.000	179.563	-113.059
-4.500	123.615	-110.940
-5.000	68.415	-110.071
-5.500	13.524	-109.327
-6.000	-40.746	-107.583
-6.500	-93.893	-104.839
-7.000	-145.418	-101.095
-7.500	-194.821	-96.351
-8.000	-231.436	-49.857
-8.500	-244.429	-1.863
-9.000	-233.049	47.631
-9.500	-196.548	98.625
-10.000	-134.174	151.119
-10.500	-45.179	205.113
-10.709	0.000	228.100

Maximum bending moment : 399.711 kN-m/m
Elevation of maximum bending moment : -1.109 m
Depth of 1st steady point (moment=0) : -5.624 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

M_p = FOS×M_a

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of FOS×M_a

NO	Elev (m)	Calculation			S (kN/m)	L (m)	M (kN-m/m)	FOS×M_a (kN-m/m)
—	5.50	1/2x	0.000x	1.000	0.000	-2.167	0.000	
—	4.50	1/2x	0.000x	1.000	0.000	-1.833	0.000	0.000
1	4.50	1/2x	5.820x	0.950	2.764	-1.183	-3.270	
2	3.55	1/2x	10.800x	0.950	5.130	-0.867	-4.448	-9.262
3	3.55	1/2x	10.800x	0.550	2.970	-0.367	-1.090	
4	3.00	1/2x	17.955x	0.550	4.938	-0.183	-0.904	-11.655
5	3.00	1/2x	17.955x	2.570	23.072	0.857	19.773	
6	0.43	1/2x	51.391x	2.570	66.037	1.713	113.121	147.818
7	0.43	1/2x	51.391x	2.430	62.440	3.380	211.047	
8	-2.00	1/2x	58.462x	2.430	71.031	4.190	297.620	758.218
9	-2.00	1/2x	94.112x	1.000	47.056	5.333	250.950	
10	-3.00	1/2x	101.112x	1.000	50.556	5.667	286.501	1403.159
11	-3.00	1/2x	38.512x	1.000	19.256	6.333	121.948	
12	-4.00	1/2x	38.512x	1.000	19.256	6.667	128.380	1703.553
13	-4.00	1/2x	38.512x	1.000	19.256	7.333	141.204	
14	-5.00	1/2x	38.512x	1.000	19.256	7.667	147.636	2050.161
15	-5.00	1/2x	38.512x	2.500	48.140	8.833	425.221	
16	-7.50	1/2x	38.512x	2.500	48.140	9.667	465.369	3118.869
17	-7.50	1/2x	38.512x	4.500	86.652	12.000	1039.824	
18	-12.00	1/2x	38.512x	4.500	86.652	13.500	1169.802	5770.420
19	-12.00	1/2x	38.512x	2.500	48.140	15.833	762.201	
20	-14.50	1/2x	38.512x	2.500	48.140	16.667	802.349	7647.880
21	-14.50	1/2x	38.512x	5.500	105.908	19.333	2047.519	
22	-20.00	1/2x	38.512x	5.500	105.908	21.167	2241.755	12795.009

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

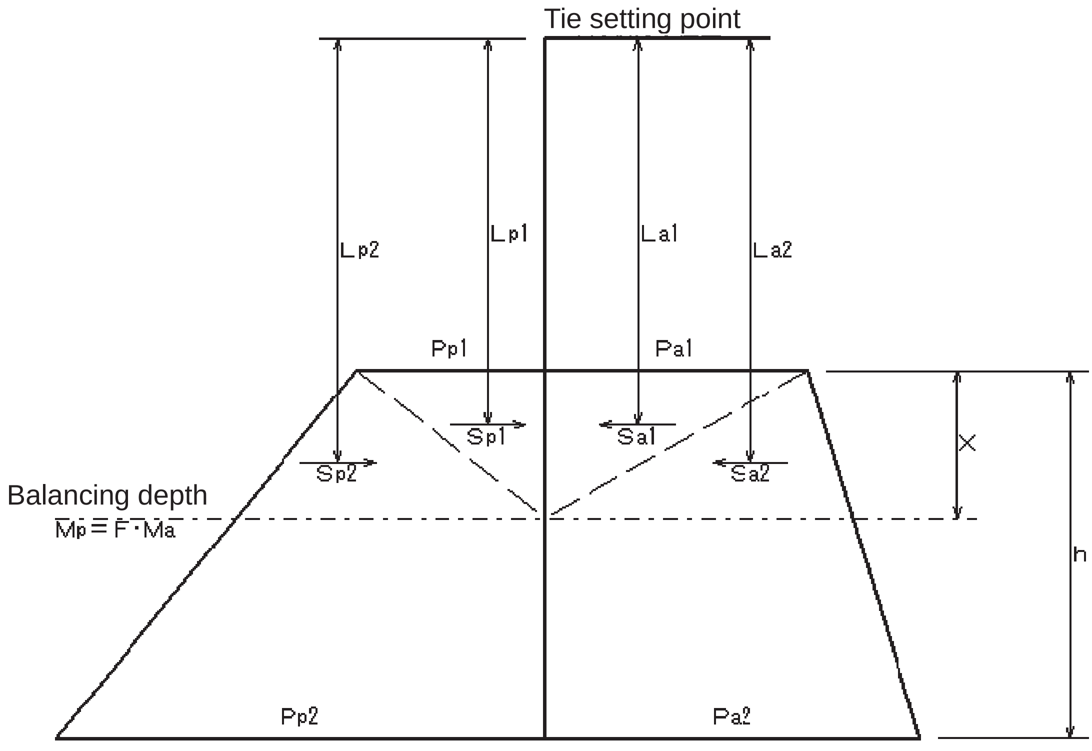
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-2.00	1/2x 30.000x 1.000	15.000	5.333	79.995	
2	-3.00	1/2x 37.000x 1.000	18.500	5.667	104.840	184.835
3	-3.00	1/2x 37.000x 1.000	18.500	6.333	117.160	
4	-4.00	1/2x 44.000x 1.000	22.000	6.667	146.674	448.669
5	-4.00	1/2x 44.000x 1.000	22.000	7.333	161.326	
6	-5.00	1/2x 39.000x 1.000	19.500	7.667	149.506	759.501
7	-5.00	1/2x 39.000x 2.500	48.750	8.833	430.609	
8	-7.50	1/2x 49.000x 2.500	61.250	9.667	592.104	1782.214
9	-7.50	1/2x 130.000x 4.500	292.500	12.000	3510.000	
10	-12.00	1/2x 157.000x 4.500	353.250	13.500	4768.875	10061.089
11	-12.00	1/2x 157.000x 2.500	196.250	15.833	3107.226	
12	-14.50	1/2x 172.000x 2.500	215.000	16.667	3583.405	16751.720
13	-14.50	1/2x 150.000x 5.500	412.500	19.333	7974.862	
14	-20.00	1/2x 183.000x 5.500	503.250	21.167	10652.293	35378.875

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1}X}{2}\ , \quad L_{a(p)1} = L + \frac{1}{3}X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \frac{P_{a(p)2} - P_{a(p)1}}{h} X \right] X}{2} \ , \quad L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

- $M_{a(p)}$: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)
- $M_{a(p)1}$: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)
- $M_{a(p)1'}$: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
- $M_{a(p)2'}$: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
- $S_{a(p)1}$: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
- $S_{a(p)2}$: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
- $L_{a(p)1}$: the arm length of $S_{a(p)1}$ from the tie setting point (m)
- $L_{a(p)2}$: the arm length of $S_{a(p)2}$ from the tie setting point (m)
- $P_{a(p)1}$: the active (passive) side pressure at the top elevation of the soil layer (kPa)
- $P_{a(p)1}$: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)
- h : the thickness of the soil layer (m)
- L : the vertical distance from the tie setting point to the top elevation of the soil layer (m)
- X : the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -7.50 m FOS×M_{a1} = 3118.869 > M_{p1} = 1782.214
at -12.00 m FOS×M_{a2} = 5770.420 < M_{p2} = 10061.089

[Moment on active side]

$$S_{a1} = \frac{38.512X}{2} = 19.256X \;,\;\; L_{a1} = 10.50 + \frac{1}{3}X$$

$$M_{a1'} = 6.419X^2 + 202.188X$$

$$S_{a2} = \frac{\left[38.512 + \frac{38.512 - 38.512}{3.500}X\right]X}{2} = 0.000X^2 + 19.256X \;,\;\; L_{a2} = 10.500 + \frac{2}{3}X$$

$$M_{a2'} = 0.000X^3 + 12.837X^2 + 202.188X$$

$$M_a = 0.000X^3 + 19.256X^2 + 404.376X + 2599.058$$

[Moment on passive side]

$$S_{p1} = \frac{130.000X}{2} = 65.000X \;,\;\; L_{p1} = 10.500 + \frac{1}{3}X$$

$$M_{p1'} = 21.667X^2 + 682.500X$$

$$S_{p2} = \frac{\left[130.000 + \frac{151.000 - 130.000}{3.500}X\right]X}{2} = 3.000X^2 + 65.000X \;,\;\; L_{p2} = 10.500 + \frac{2}{3}X$$

$$M_{p2'} = 2.000X^3 + 74.833X^2 + 682.500X$$

$$M_p = 2.000X^3 + 96.500X^2 + 1365.000X + 1782.214$$

[Balancing depth]

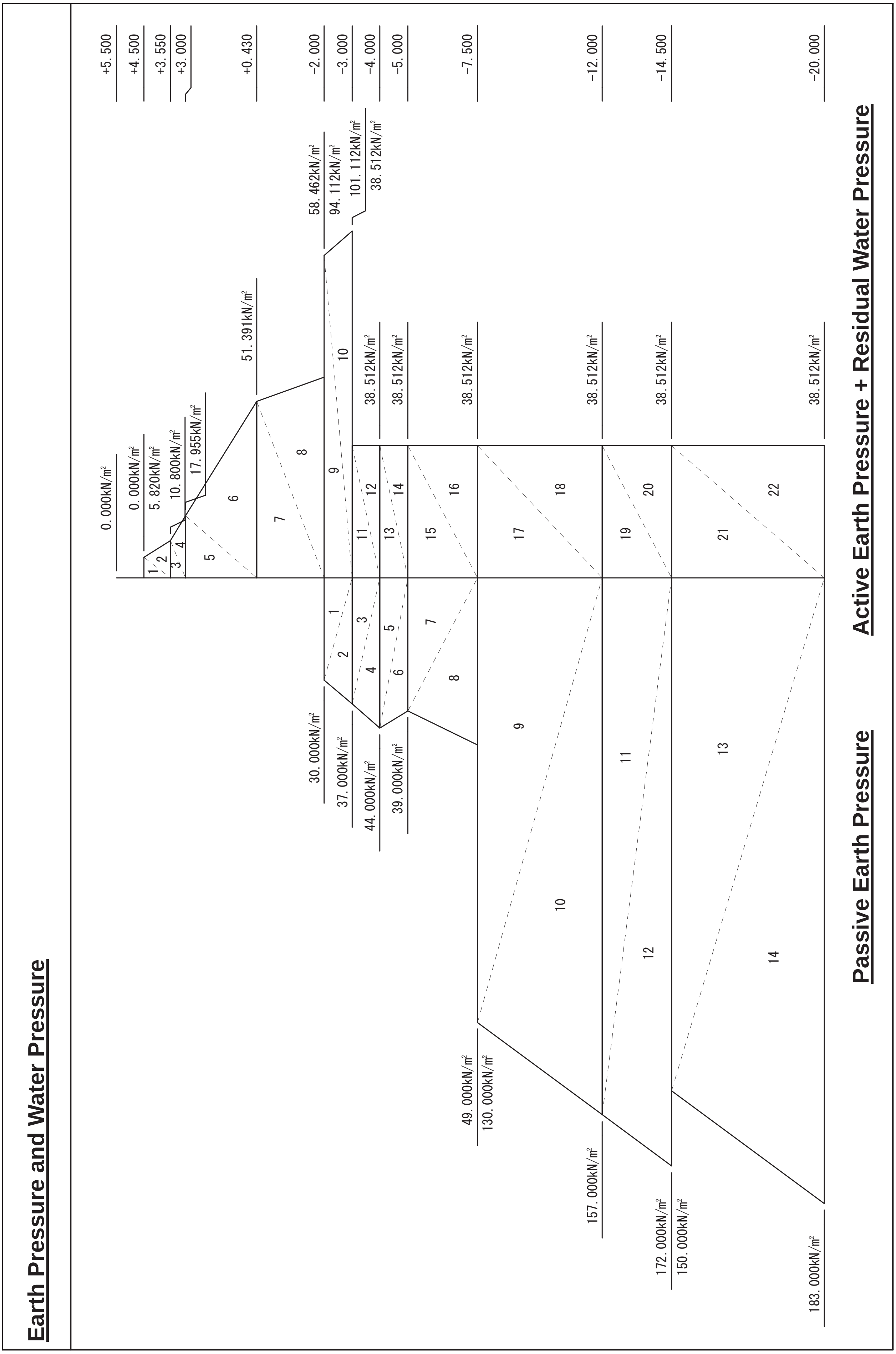
$$FOS \cdot M_a = M_p$$

$$1.2 \times (0.000X^3 + 19.256X^2 + 404.376X + 2599.058)$$

$$= 2.000X^3 + 96.500X^2 + 1365.000X + 1782.214$$

X= 1.359 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -7.500 – 1.359 = -8.859 m



Earth Pressure and Water Pressure
Active Earth Pressure + Residual Water Pressure
Passive Earth Pressure
+5. 500
+4. 500
+3. 550
+3. 000
+0. 430
−2. 000
−3. 000
−4. 000
−5. 000
−7. 500
−12. 000
−14. 500
−20. 000
0. 000kN/m²
0. 000kN/m²
5. 820kN/m²
10. 800kN/m²
17. 955kN/m²
51. 391kN/m²
58. 462kN/m²
94. 112kN/m²
101. 112kN/m²
38. 512kN/m²
38. 512kN/m²
38. 512kN/m²
38. 512kN/m²
38. 512kN/m²
38. 512kN/m²
38. 512kN/m²
38. 512kN/m²
30. 000kN/m²
37. 000kN/m²
44. 000kN/m²
39. 000kN/m²
49. 000kN/m²
130. 000kN/m²
157. 000kN/m²
172. 000kN/m²
150. 000kN/m²
183. 000kN/m²

(2) Calculation of maximum bending moment

1) External forces

Elev (m)	$P_a + P_w$ (kN/m^2)	P_p (kN/m^2)	$P_a - P_p$ (kN/m^2)
5.50 4.50	0.000 0.000	——— ———	0.000 0.000
4.50 3.55	5.820 10.800	——— ———	5.820 10.800
3.55 3.00	10.800 17.955	——— ———	10.800 17.955
3.00 0.43	17.955 51.391	——— ———	17.955 51.391
0.43 -2.00	51.391 58.462	——— ———	51.391 58.462
-2.00 -3.00	94.112 101.112	30.000 37.000	64.112 64.112
-3.00 -4.00	38.512 38.512	37.000 44.000	1.512 -5.488
-4.00 -5.00	38.512 38.512	44.000 39.000	-5.488 -0.488
-5.00 -7.50	38.512 38.512	39.000 49.000	-0.488 -10.488
-7.50 -12.00	38.512 38.512	130.000 157.000	-91.488 -118.488
-12.00 -14.50	38.512 38.512	157.000 172.000	-118.488 -133.488
-14.50 -20.00	38.512 38.512	150.000 183.000	-111.488 -144.488

2) Virtual seabed level

The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -3.00 m $P_{a1} = 38.512 > P_{p1} = 37.000$
at -4.00 m $P_{a2} = 38.512 < P_{p2} = 44.000$

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

- EL_{top} : the top elevation of the soil layer in question (m)
- P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)
- P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)
- P_{p1} : the passive earth pressure at the top of the soil layer (kPa)
- P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)
- h : the thickness of the soil layer (m)

$$X = -3.00 - \frac{1.00 \times (37.000 - 38.512)}{(38.512 - 38.512) - (44.000 - 37.000)} = -3.216m$$

Accordingly, the virtual seabed level is obtained as -3.216m.

3) Moment about tie setting point

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	5.820x	0.950	2.764	-1.183	-3.270
2	1/2x	10.800x	0.950	5.130	-0.867	-4.448
3	1/2x	10.800x	0.550	2.970	-0.367	-1.090
4	1/2x	17.955x	0.550	4.938	-0.183	-0.904
5	1/2x	17.955x	2.570	23.072	0.857	19.773
6	1/2x	51.391x	2.570	66.037	1.713	113.121
7	1/2x	51.391x	2.430	62.440	3.380	211.047
8	1/2x	58.462x	2.430	71.031	4.190	297.620
9	1/2x	64.112x	1.000	32.056	5.333	170.955
10	1/2x	64.112x	1.000	32.056	5.667	181.661
11	1/2x	1.512x	0.216	0.163	6.072	0.990
Total				302.657	———	985.455

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

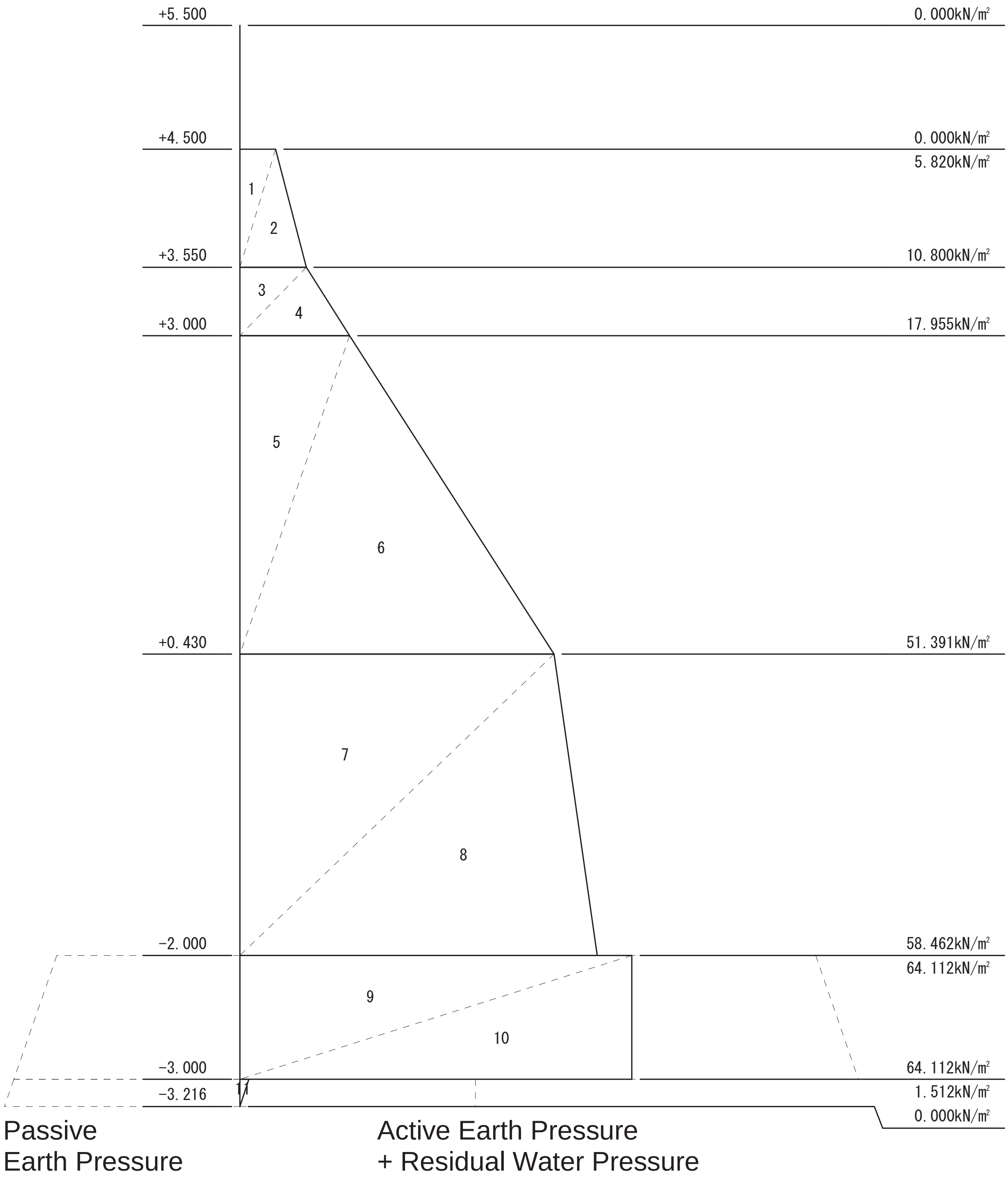
4) Reaction forces

Distance between supports : L_T = 3.000 – (-3.216) = 6.216 m

Reaction at virtual seabed : $R_0 = \frac{\Sigma M}{L_T} = \frac{985.455}{6.216} = 158.535 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 302.657 - 158.535 = 144.122 kN/m$

External Force Diagram



5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 4.50	0.000 0.000	0.000		0.000
4.50 3.55	2.764 5.130	7.894		-7.894
3.55 3.00	2.970 4.938	15.802	144.122	128.320
3.00 0.43	23.072 66.037	104.911	144.122	39.211
0.43 -2.00	62.440 71.031	238.382	144.122	-94.260
-2.00 -3.00	32.056 32.056	302.494	144.122	-158.372
-3.00 -3.22	0.163 0.000	302.657	144.122	-158.535

Shear force $Q = A_p - \sum S$

The above table suggests that the shear force zero point exists in between 0.430m and -1.000m.

$$Q = 39.211 - \frac{[51.391 + (51.391 + 2.910X)]X}{2} = 0$$

X = 0.747 m

Shear force zero point : DL = +0.43 – 0.747 = -0.371m

6) Calculation of moment

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	5.820x	0.950	-2.764	4.500	-12.438
2	1/2x	10.800x	0.950	-5.130	4.184	-21.464
3	1/2x	10.800x	0.550	-2.970	3.684	-10.941
4	1/2x	17.955x	0.550	-4.938	3.500	-17.283
5	1/2x	17.955x	2.570	-23.072	2.460	-56.757
6	1/2x	51.391x	2.570	-66.037	1.604	-105.923
7	1/2x	51.391x	0.747	-19.195	0.498	-9.559
8	1/2x	53.565x	0.747	-20.007	0.249	-4.982
Total				———	———	-239.347

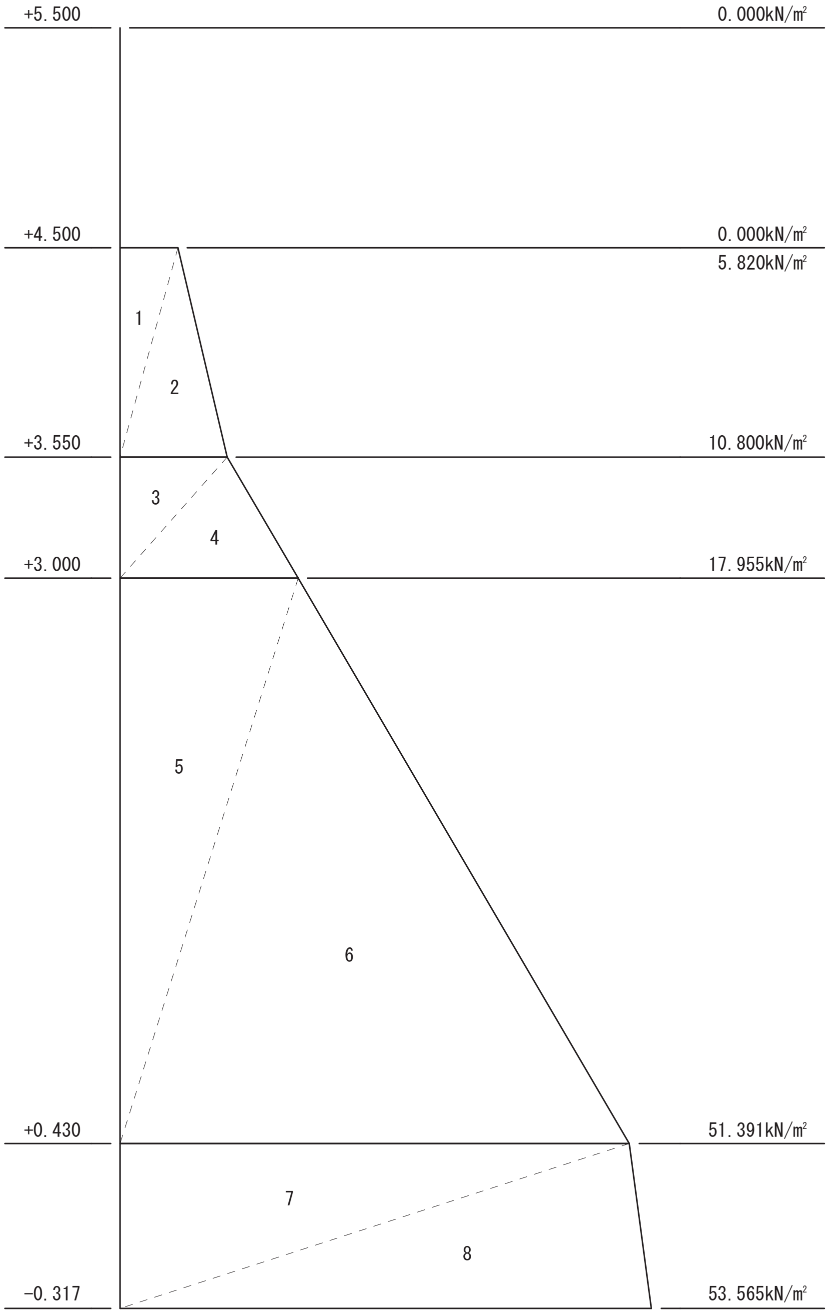
where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

7) Maximum bending moment

- Distance of the shear zero point to the tie setting point
  h = 3.000 – (-0.371) = 3.371 m

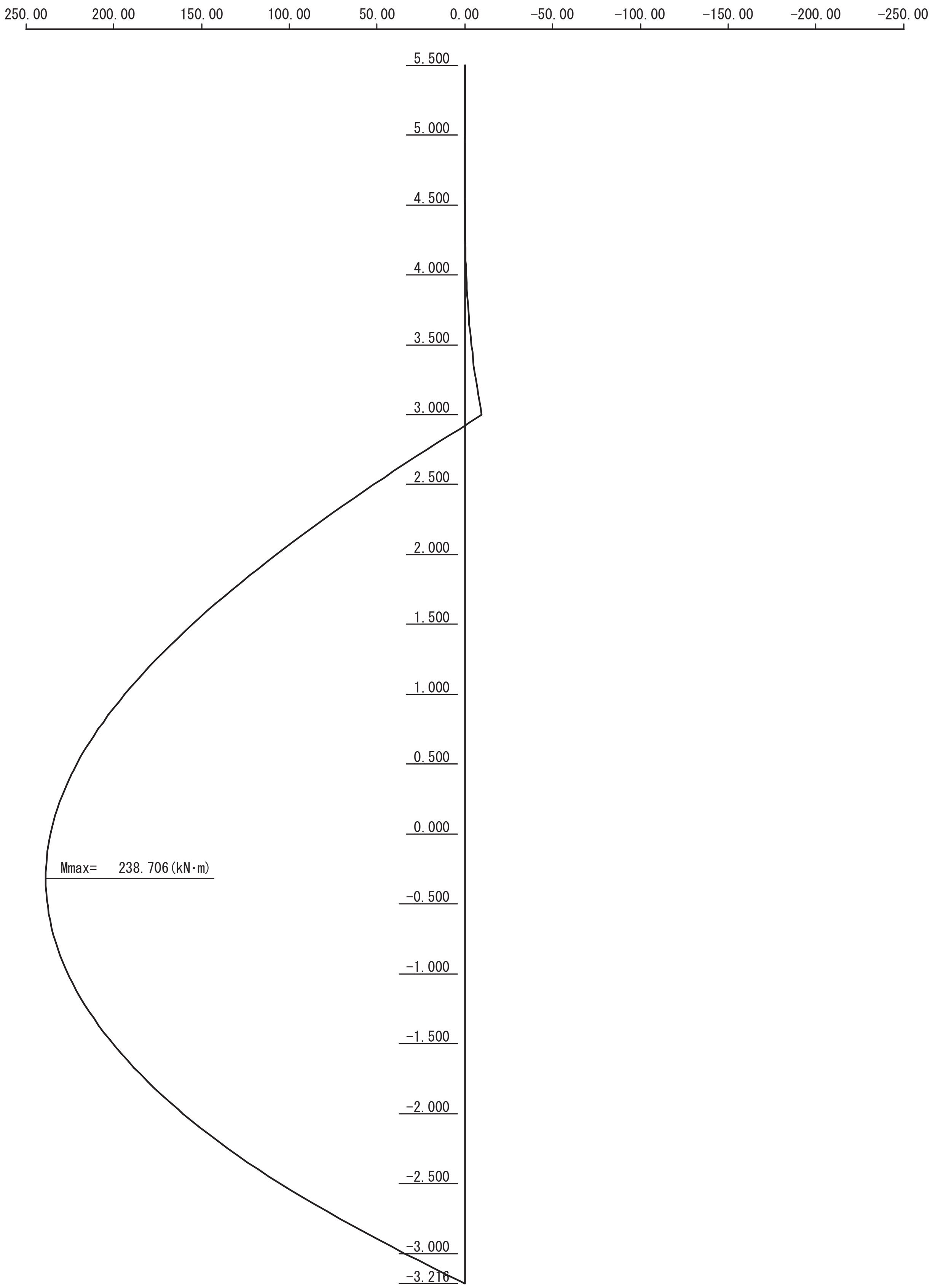
- Maximum bending moment
  $M_{max} = A_p \times h + \sum M = 144.122 \times 3.371 - 239.347 = 238.706$ kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type : ϕ800 × t10 (P-T joint)

Modulus of elasticity : E = 200.0 kN/mm^2
Moment of inertia : I = 193647 cm^4
Section modulus : Z = 4841 cm^3

Section property (per 1m) before corrosion
- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 197599 cm^4/m
- Section modulus : Z = 4940 cm^3/m

Section property (per 1m) after corrosion
- Design life time : 50 years
- Effect of cathodic protection : 90%
- Corrosion rate : 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance : t = 0.030 × 50 years = 1.50 mm

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 166997 cm^4/m
- Section modulus : Z = 4191 cm^3/m

(2) Embedded depth of pipe wall

Toe level of the pipe wall is obtained as follows:
- Deflection curve method : -12.451 m --- adopted
- Free earth support method : -8.859 m

Therefore, the minimum length of the pipe wall is;
L = 3.500 – (-12.451) = 15.951m → 16.000 m

Accordingly the design toe level of the pipe wall is;
EL = +3.500 – 16.000 = -12.500 m

(3) Stress on pipe wall section

Maximum bending moment on the pipe wall is as follows:
- Deflection curve method : 399.711 kN-m/m --- adopted
- Free earth support method : 238.706 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{399.711\times10^6}{4191\times10^3} = 95.4MPa \quad \leq \quad \sigma_a = 140MPa \ \ .... \ OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

T	is the tension force on tie wire (kN/wire)
A_p	is the reaction force of the pipe wall at tie setting point (kN/m)
L	is the spacing of the tie wire (m)
θ_1	is the vertical angle of the tie wire to horizontal (deg.)
θ_2	is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 187.448 kN-m/m --- adopted
- Free earth support method : 144.122 kN-m/m

T = 187.448 × 1.960 × sec(0.000) × sec (0.000) = 367.398 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 367.398 × 3.8 = 1396.112 kN/wire

Tie wire shall have minimum tensile strength of 1397 kN.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max} is the maximum bending moment on the waling beam (kN-m)
T is the tension force on tie wire (kN/wire)
L is the spacing of the tie wire (m)

$$M_{maz} = \frac{367.398 \times 1.960}{10.0} = 72.010 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[250×90×11.0×14.5

Steel grade : SS400
Section modulus : Z = 374.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \leq \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{72.010 \times 10^6}{2 \times 374.0 \times 10^3} = 96.3 MPa \quad \leq \quad \sigma_a = 140 MPa \quad .... \ OK$$

Output of Design Software for Anchor Wall (During Construction)
– Revetment Block b

1. Design Conditions

1-1 Dimensions

Ground elevation	+4.50 m
Top of cope concrete	+5.50 m
Top of pipe wall	+3.50 m
Tie elevation	+3.00 m
Seabed elevation	-2.00 m
Angle of seabed slope	18.4°

1-2 Tide Levels

H.W.L	+3.55 m
L.W.L	+0.43 m

1-3 Residual Water Level

R.W.L	+3.55 m

1-4 Base Elevation of Cohesion Increment +0.00 m (not used)

1-5 Surcharge Load	(Active side)	20 kPa
	(Passive side)	0 kPa

1-6 Unit Weight of Water $10.10\ kN/m^3$

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

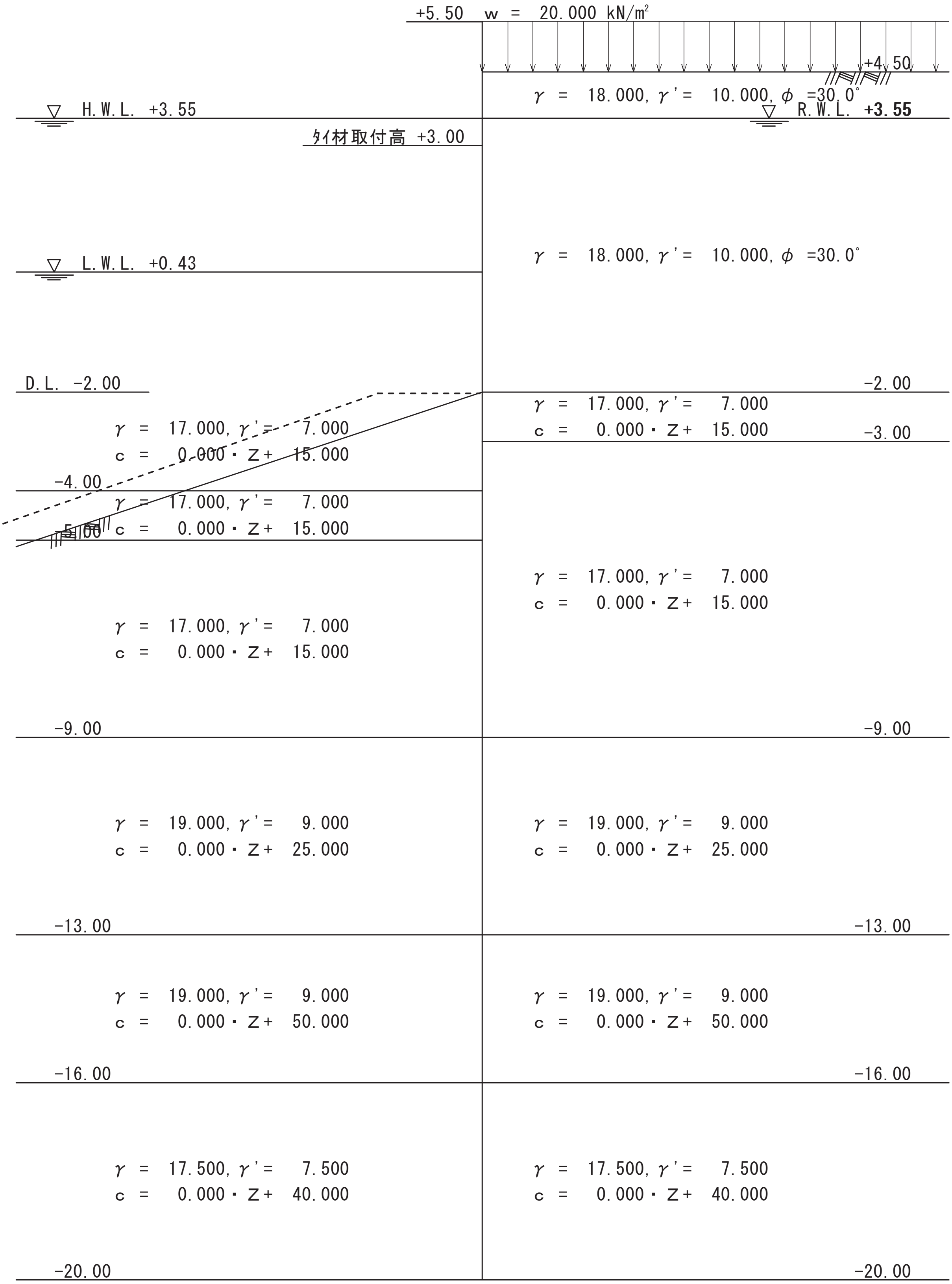
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	: Deflection Curve Method
Calculation Method 2	: Free Earth Support Method
Factor of Safety	: FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
4.50 3.55	0.95	5.820 10.800
3.55 3.00	0.55	10.800 12.400
3.00 -2.00	5.00	12.400 26.950
-2.00 -3.00	1.00	62.600 69.600
-3.00 -9.00	6.00	7.000 7.000
-9.00 -12.00	3.00	7.000 7.000
-12.00 -13.00	1.00	7.000 7.000
-13.00 -16.00	3.00	7.000 7.000
-16.00 -20.00	4.00	7.000 7.000

(2) Residual water pressure

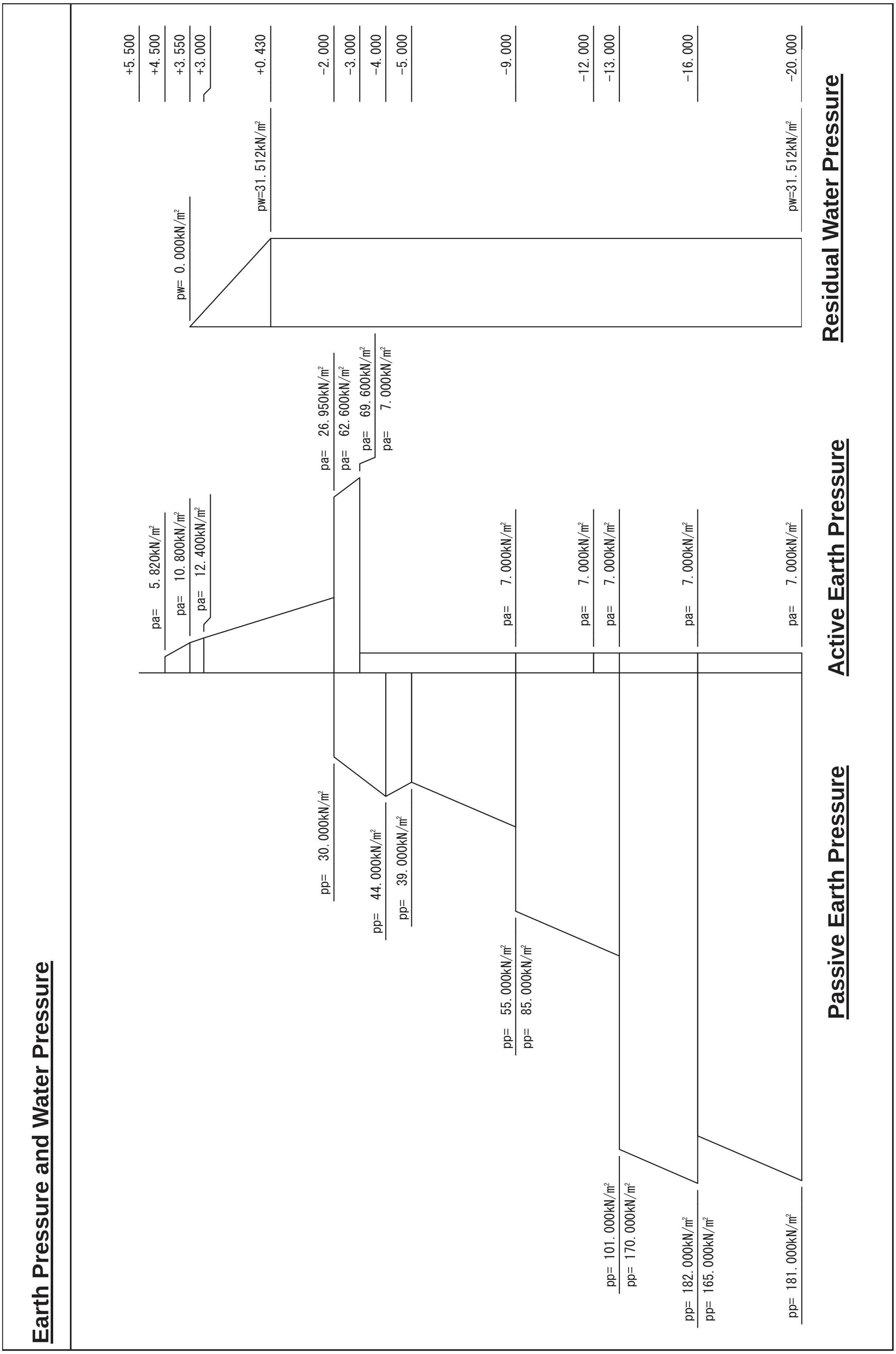
$p_w = \gamma_w \times h_w$

where; p_w is the residual water pressure (kPa)
h_w is the height of the tidal lag (m)
γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-2.00 -4.00	2.00	30.000 44.000
-4.00 -5.00	1.00	44.000 39.000
-5.00 -9.00	4.00	39.000 55.000
-9.00 -13.00	4.00	85.000 101.000
-13.00 -16.00	3.00	170.000 182.000
-16.00 -20.00	4.00	165.000 181.000


Earth Pressure and Water Pressure
+5.500
+4.500
+3.550
+3.000
+0.430
-2.000
-3.000
-4.000
-5.000
-9.000
-12.000
-13.000
-16.000
-20.000
pw= 0.000kN/㎡
pw=31.512kN/㎡
pw=31.512kN/㎡
pa= 5.820kN/㎡
pa= 10.800kN/㎡
pa= 12.400kN/㎡
pa= 26.950kN/㎡
pa= 62.600kN/㎡
pa= 69.600kN/㎡
pa= 7.000kN/㎡
pa= 7.000kN/㎡
pa= 7.000kN/㎡
pa= 7.000kN/㎡
pa= 7.000kN/㎡
pa= 7.000kN/㎡
pa= 7.000kN/㎡
pp= 30.000kN/㎡
pp= 44.000kN/㎡
pp= 39.000kN/㎡
pp= 55.000kN/㎡
pp= 85.000kN/㎡
pp= 101.000kN/㎡
pp= 170.000kN/㎡
pp= 182.000kN/㎡
pp= 165.000kN/㎡
pp= 181.000kN/㎡
Residual Water Pressure
Active Earth Pressure
Passive Earth Pressure

(4) Summary of Forces on the Wall

Elev (m)	Active side (kPa) $P_a + P_w$	Passive side(kPa) P_p
5.50 4.50	0.000+ 0.000= 0.000 0.000+ 0.000= 0.000	——— ———
4.50 3.55	5.820+ 0.000= 5.820 10.800+ 0.000= 10.800	——— ———
3.55 3.00	10.800+ 0.000= 10.800 12.400+ 5.555= 17.955	——— ———
3.00 0.43	12.400+ 5.555= 17.955 19.879+ 31.512= 51.391	——— ———
0.43 -2.00	19.879+ 31.512= 51.391 26.950+ 31.512= 58.462	——— ———
-2.00 -3.00	62.600+ 31.512= 94.112 69.600+ 31.512= 101.112	30.000 37.000
-3.00 -4.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	37.000 44.000
-4.00 -5.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	44.000 39.000
-5.00 -9.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	39.000 55.000
-9.00 -12.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	85.000 97.000
-12.00 -13.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	97.000 101.000
-13.00 -16.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	170.000 182.000
-16.00 -20.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	165.000 181.000

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -2.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
-2.000	-239.109	112.012	126.370
-3.000	-446.199	138.417	164.077
-4.000	-686.260	161.798	138.708
-5.000	-899.495	178.897	118.621
-6.000	-1095.816	191.976	103.054
-7.000	-1271.134	201.990	86.552
-8.000	-1414.513	209.412	68.642
-9.000	-1512.401	214.558	49.008
-10.000	-1488.716	216.488	-1.410
-11.000	-1264.008	214.536	-51.946
-12.000	-814.954	209.213	-103.111
-13.000	-114.823	200.899	-155.285
-14.000	1050.320	187.858	-275.732

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -13.00 and -14.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-13.131	0.000	199.570	-171.188

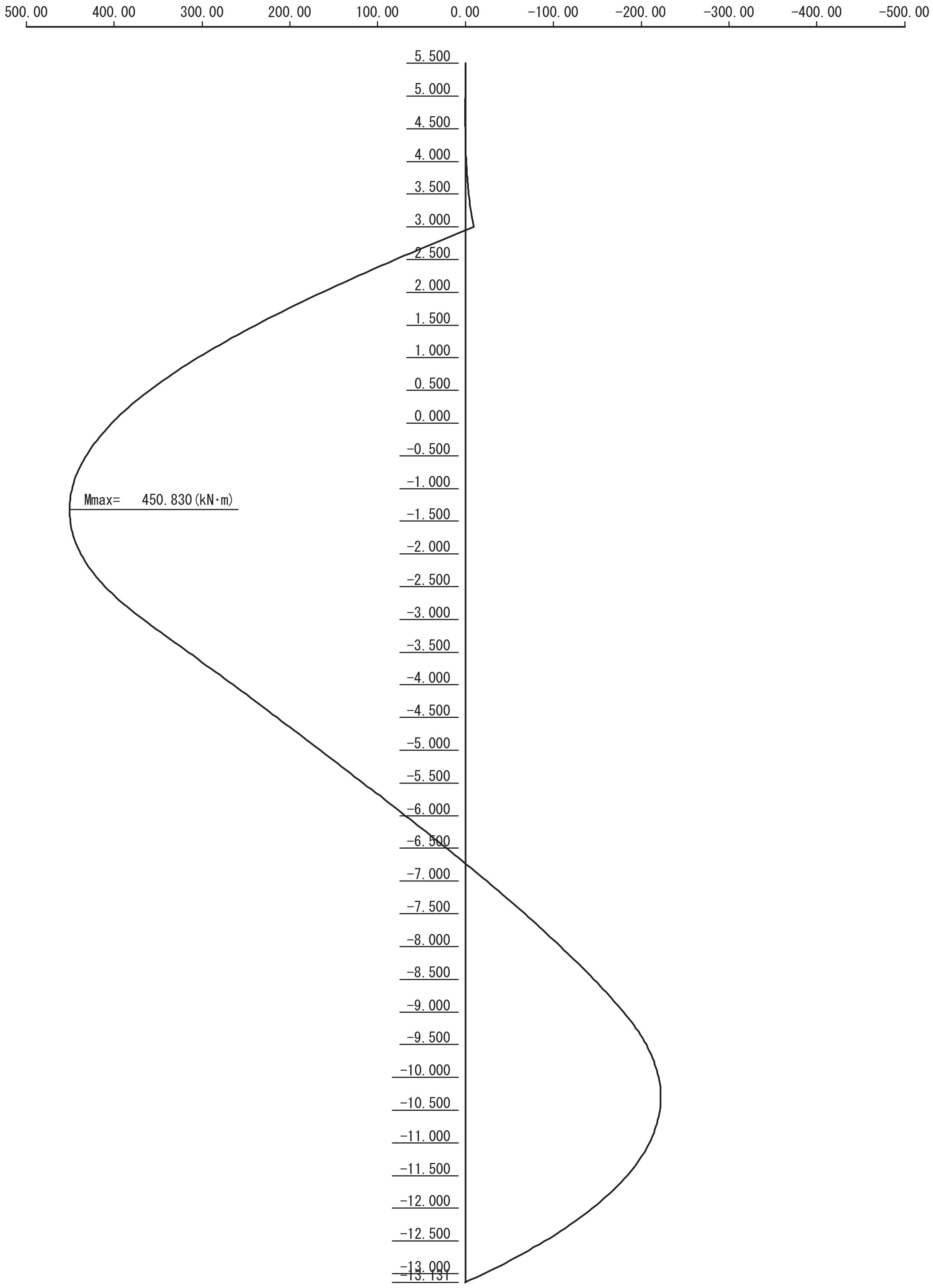
Embedded length of the pipe wall : $L = 1.2 \times (-2.000 + 13.131) = 13.357$ m
Toe elevation : $D = -2.000 – 13.357 = -15.357$ m
Reaction force at tie setting point : 199.570 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	0.000	0.000
4.500	0.000	0.000
4.000	-0.837	-3.565
3.550	-3.375	-7.894
3.050	-8.944	-14.921
3.000	-9.712	-15.802
2.500	79.657	173.164
2.000	162.910	159.308
1.500	238.423	142.199
1.000	304.567	121.838
0.500	359.718	98.224
0.430	366.469	94.658
-0.070	407.314	68.599
-0.570	434.947	41.812
-1.070	449.005	14.298
-1.570	449.124	-13.943
-2.000	437.801	-38.813
-2.500	410.380	-70.869
-3.000	366.932	-102.925
-3.500	315.426	-102.806
-4.000	264.417	-100.937
-4.500	214.530	-98.818
-5.000	165.391	-97.949
-5.500	116.561	-97.205
-6.000	68.352	-95.461
-6.500	21.266	-92.717
-7.000	-24.198	-88.973
-7.500	-67.540	-84.229
-8.000	-108.261	-78.485
-8.500	-145.859	-71.741
-9.000	-179.835	-63.997
-9.500	-205.939	-40.253
-10.000	-219.922	-15.509
-10.500	-221.282	10.235
-11.000	-209.520	36.979
-11.500	-184.136	64.723
-12.000	-144.631	93.467
-12.500	-90.503	123.211
-13.000	-21.253	153.955
-13.131	0.000	171.188

Maximum bending moment : 450.830 kN-m/m
Elevation of maximum bending moment : -1.325 m
Depth of 1st steady point (moment=0) : -6.731 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

$$M_p = FOS \times M_a$$

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of $FOS \times M_a$

NO	Elev (m)	Calculation			S (kN/m)	L (m)	M (kN-m/m)	$FOS \times M_a$ (kN-m/m)
—	5.50	1/2x	0.000x	1.000	0.000	-2.167	0.000	
—	4.50	1/2x	0.000x	1.000	0.000	-1.833	0.000	0.000
1	4.50	1/2x	5.820x	0.950	2.764	-1.183	-3.270	
2	3.55	1/2x	10.800x	0.950	5.130	-0.867	-4.448	-9.262
3	3.55	1/2x	10.800x	0.550	2.970	-0.367	-1.090	
4	3.00	1/2x	17.955x	0.550	4.938	-0.183	-0.904	-11.655
5	3.00	1/2x	17.955x	2.570	23.072	0.857	19.773	
6	0.43	1/2x	51.391x	2.570	66.037	1.713	113.121	147.818
7	0.43	1/2x	51.391x	2.430	62.440	3.380	211.047	
8	-2.00	1/2x	58.462x	2.430	71.031	4.190	297.620	758.218
9	-2.00	1/2x	94.112x	1.000	47.056	5.333	250.950	
10	-3.00	1/2x	101.112x	1.000	50.556	5.667	286.501	1403.159
11	-3.00	1/2x	38.512x	1.000	19.256	6.333	121.948	
12	-4.00	1/2x	38.512x	1.000	19.256	6.667	128.380	1703.553
13	-4.00	1/2x	38.512x	1.000	19.256	7.333	141.204	
14	-5.00	1/2x	38.512x	1.000	19.256	7.667	147.636	2050.161
15	-5.00	1/2x	38.512x	4.000	77.024	9.333	718.865	
16	-9.00	1/2x	38.512x	4.000	77.024	10.667	821.615	3898.737
17	-9.00	1/2x	38.512x	3.000	57.768	13.000	750.984	
18	-12.00	1/2x	38.512x	3.000	57.768	14.000	808.752	5770.420
19	-12.00	1/2x	38.512x	1.000	19.256	15.333	295.252	
20	-13.00	1/2x	38.512x	1.000	19.256	15.667	301.684	6486.743
21	-13.00	1/2x	38.512x	3.000	57.768	17.000	982.056	
22	-16.00	1/2x	38.512x	3.000	57.768	18.000	1039.824	8912.999
23	-16.00	1/2x	38.512x	4.000	77.024	20.333	1566.129	
24	-20.00	1/2x	38.512x	4.000	77.024	21.667	1668.879	12795.009

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

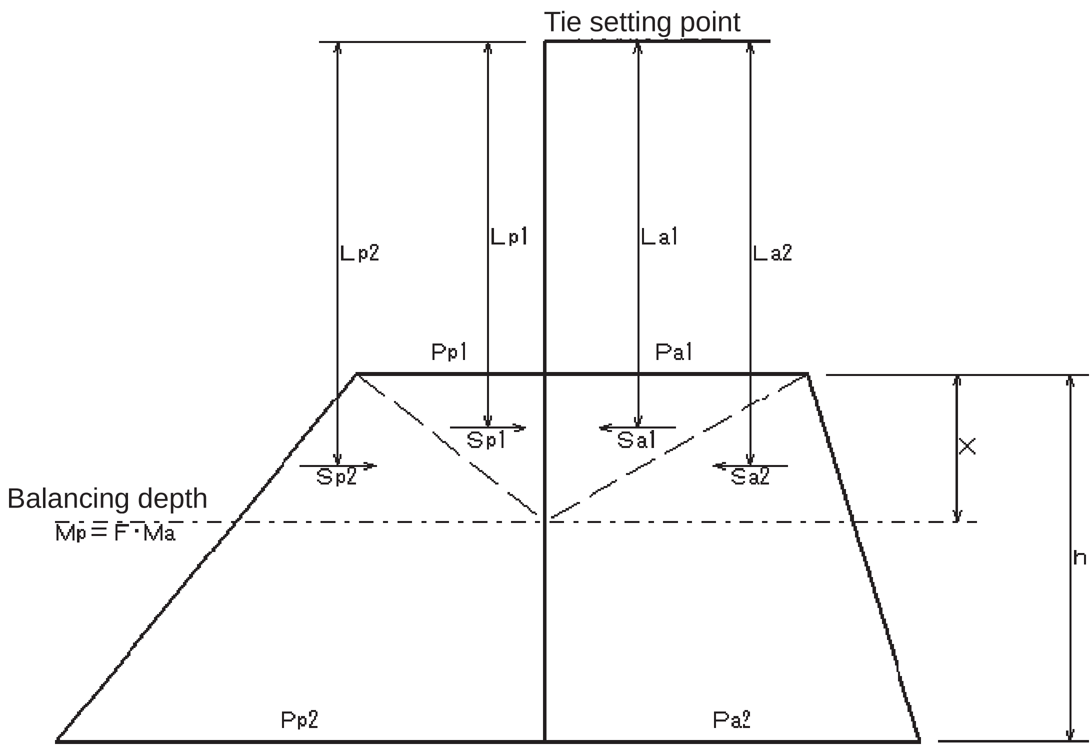
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-2.00	1/2x 30.000x 1.000	15.000	5.333	79.995	
2	-3.00	1/2x 37.000x 1.000	18.500	5.667	104.840	184.835
3	-3.00	1/2x 37.000x 1.000	18.500	6.333	117.160	
4	-4.00	1/2x 44.000x 1.000	22.000	6.667	146.674	448.669
5	-4.00	1/2x 44.000x 1.000	22.000	7.333	161.326	
6	-5.00	1/2x 39.000x 1.000	19.500	7.667	149.506	759.501
7	-5.00	1/2x 39.000x 4.000	78.000	9.333	727.974	
8	-9.00	1/2x 55.000x 4.000	110.000	10.667	1173.370	2660.845
9	-9.00	1/2x 85.000x 3.000	127.500	13.000	1657.500	
10	-12.00	1/2x 97.000x 3.000	145.500	14.000	2037.000	6355.345
11	-12.00	1/2x 97.000x 1.000	48.500	15.333	743.650	
12	-13.00	1/2x 101.000x 1.000	50.500	15.667	791.184	7890.179
13	-13.00	1/2x 170.000x 3.000	255.000	17.000	4335.000	
14	-16.00	1/2x 182.000x 3.000	273.000	18.000	4914.000	17139.179
15	-16.00	1/2x 165.000x 4.000	330.000	20.333	6709.890	
16	-20.00	1/2x 181.000x 4.000	362.000	21.667	7843.454	31692.523

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1} X}{2}, \quad L_{a(p)1} = L + \frac{1}{3} X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \frac{P_{a(p)2} - P_{a(p)1}}{h} X \right] X}{2}, \quad L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

$M_{a(p)}$	: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)
$M_{a(p)1}$	: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)
$M_{a(p)1'}$	: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$M_{a(p)2'}$	: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$S_{a(p)1}$	: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$S_{a(p)2}$	: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$L_{a(p)1}$	: the arm length of $S_{a(p)1}$ from the tie setting point (m)
$L_{a(p)2}$	: the arm length of $S_{a(p)2}$ from the tie setting point (m)
$P_{a(p)1}$	: the active (passive) side pressure at the top elevation of the soil layer (kPa)
$P_{a(p)1}$	: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)
h	: the thickness of the soil layer (m)
L	: the vertical distance from the tie setting point to the top elevation of the soil layer (m)
X	: the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -9.00 m	FOS×M_{a1} = 3898.737	> M_{p1} = 2660.845
at -12.00 m	FOS×M_{a2} = 5770.420	< M_{p2} = 6355.345

[Moment on active side]

$$S_{a1} = \frac{38.512X}{2} = 19.256X \ , \quad L_{a1} = 12.000 + \frac{1}{3}X$$

$$M_{a1'} = 6.419X^2 + 231.072X$$

$$S_{a2} = \frac{\left[38.512 + \dfrac{38.512 - 38.512}{2.000}X\right]X}{2} = 0.000X^2 + 19.256X \ , \quad L_{a2} = 12.000 + \frac{2}{3}X$$

$$M_{a2'} = 0.000X^3 + 12.837X^2 + 231.072X$$

$$M_a = 0.000X^3 + 19.256X^2 + 462.144X + 3248.948$$

[Moment on passive side]

$$S_{p1} = \frac{85.000X}{2} = 42.500X \ , \quad L_{p1} = 12.000 + \frac{1}{3}X$$

$$M_{p1'} = 14.167X^2 + 510.000X$$

$$S_{p2} = \frac{\left[85.000 + \dfrac{97.000 - 85.000}{2.000}X\right]X}{2} = 2.000X^2 + 42.500X \ , \quad L_{p2} = 14.000 + \frac{2}{3}X$$

$$M_{p2'} = 1.333X^3 + 52.333X^2 + 510.000X$$

$$M_p = 1.333X^3 + 66.500X^2 + 1020.000X + 2660.845$$

[Balancing depth]

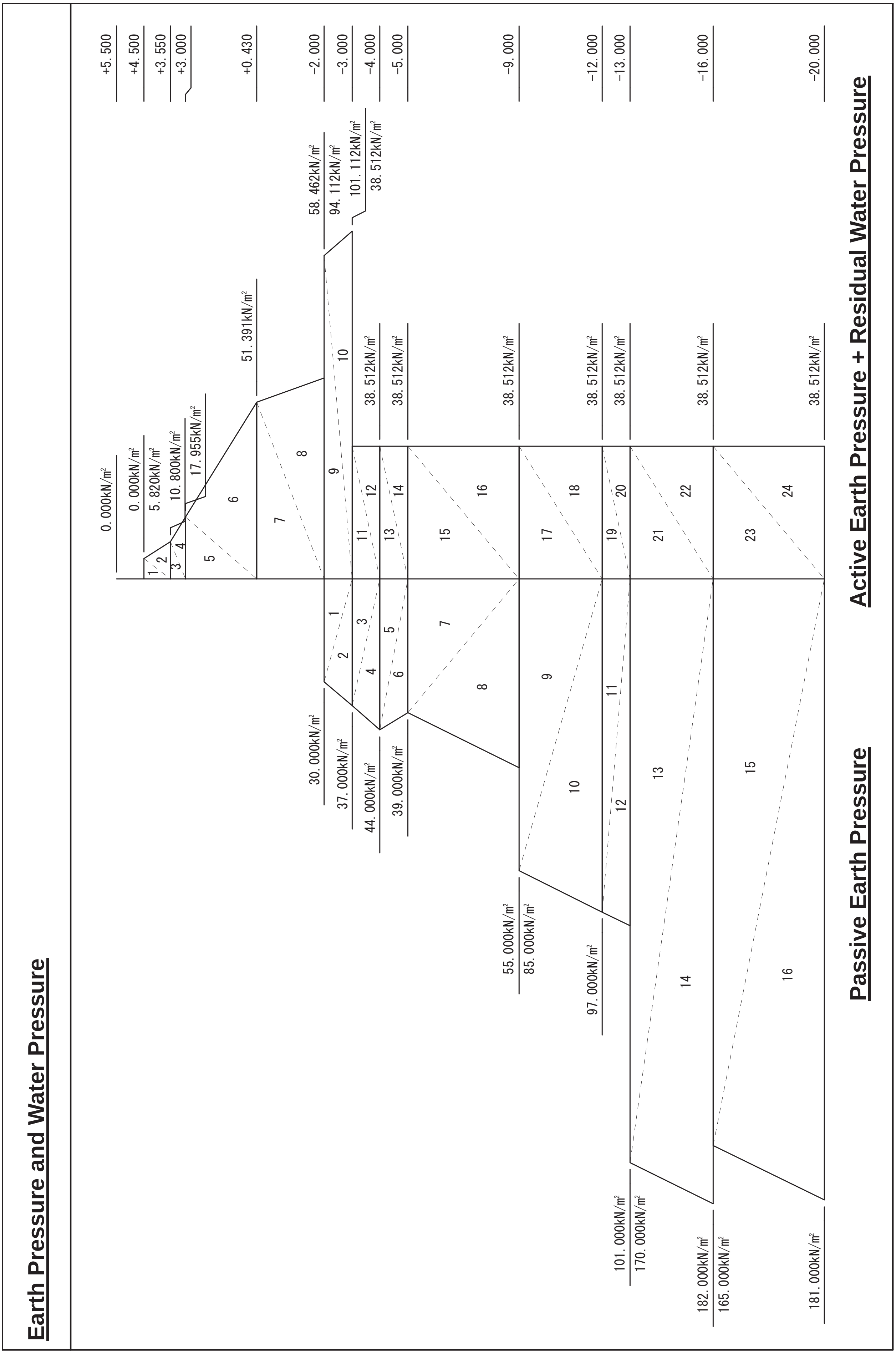
$$FOS \cdot M_a = M_p$$

$$1.2 \times (0.000X^3 + 19.256X^2 + 462.144X + 3248.948)$$

$$= 1.333X^3 + 66.500X^2 + 1020.000X + 2660.845$$

X= 2.185 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -9.000 – 2.185 = -11.185 m



Earth Pressure and Water Pressure
Active Earth Pressure + Residual Water Pressure
Passive Earth Pressure
+5.500
+4.500
+3.550
+3.000
+0.430
-2.000
-3.000
-4.000
-5.000
-9.000
-12.000
-13.000
-16.000
-20.000
0.000kN/m²
0.000kN/m²
5.820kN/m²
10.800kN/m²
17.955kN/m²
51.391kN/m²
58.462kN/m²
94.112kN/m²
101.112kN/m²
38.512kN/m²
30.000kN/m²
37.000kN/m²
44.000kN/m²
39.000kN/m²
55.000kN/m²
85.000kN/m²
97.000kN/m²
101.000kN/m²
170.000kN/m²
182.000kN/m²
165.000kN/m²
181.000kN/m²

(2) Calculation of maximum bending moment

1) External forces

Elev (m)	$P_a + P_w$ (kN/m^2)	P_p (kN/m^2)	$P_a - P_p$ (kN/m^2)
5.50 4.50	0.000 0.000	——— ———	0.000 0.000
4.50 3.55	5.820 10.800	——— ———	5.820 10.800
3.55 3.00	10.800 17.955	——— ———	10.800 17.955
3.00 0.43	17.955 51.391	——— ———	17.955 51.391
0.43 -2.00	51.391 58.462	——— ———	51.391 58.462
-2.00 -3.00	94.112 101.112	30.000 37.000	64.112 64.112
-3.00 -4.00	38.512 38.512	37.000 44.000	1.512 -5.488
-4.00 -5.00	38.512 38.512	44.000 39.000	-5.488 -0.488
-5.00 -9.00	38.512 38.512	39.000 55.000	-0.488 -16.488
-9.00 -12.00	38.512 38.512	85.000 97.000	-46.488 -58.488
-12.00 -13.00	38.512 38.512	97.000 101.000	-58.488 -62.488
-13.00 -16.00	38.512 38.512	170.000 182.000	-131.488 -143.488
-16.00 -20.00	38.512 38.512	165.000 181.000	-126.488 -142.488

2) Virtual seabed level

The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -3.00 m $\quad P_{a1} = 38.512 \quad > \quad P_{p1} = 37.000$
at -4.00 m $\quad P_{a2} = 38.512 \quad < \quad P_{p2} = 44.000$

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

EL_{top} : the top elevation of the soil layer in question (m)

P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)

P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)

P_{p1} : the passive earth pressure at the top of the soil layer (kPa)

P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)

h : the thickness of the soil layer (m)

$$X = -3.00 - \frac{1.00 \times (37.000 - 38.512)}{(38.512 - 38.512) - (44.000 - 37.000)} = -3.216m$$

Accordingly, the virtual seabed level is obtained as -3.216m.

3) Moment about tie setting point

No	Calculation	S (kN/m)	L (m)	M (kN-m/m)
1	1/2x 5.820x 0.950	2.764	-1.183	-3.270
2	1/2x 10.800x 0.950	5.130	-0.867	-4.448
3	1/2x 10.800x 0.550	2.970	-0.367	-1.090
4	1/2x 17.955x 0.550	4.938	-0.183	-0.904
5	1/2x 17.955x 2.570	23.072	0.857	19.773
6	1/2x 51.391x 2.570	66.037	1.713	113.121
7	1/2x 51.391x 2.430	62.440	3.380	211.047
8	1/2x 58.462x 2.430	71.031	4.190	297.620
9	1/2x 64.112x 1.000	32.056	5.333	170.955
10	1/2x 64.112x 1.000	32.056	5.667	181.661
11	1/2x 1.512x 0.216	0.163	6.072	0.990
Total		302.657	———	985.455

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

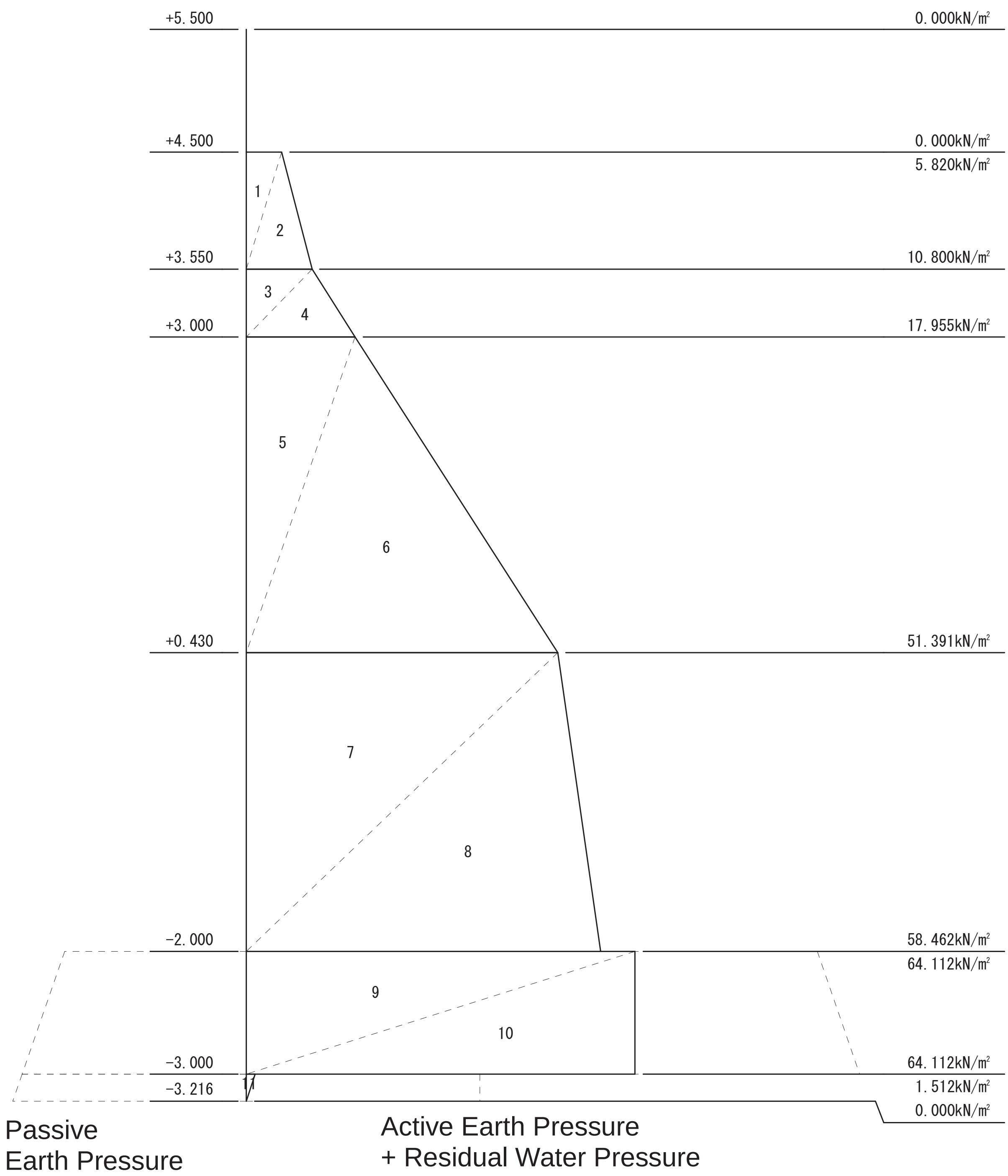
4) Reaction forces

Distance between supports : L_T = 3.000 – (-3.216) = 6.216 m

Reaction at virtual seabed : $R_0 = \frac{\Sigma M}{L_T} = \frac{985.455}{6.216} = 158.535 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 302.657 - 158.535 = 144.122 kN/m$

External Force Diagram



5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 4.50	0.000 0.000	0.000		0.000
4.50 3.55	2.764 5.130	7.894		-7.894
3.55 3.00	2.970 4.938	15.802	144.122	128.320
3.00 0.43	23.072 66.037	104.911	144.122	39.211
0.43 -2.00	62.440 71.031	238.382	144.122	-94.260
-2.00 -3.00	32.056 32.056	302.494	144.122	-158.372
-3.00 -3.22	0.163 0.000	302.657	144.122	-158.535

Shear force $Q = A_p - \sum S$

The above table suggests that the shear force zero point exists in between 0.430m and -2.000m.

$$Q = 39.211 - \frac{[51.391 + (51.391 + 2.910X)]X}{2} = 0$$

X = 0.747 m

Shear force zero point : DL = +0.43 – 0.747 = -0.317m

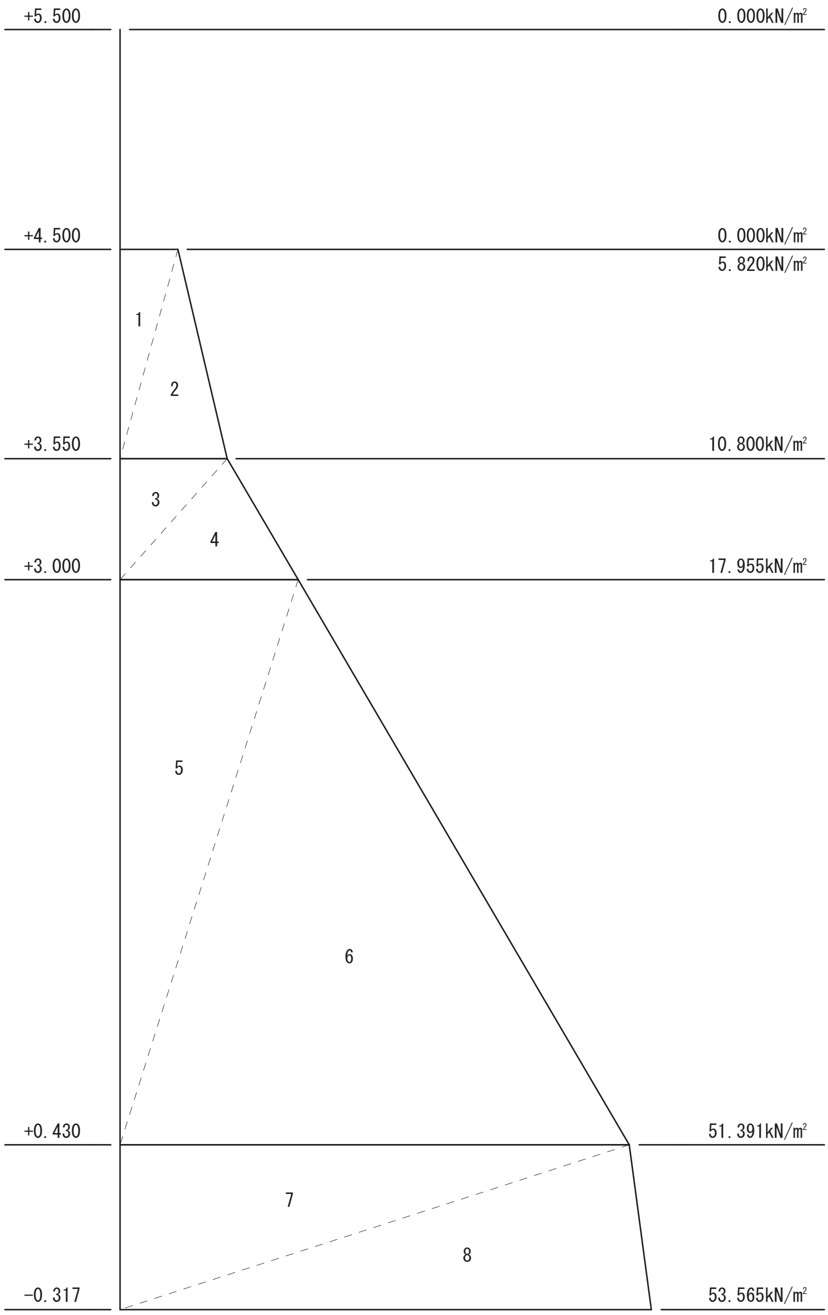
6) Calculation of moment

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	5.820x	0.950	-2.764	4.500	-12.438
2	1/2x	10.800x	0.950	-5.130	4.184	-21.464
3	1/2x	10.800x	0.550	-2.970	3.684	-10.941
4	1/2x	17.955x	0.550	-4.938	3.500	-17.283
5	1/2x	17.955x	2.570	-23.072	2.460	-56.757
6	1/2x	51.391x	2.570	-66.037	1.604	-105.923
7	1/2x	51.391x	0.747	-19.195	0.498	-9.559
8	1/2x	53.565x	0.747	-20.007	0.249	-4.982
Total				———	———	-239.347

where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

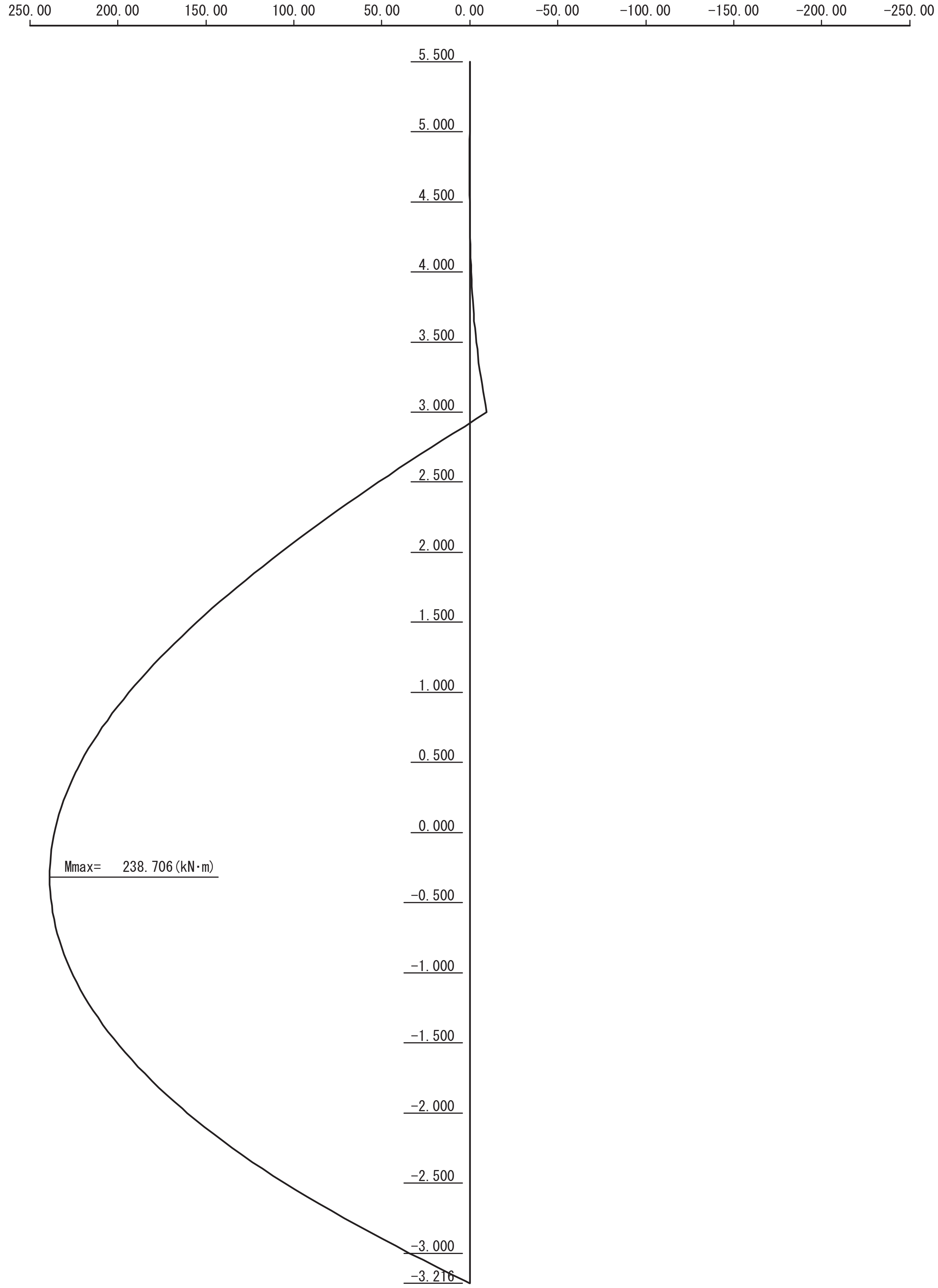
7) Maximum bending moment
- Distance of the shear zero point to the tie setting point
  h = 3.000 – (-0.317) = 3.317 m
- Maximum bending moment
  $M_{max} = A_p \times h + \sum M = 144.122 \times 3.317 - 239.347 = 238.706$ kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type : ϕ800 × t10 (P-T joint)

Modulus of elasticity : E = 200.0 kN/mm^2
Moment of inertia : I = 193647 cm^4
Section modulus : Z = 4841 cm^3

Section property (per 1m) before corrosion
- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 197599 cm^4/m
- Section modulus : Z = 4940 cm^3/m

Section property (per 1m) after corrosion
- Design life time : 50 years
- Effect of cathodic protection : 90%
- Corrosion rate : 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance : t = 0.030 × 50 years = 1.50 mm

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 166997 cm^4/m
- Section modulus : Z = 4191 cm^3/m

(2) Embedded depth of pipe wall

Toe level of the pipe wall is obtained as follows:
- Deflection curve method : -15.357 m --- adopted
- Free earth support method : -11.185 m

Therefore, the minimum length of the pipe wall is;

L = 3.500 – (-15.357) = 18.857m → 19.000 m

Accordingly the design toe level of the pipe wall is;

EL = +3.500 – 19.000 = -15.500 m

(3) Stress on pipe wall section

Maximum bending moment on the pipe wall is as follows:
- Deflection curve method : 450.830 kN-m/m --- adopted
- Free earth support method : 238.706 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{450.830 \times 10^6}{4191 \times 10^3} = 107.6 MPa \quad \leq \quad \sigma_a = 140 MPa \;\; .... \; OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

T	is the tension force on tie wire (kN/wire)
A_p	is the reaction force of the pipe wall at tie setting point (kN/m)
L	is the spacing of the tie wire (m)
θ_1	is the vertical angle of the tie wire to horizontal (deg.)
θ_2	is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 199.570 kN-m/m --- adopted
- Free earth support method : 144.122 kN-m/m

T = 199.570 × 1.960 × sec(0.000) × sec (0.000) = 391.157 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 391.157 × 3.8 = 1486.400 kN/wire

Tie wire shall have minimum tensile strength of 1487 kN.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max}	is the maximum bending moment on the waling beam (kN-m)
T	is the tension force on tie wire (kN/wire)
L	is the spacing of the tie wire (m)

$$M_{maz} = \frac{391.157 \times 1.960}{10.0} = 76.667 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[250×90×11.0×14.5

Steel grade : SS400
Section modulus : Z = 374.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \leq \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{76.667 \times 10^6}{2 \times 374.0 \times 10^3} = 102.5 MPa \quad \leq \quad \sigma_a = 140 MPa \quad .... \ OK$$

Output of Design Software for Anchor Wall (During Construction) – Revetment Block c

1. Design Conditions

1-1 Dimensions

Ground elevation	+4.50 m
Top of cope concrete	+5.50 m
Top of pile wall	+3.50 m
Tie elevation	+3.00 m
Seabed elevation	-2.00 m
Angle of seabed slope	18.4°

1-2 Tide Levels

H.W.L	+3.55 m
L.W.L	+0.43 m

1-3 Residual Water Level

R.W.L	+3.55 m

1-4 Base Elevation of Cohesion Increment +0.00 m (not used)

1-5 Surcharge Load	(Active side)	20 kPa
	(Passive side)	0 kPa

1-6 Unit Weight of Water 10.10 kN/m^3

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

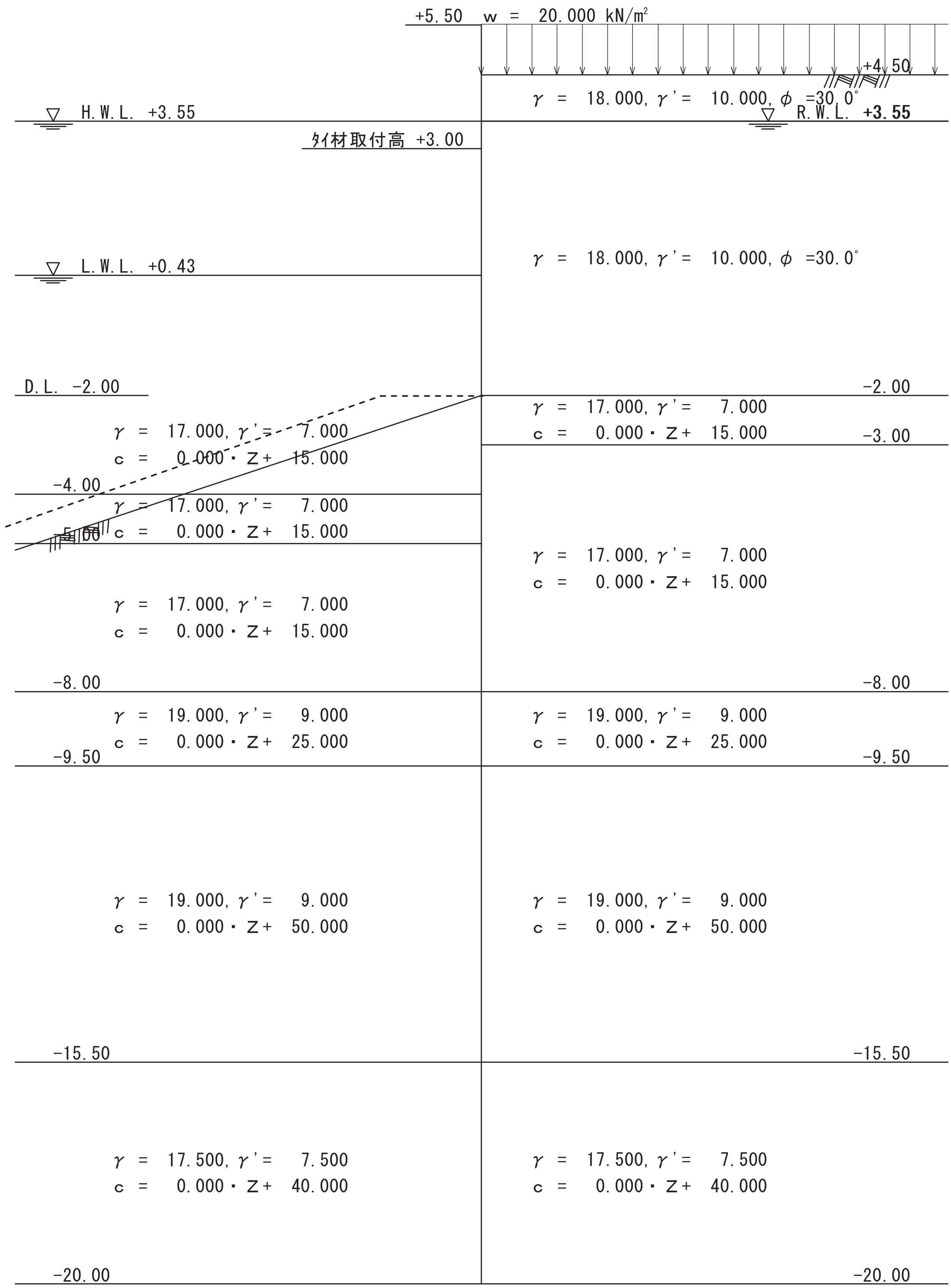
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	:	Deflection Curve Method
Calculation Method 2	:	Free Earth Support Method
Factor of Safety	:	FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
4.50 3.55	0.95	5.820 10.800
3.55 3.00	0.55	10.800 12.400
3.00 -2.00	5.00	12.400 26.950
-2.00 -3.00	1.00	62.600 69.600
-3.00 -8.00	5.00	7.000 7.000
-8.00 -9.50	1.50	7.000 7.000
-9.50 -12.00	2.50	7.000 7.000
-12.00 -15.50	3.50	7.000 7.000
-15.50 -20.00	4.50	7.000 7.000

(2) Residual water pressure

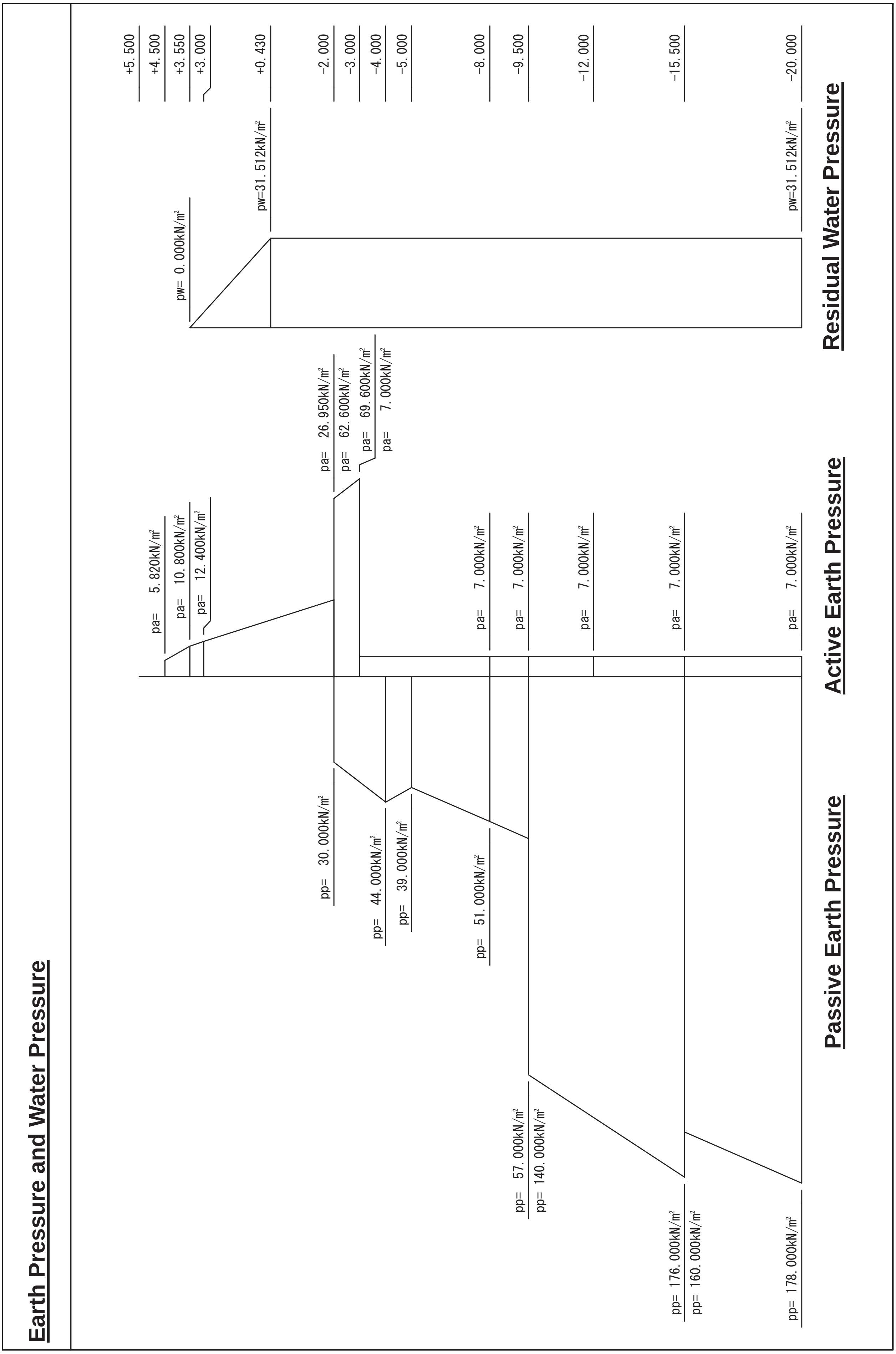
$p_w = \gamma_w \times h_w$

where; p_w is the residual water pressure (kPa)
h_w is the height of the tidal lag (m)
γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-2.00 -4.00	2.00	30.000 44.000
-4.00 -5.00	1.00	44.000 39.000
-5.00 -8.00	3.00	39.000 51.000
-8.00 -9.50	1.50	51.000 57.000
-9.50 -15.50	6.00	140.000 176.000
-15.50 -20.00	4.50	160.000 178.000


Earth Pressure and Water Pressure
+5. 500
+4. 500
+3. 550
+3. 000
+0. 430
-2. 000
-3. 000
-4. 000
-5. 000
-8. 000
-9. 500
-12. 000
-15. 500
-20. 000
pw= 0. 000kN/m²
pw=31. 512kN/m²
pw=31. 512kN/m²
Residual Water Pressure
pa= 5. 820kN/m²
pa= 10. 800kN/m²
pa= 12. 400kN/m²
pa= 26. 950kN/m²
pa= 62. 600kN/m²
pa= 69. 600kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
Active Earth Pressure
pp= 30. 000kN/m²
pp= 44. 000kN/m²
pp= 39. 000kN/m²
pp= 51. 000kN/m²
pp= 57. 000kN/m²
pp= 140. 000kN/m²
pp= 176. 000kN/m²
pp= 160. 000kN/m²
pp= 178. 000kN/m²
Passive Earth Pressure

(4) Summary of Forces on the Wall

Elev	Active side (kPa)			Passive side(kPa)
(m)	P_a +	P_w		P_p
5.50	0.000+	0.000=	0.000	—
4.50	0.000+	0.000=	0.000	—
4.50	5.820+	0.000=	5.820	—
3.55	10.800+	0.000=	10.800	—
3.55	10.800+	0.000=	10.800	—
3.00	12.400+	5.555=	17.955	—
3.00	12.400+	5.555=	17.955	—
0.43	19.879+	31.512=	51.391	—
0.43	19.879+	31.512=	51.391	—
-2.00	26.950+	31.512=	58.462	—
-2.00	62.600+	31.512=	94.112	30.000
-3.00	69.600+	31.512=	101.112	37.000
-3.00	7.000+	31.512=	38.512	37.000
-4.00	7.000+	31.512=	38.512	44.000
-4.00	7.000+	31.512=	38.512	44.000
-5.00	7.000+	31.512=	38.512	39.000
-5.00	7.000+	31.512=	38.512	39.000
-8.00	7.000+	31.512=	38.512	51.000
-8.00	7.000+	31.512=	38.512	51.000
-9.50	7.000+	31.512=	38.512	57.000
-9.50	7.000+	31.512=	38.512	140.000
-12.00	7.000+	31.512=	38.512	155.000
-12.00	7.000+	31.512=	38.512	155.000
-15.50	7.000+	31.512=	38.512	176.000
-15.50	7.000+	31.512=	38.512	160.000
-20.00	7.000+	31.512=	38.512	178.000

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -2.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
-2.000	-239.109	112.012	126.370
-3.000	-446.199	138.417	164.077
-4.000	-686.260	161.798	138.708
-5.000	-899.495	178.897	118.621
-6.000	-1095.816	191.976	103.054
-7.000	-1271.134	201.990	86.552
-8.000	-1414.513	209.412	68.642
-9.000	-1512.401	214.557	49.009
-10.000	-1505.391	216.840	-13.512
-11.000	-1110.287	212.072	-116.232
-12.000	-249.074	200.574	-218.222
-13.000	1120.106	183.232	-320.368

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -12.00 and -13.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-12.214	0.000	197.324	-240.070

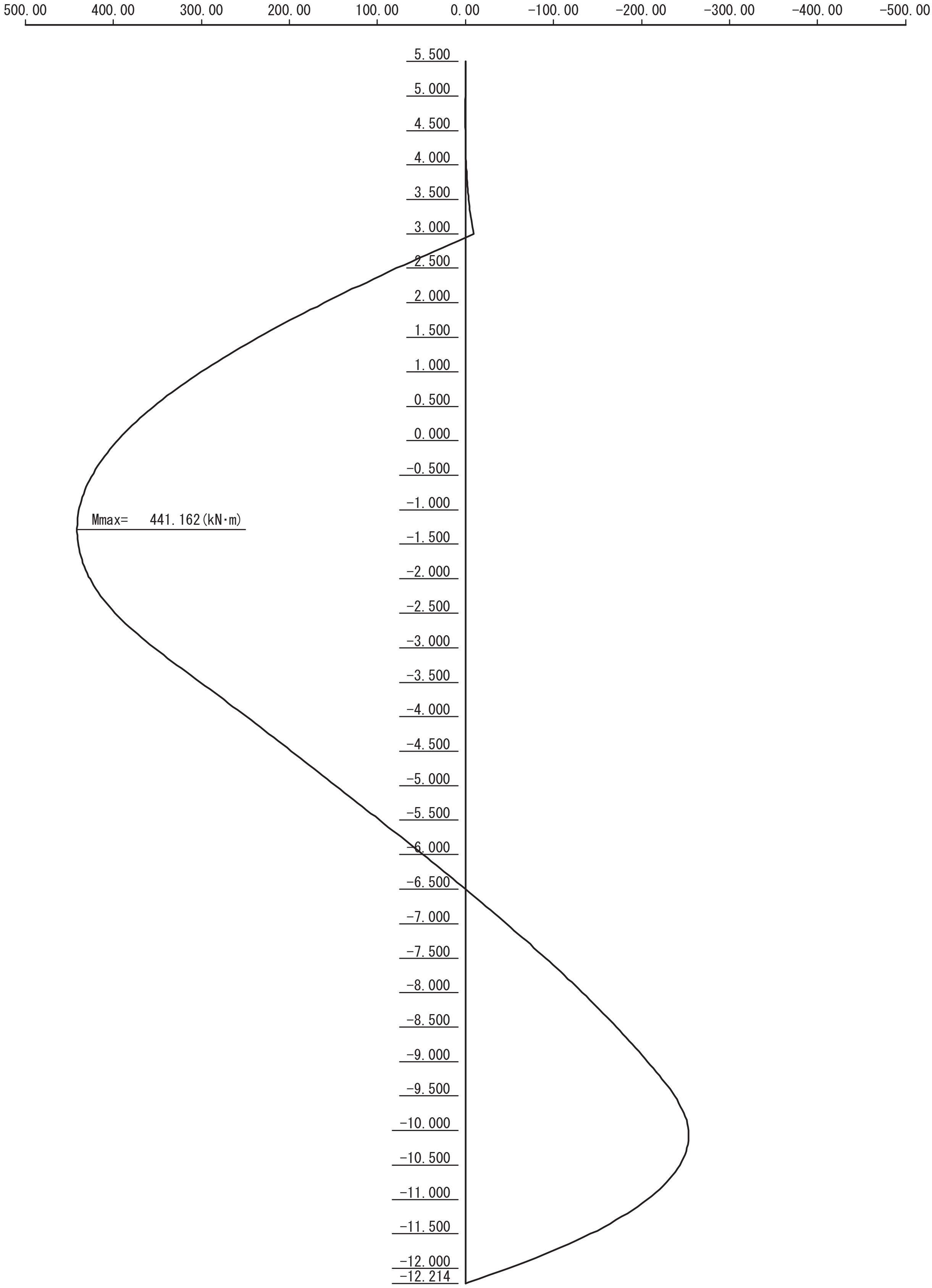
Embedded length of the pipe wall : L = 1.2 × (-2.000 + 12.214) = 12.257 m
Toe elevation : D = -2.000 – 12.257 = -14.257 m
Reaction force at tie setting point : 197.324 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	0.000	0.000
4.500	0.000	0.000
4.000	-0.837	-3.565
3.550	-3.375	-7.894
3.050	-8.944	-14.921
3.000	-9.712	-15.802
2.500	78.534	170.918
2.000	160.664	157.062
1.500	235.054	139.953
1.000	300.075	119.592
0.500	354.103	95.978
0.430	360.697	92.412
-0.070	400.419	66.353
-0.570	426.929	39.566
-1.070	439.864	12.052
-1.570	438.860	-16.189
-2.000	426.571	-41.059
-2.500	398.027	-73.115
-3.000	353.456	-105.171
-3.500	300.827	-105.052
-4.000	248.695	-103.183
-4.500	197.685	-101.064
-5.000	147.423	-100.195
-5.500	97.469	-99.451
-6.000	48.138	-97.707
-6.500	-0.071	-94.963
-7.000	-46.658	-91.219
-7.500	-91.123	-86.475
-8.000	-132.967	-80.731
-8.500	-171.688	-73.987
-9.000	-206.787	-66.243
-9.500	-237.764	-57.499
-10.000	-253.703	-6.005
-10.500	-243.519	46.989
-11.000	-206.464	101.483
-11.500	-141.787	157.477
-12.000	-48.737	214.971
-12.214	0.000	240.070

Maximum bending moment : 441.162 kN-m/m
Elevation of maximum bending moment : -1.285 m
Depth of 1st steady point (moment=0) : -6.499 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

M_p = FOS×M_a

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of FOS×M_a

NO	Elev (m)	Calculation			S (kN/m)	L (m)	M (kN-m/m)	FOS×M_a (kN-m/m)
—	5.50	1/2x	0.000x	1.000	0.000	-2.167	0.000	
—	4.50	1/2x	0.000x	1.000	0.000	-1.833	0.000	0.000
1	4.50	1/2x	5.820x	0.950	2.764	-1.183	-3.270	
2	3.55	1/2x	10.800x	0.950	5.130	-0.867	-4.448	-9.262
3	3.55	1/2x	10.800x	0.550	2.970	-0.367	-1.090	
4	3.00	1/2x	17.955x	0.550	4.938	-0.183	-0.904	-11.655
5	3.00	1/2x	17.955x	2.570	23.072	0.857	19.773	
6	0.43	1/2x	51.391x	2.570	66.037	1.713	113.121	147.818
7	0.43	1/2x	51.391x	2.430	62.440	3.380	211.047	
8	-2.00	1/2x	58.462x	2.430	71.031	4.190	297.620	758.218
9	-2.00	1/2x	94.112x	1.000	47.056	5.333	250.950	
10	-3.00	1/2x	101.112x	1.000	50.556	5.667	286.501	1403.159
11	-3.00	1/2x	38.512x	1.000	19.256	6.333	121.948	
12	-4.00	1/2x	38.512x	1.000	19.256	6.667	128.380	1703.553
13	-4.00	1/2x	38.512x	1.000	19.256	7.333	141.204	
14	-5.00	1/2x	38.512x	1.000	19.256	7.667	147.636	2050.161
15	-5.00	1/2x	38.512x	3.000	57.768	9.000	519.912	
16	-8.00	1/2x	38.512x	3.000	57.768	10.000	577.680	3367.271
17	-8.00	1/2x	38.512x	1.500	28.884	11.500	332.166	
18	-9.50	1/2x	38.512x	1.500	28.884	12.000	346.608	4181.800
19	-9.50	1/2x	38.512x	2.500	48.140	13.333	641.851	
20	-12.00	1/2x	38.512x	2.500	48.140	14.167	681.999	5770.420
21	-12.00	1/2x	38.512x	3.500	67.396	16.167	1089.591	
22	-15.50	1/2x	38.512x	3.500	67.396	17.333	1168.175	8479.739
23	-15.50	1/2x	38.512x	4.500	86.652	20.000	1733.040	
24	-20.00	1/2x	38.512x	4.500	86.652	21.500	1863.018	12795.009

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

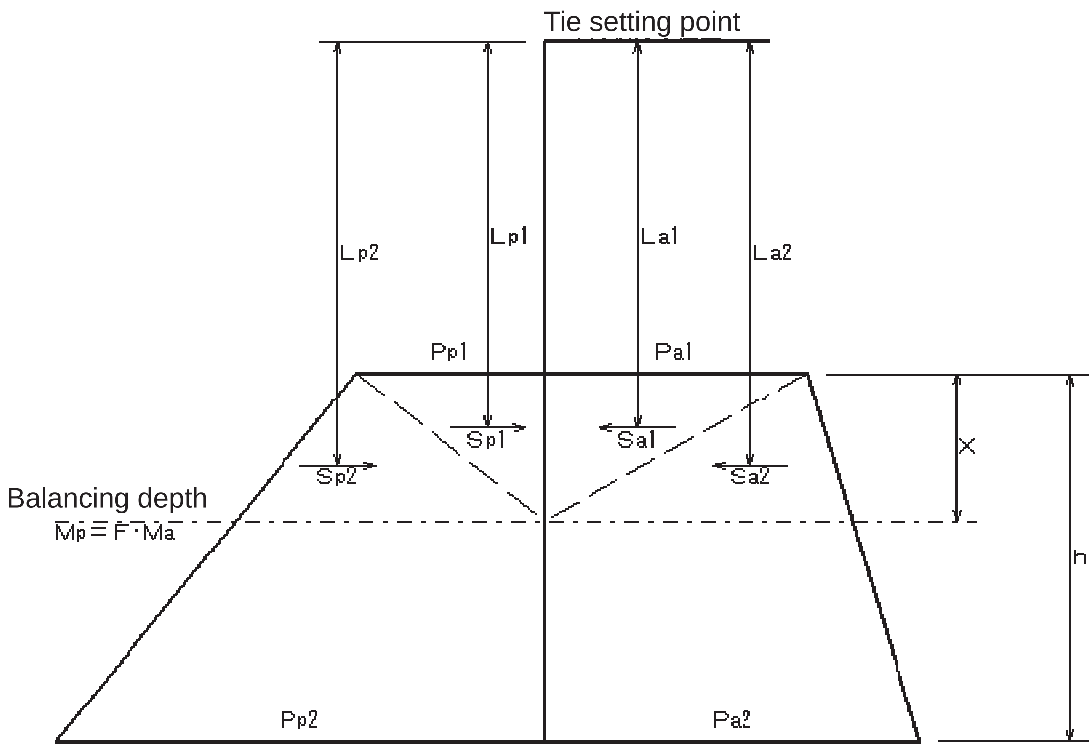
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-2.00	1/2x 30.000x 1.000	15.000	5.333	79.995	
2	-3.00	1/2x 37.000x 1.000	18.500	5.667	104.840	184.835
3	-3.00	1/2x 37.000x 1.000	18.500	6.333	117.160	
4	-4.00	1/2x 44.000x 1.000	22.000	6.667	146.674	448.669
5	-4.00	1/2x 44.000x 1.000	22.000	7.333	161.326	
6	-5.00	1/2x 39.000x 1.000	19.500	7.667	149.506	759.501
7	-5.00	1/2x 39.000x 3.000	58.500	9.000	526.500	
8	-8.00	1/2x 51.000x 3.000	76.500	10.000	765.000	2051.001
9	-8.00	1/2x 51.000x 1.500	38.250	11.500	439.875	
10	-9.50	1/2x 57.000x 1.500	42.750	12.000	513.000	3003.876
11	-9.50	1/2x 140.000x 2.500	175.000	13.333	2333.275	
12	-12.00	1/2x 155.000x 2.500	193.750	14.167	2744.856	8082.007
13	-12.00	1/2x 155.000x 3.500	271.250	16.167	4385.299	
14	-15.50	1/2x 176.000x 3.500	308.000	17.333	5338.564	17805.870
15	-15.50	1/2x 160.000x 4.500	360.000	20.000	7200.000	
16	-20.00	1/2x 178.000x 4.500	400.500	21.500	8610.750	33616.620

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1}X}{2}, \quad L_{a(p)1} = L + \frac{1}{3}X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \frac{P_{a(p)2} - P_{a(p)1}}{h} X\right] X}{2} \ , \ \ L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

$M_{a(p)}$	: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)
$M_{a(p)1}$	: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)
$M_{a(p)1'}$	: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$M_{a(p)2'}$	: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)
$S_{a(p)1}$	: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$S_{a(p)2}$	: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)
$L_{a(p)1}$	: the arm length of $S_{a(p)1}$ from the tie setting point (m)
$L_{a(p)2}$	: the arm length of $S_{a(p)2}$ from the tie setting point (m)
$P_{a(p)1}$	: the active (passive) side pressure at the top elevation of the soil layer (kPa)
$P_{a(p)1}$	: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)
h	: the thickness of the soil layer (m)
L	: the vertical distance from the tie setting point to the top elevation of the soil layer (m)
X	: the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -9.50 m	FOS×M_{a1} = 4181.800	> M_{p1} = 3003.876
at -12.00 m	FOS×M_{a2} = 5770.420	< M_{p2} = 8082.007

[Moment on active side]

$$S_{a1}=\frac{38.512X}{2}=19.256X\ ,\quad L_{a1}=12.500+\frac{1}{3}X$$

$$M_{a1'}=6.419X^2+240.700X$$

$$S_{a2}=\frac{\left[38.512+\dfrac{38.512-38.512}{1.500}X\right]X}{2}=0.000X^2+19.256X\ ,\quad L_{a2}=12.500+\frac{2}{3}X$$

$$M_{a2'}=0.000X^3+12.837X^2+240.700X$$

$$M_a=0.000X^3+19.256X^2+481.400X+3484.834$$

[Moment on passive side]

$$S_{p1}=\frac{140.000X}{2}=70.000X\ ,\quad L_{p1}=12.500+\frac{1}{3}X$$

$$M_{p1'}=23.333X^2+875.000X$$

$$S_{p2}=\frac{\left[140.000+\dfrac{149.000-140.000}{1.500}X\right]X}{2}=3.000X^2+70.000X\ ,\quad L_{p2}=12.500+\frac{2}{3}X$$

$$M_{p2'}=2.000X^3+84.167X^2+875.000X$$

$$M_p=2.000X^3+107.500X^2+1750.000X+3003.876$$

[Balancing depth]

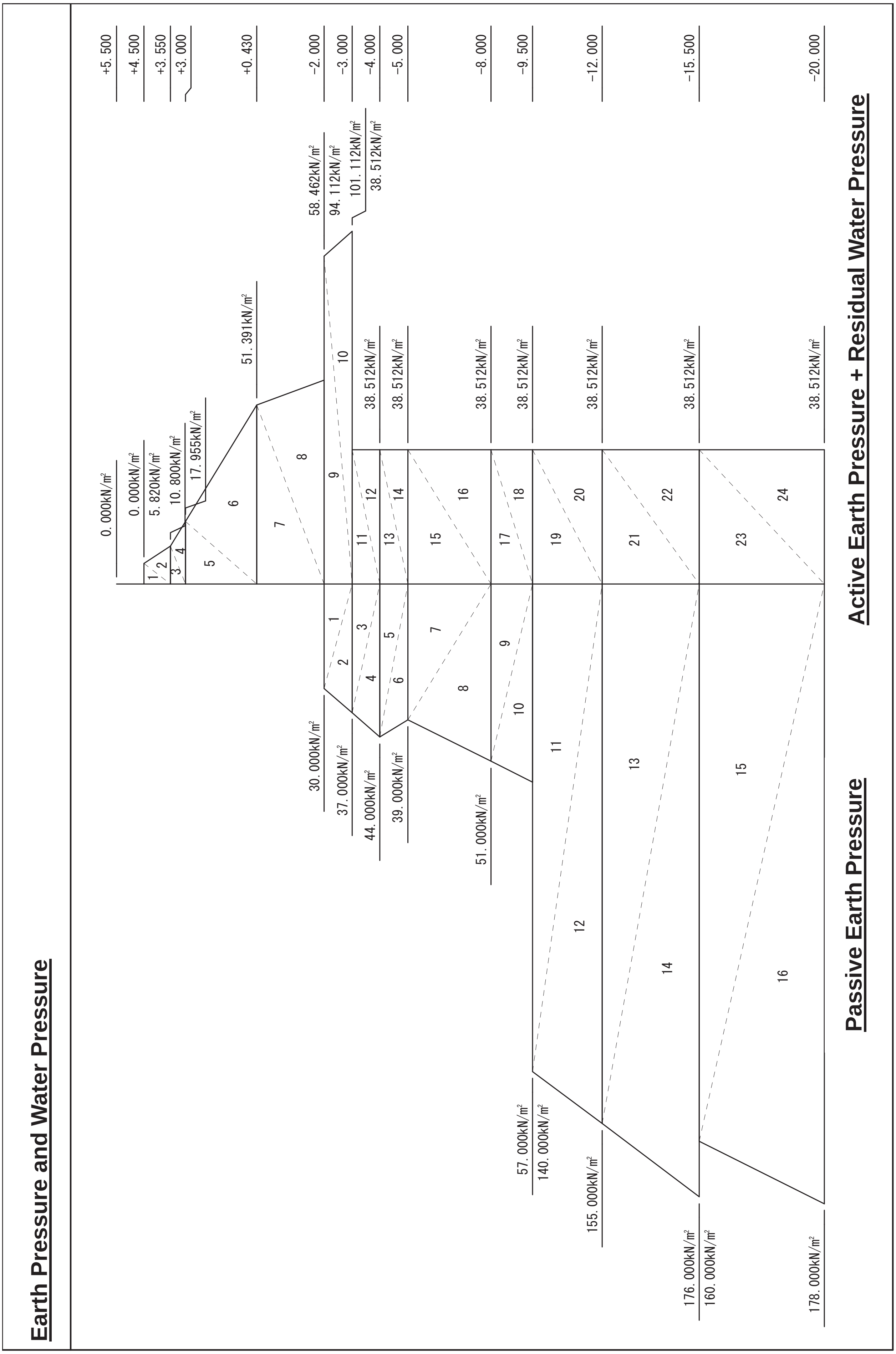
$$FOS\cdot M_a=M_p$$

$$1.2\times(0.000X^3+19.256X^2+481.400X+3484.834)$$

$$=2.000X^3+107.500X^2+1750.000X+3003.876$$

X= 0.940 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -9.500 – 0.940 = -10.440 m


Earth Pressure and Water Pressure
+5.500
+4.500
+3.550
+3.000
+0.430
-2.000
-3.000
-4.000
-5.000
-8.000
-9.500
-12.000
-15.500
-20.000
0.000kN/m²
0.000kN/m²
5.820kN/m²
10.800kN/m²
17.955kN/m²
51.391kN/m²
58.462kN/m²
94.112kN/m²
101.112kN/m²
38.512kN/m²
30.000kN/m²
37.000kN/m²
44.000kN/m²
39.000kN/m²
51.000kN/m²
57.000kN/m²
140.000kN/m²
155.000kN/m²
176.000kN/m²
160.000kN/m²
178.000kN/m²
Active Earth Pressure + Residual Water Pressure
Passive Earth Pressure

(2) Calculation of maximum bending moment

1) External forces

Elev (m)	$P_a + P_w$ (kN/m^2)	P_p (kN/m^2)	$P_a - P_p$ (kN/m^2)
5.50 4.50	0.000 0.000	——— ———	0.000 0.000
4.50 3.55	5.820 10.800	——— ———	5.820 10.800
3.55 3.00	10.800 17.955	——— ———	10.800 17.955
3.00 0.43	17.955 51.391	——— ———	17.955 51.391
0.43 -2.00	51.391 58.462	——— ———	51.391 58.462
-2.00 -3.00	94.112 101.112	30.000 37.000	64.112 64.112
-3.00 -4.00	38.512 38.512	37.000 44.000	1.512 -5.488
-4.00 -5.00	38.512 38.512	44.000 39.000	-5.488 -0.488
-5.00 -8.00	38.512 38.512	39.000 51.000	-0.488 -12.488
-8.00 -9.50	38.512 38.512	51.000 57.000	-12.488 -18.488
-9.50 -12.00	38.512 38.512	140.000 155.000	-101.488 -116.488
-12.00 -15.50	38.512 38.512	155.000 176.000	-116.488 -137.488
-15.50 -20.00	38.512 38.512	160.000 178.000	-121.488 -139.488

2) Virtual seabed level

The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -3.00 m $P_{a1} = 38.512$ > $P_{p1} = 37.000$

at -4.00 m $P_{a2} = 38.512$ < $P_{p2} = 44.000$

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

EL_{top} : the top elevation of the soil layer in question (m)

P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)

P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)

P_{p1} : the passive earth pressure at the top of the soil layer (kPa)

P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)

h : the thickness of the soil layer (m)

$$X = -3.00 - \frac{1.00 \times (37.000 - 38.512)}{(38.512 - 38.512) - (44.000 - 37.000)} = -3.216m$$

Accordingly, the virtual seabed level is obtained as -3.216m.

3) Moment about tie setting point

No	Calculation	S (kN/m)	L (m)	M (kN-m/m)
1	1/2x 5.820x 0.950	2.764	-1.183	-3.270
2	1/2x 10.800x 0.950	5.130	-0.867	-4.448
3	1/2x 10.800x 0.550	2.970	-0.367	-1.090
4	1/2x 17.955x 0.550	4.938	-0.183	-0.904
5	1/2x 17.955x 2.570	23.072	0.857	19.773
6	1/2x 51.391x 2.570	66.037	1.713	113.121
7	1/2x 51.391x 2.430	62.440	3.380	211.047
8	1/2x 58.462x 2.430	71.031	4.190	297.620
9	1/2x 64.112x 1.000	32.056	5.333	170.955
10	1/2x 64.112x 1.000	32.056	5.667	181.661
11	1/2x 1.512x 0.216	0.163	6.072	0.990
Total		302.657	——	985.455

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

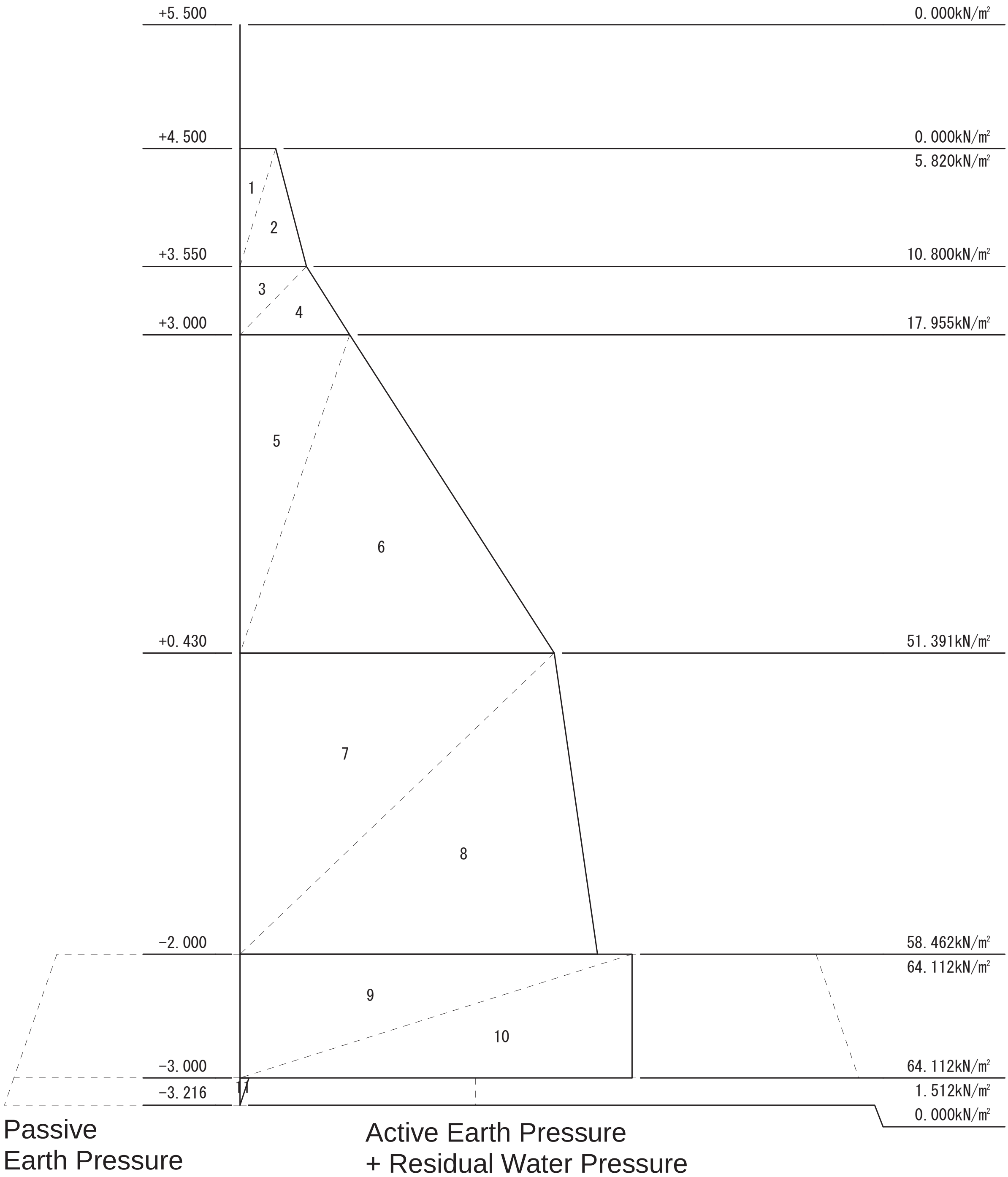
4) Reaction forces

Distance between supports : L_T = 3.000 – (-3.216) = 6.216 m

Reaction at virtual seabed : $R_0 = \frac{\Sigma M}{L_T} = \frac{985.455}{6.216} = 158.535 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 302.657 - 158.535 = 144.122 kN/m$

External Force Diagram



5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 4.50	0.000 0.000	0.000		0.000
4.50 3.55	2.764 5.130	7.894		-7.894
3.55 3.00	2.970 4.938	15.802	144.122	128.320
3.00 0.43	23.072 66.037	104.911	144.122	39.211
0.43 -2.00	62.440 71.031	238.382	144.122	-94.260
-2.00 -3.00	32.056 32.056	302.494	144.122	-158.372
-3.00 -3.22	0.163 0.000	302.657	144.122	-158.535

Shear force $Q = A_p - \sum S$

The above table suggests that the shear force zero point exists in between 0.430m and -2.000m.

$$Q = 39.211 - \frac{[51.391 + (51.391 + 2.910X)]X}{2} = 0$$

X = 0.747 m

Shear force zero point : DL = +0.43 – 0.747 = -0.317m

6) Calculation of moment

No	Calculation			S (kN/m)	L (m)	M (kN-m/m)
1	1/2x	5.820x	0.950	-2.764	4.500	-12.438
2	1/2x	10.800x	0.950	-5.130	4.184	-21.464
3	1/2x	10.800x	0.550	-2.970	3.684	-10.941
4	1/2x	17.955x	0.550	-4.938	3.500	-17.283
5	1/2x	17.955x	2.570	-23.072	2.460	-56.757
6	1/2x	51.391x	2.570	-66.037	1.604	-105.923
7	1/2x	51.391x	0.747	-19.195	0.498	-9.559
8	1/2x	53.565x	0.747	-20.007	0.249	-4.982
Total				———	———	-239.347

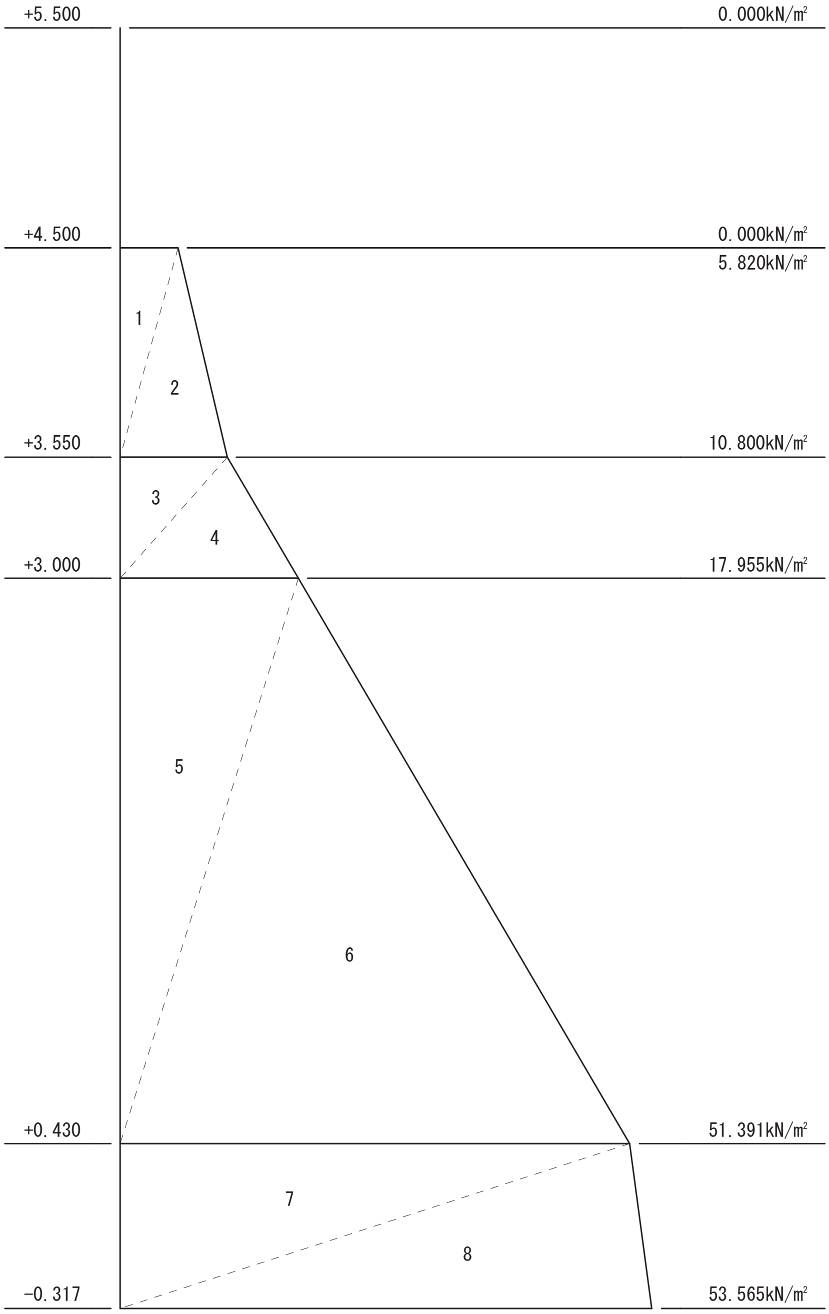
where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

7) Maximum bending moment

- Distance of the shear zero point to the tie setting point
  h = 3.000 – (-0.317) = 3.317 m

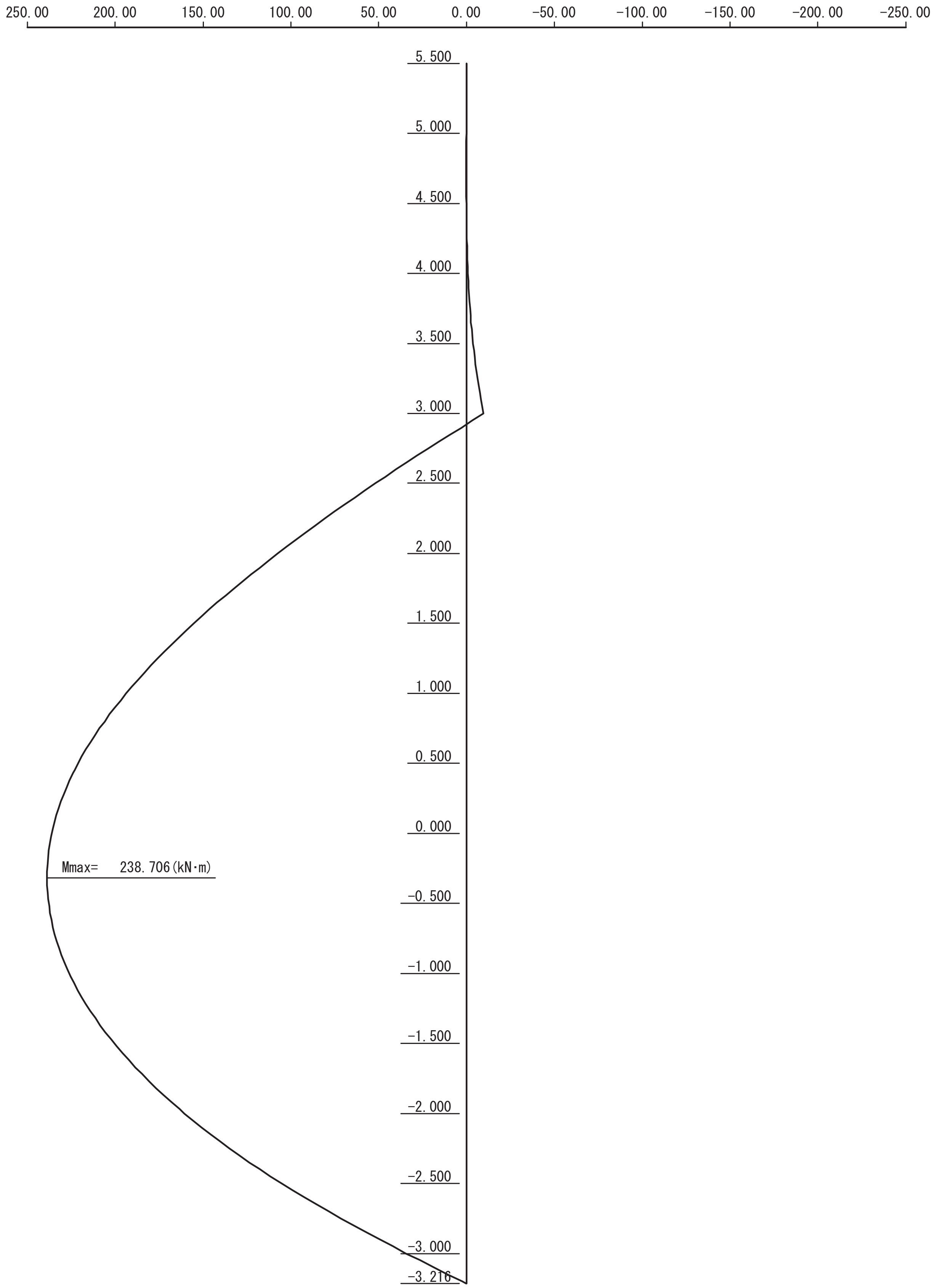
- Maximum bending moment
  $M_{max} = A_p \times h + \sum M = 144.122 \times 3.317 - 239.347 = 238.706$ kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type : ϕ800 × t10 (P-T joint)

Modulus of elasticity : E = 200.0 kN/mm^2
Moment of inertia : I = 193647 cm^4
Section modulus : Z = 4841 cm^3

Section property (per 1m) before corrosion
- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 197599 cm^4/m
- Section modulus : Z = 4940 cm^3/m

Section property (per 1m) after corrosion
- Design life time : 50 years
- Effect of cathodic protection : 90%
- Corrosion rate : 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance : t = 0.030 × 50 years = 1.50 mm

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 166997 cm^4/m
- Section modulus : Z = 4191 cm^3/m

(2) Embedded depth of pipe wall

Toe level of the pipe wall is obtained as follows:
- Deflection curve method : -14.257 m --- adopted
- Free earth support method : -10.440 m

Therefore, the minimum length of the pipe wall is;
L = 3.500 – (-14.257) = 17.757m → 18.000 m

Accordingly the design toe level of the pipe wall is;
EL = +3.500 – 18.000 = -14.500 m

(3) Stress on pipe wall section

Maximum bending moment on the pipe wall is as follows:
- Deflection curve method : 441.162 kN-m/m --- adopted
- Free earth support method : 238.706 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{441.162\times 10^6}{4191\times 10^3} = 105.3 MPa \quad \leq \quad \sigma_a = 140 MPa \text{ .... } OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

T	is the tension force on tie wire (kN/wire)
A_p	is the reaction force of the pipe wall at tie setting point (kN/m)
L	is the spacing of the tie wire (m)
θ_1	is the vertical angle of the tie wire to horizontal (deg.)
θ_2	is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 197.324 kN-m/m --- adopted
- Free earth support method : 144.122 kN-m/m

T = 197.324 × 1.960 × sec(0.000) × sec (0.000) = 386.755 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 386.755 × 3.8 = 1469.669 kN/wire

Tie wire shall have minimum tensile strength of 1470 kN.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max} is the maximum bending moment on the waling beam (kN-m)
T is the tension force on tie wire (kN/wire)
L is the spacing of the tie wire (m)

$$M_{maz} = \frac{386.755 \times 1.960}{10.0} = 75.804 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[250×90×11.0×14.5

Steel grade : SS400
Section modulus : Z = 374.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \leq \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{75.804 \times 10^6}{2 \times 374.0 \times 10^3} = 101.3 MPa \quad \leq \quad \sigma_a = 140 MPa \ \text{.... } OK$$

Output of Design Software for Anchor Wall (During Construction)
– Revetment Block d

1. Design Conditions

1-1 Dimensions

Ground elevation	+4.50 m
Top of cope concrete	+5.50 m
Top of pipe wall	+3.50 m
Tie elevation	+3.00 m
Seabed elevation	-2.00 m
Angle of seabed slope	18.4°

1-2 Tide Levels

H.W.L	+3.55 m
L.W.L	+0.43 m

1-3 Residual Water Level

R.W.L	+3.55 m

1-4 Base Elevation of Cohesion Increment +0.00 m (not used)

1-5 Surcharge Load	(Active side)	20 kPa
	(Passive side)	0 kPa

1-6 Unit Weight of Water 10.10 kN/m^3

1-7 Allowable Stresses

Pipe Wall	(SKY400)	140 MPa
Structural Steel	(SS400)	140 MPa

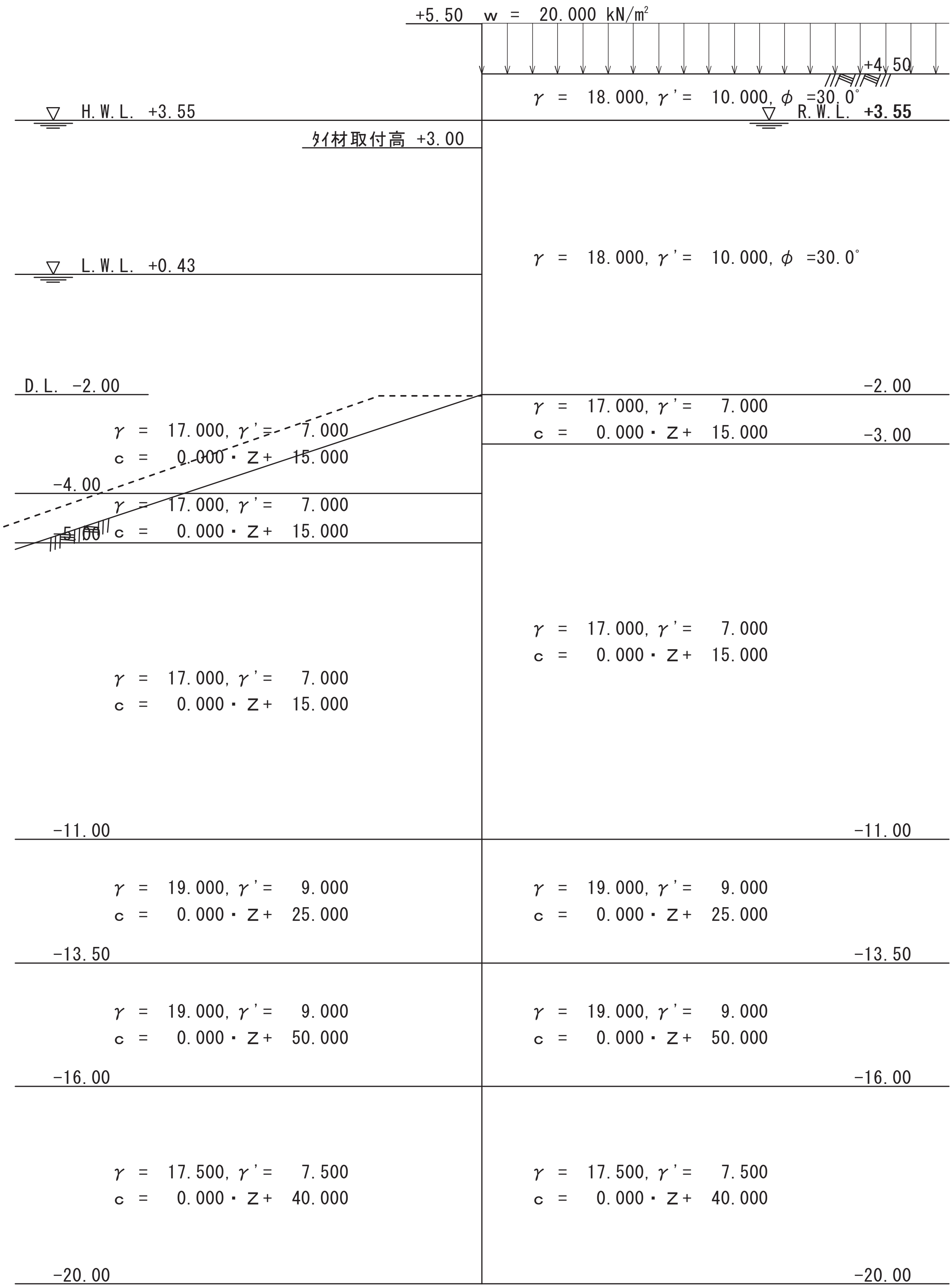
1-8 Corrosion Allowance

Pipe Wall	0.03 mm/yr × 50 yrs =	1.50 mm (outside only)

1-9 Embedded Length of Pipe Wall

Calculation Method 1	:	Deflection Curve Method
Calculation Method 2	:	Free Earth Support Method
Factor of Safety	:	FOS = 1.2

Profile of Revetment and Soil Conditions



2. Pipe Wall

2-1 Earth Pressure and Water Pressure

(1) Active earth pressure

Elev. (m)	h (m)	P_a (kPa)
4.50 3.55	0.95	5.820 10.800
3.55 3.00	0.55	10.800 12.400
3.00 -2.00	5.00	12.400 26.950
-2.00 -3.00	1.00	62.600 69.600
-3.00 -11.00	8.00	7.000 7.000
-11.00 -12.00	1.00	7.000 7.000
-12.00 -13.50	1.50	7.000 7.000
-13.50 -16.00	2.50	7.000 7.000
-16.00 -20.00	4.00	7.000 7.000

(2) Residual water pressure

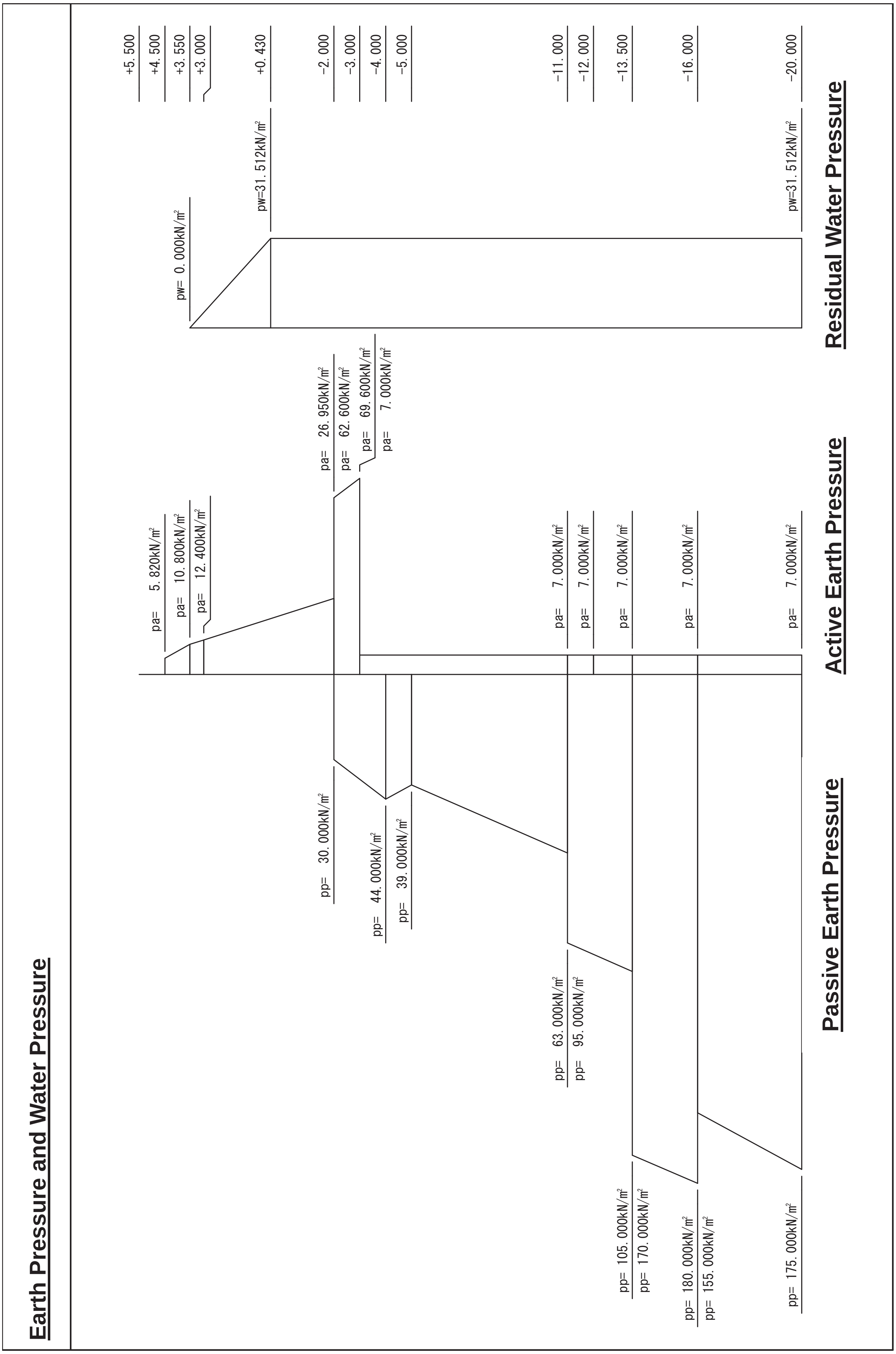
$p_w = \gamma_w \times h_w$

where; p_w is the residual water pressure (kPa)
h_w is the height of the tidal lag (m)
γ_w is the unit weight of water (kN/m^3)

pw = 10.100 × 3.120 = 31.512 kPa

(3) Passive earth pressure

Elev. (m)	h (m)	P_p (kPa)
-2.00 -4.00	2.00	30.000 44.000
-4.00 -5.00	1.00	44.000 39.000
-5.00 -11.00	6.00	39.000 63.000
-11.00 -13.50	2.50	95.000 105.000
-13.50 -16.00	2.50	170.000 180.000
-16.00 -20.00	4.00	155.000 175.000



Earth Pressure and Water Pressure
+5. 500
+4. 500
+3. 550
+3. 000
+0. 430
-2. 000
-3. 000
-4. 000
-5. 000
-11. 000
-12. 000
-13. 500
-16. 000
-20. 000
pw= 0. 000kN/m²
pw=31. 512kN/m²
pw=31. 512kN/m²
Residual Water Pressure
pa= 5. 820kN/m²
pa= 10. 800kN/m²
pa= 12. 400kN/m²
pa= 26. 950kN/m²
pa= 62. 600kN/m²
pa= 69. 600kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
pa= 7. 000kN/m²
Active Earth Pressure
pp= 30. 000kN/m²
pp= 44. 000kN/m²
pp= 39. 000kN/m²
pp= 63. 000kN/m²
pp= 95. 000kN/m²
pp= 105. 000kN/m²
pp= 170. 000kN/m²
pp= 180. 000kN/m²
pp= 155. 000kN/m²
pp= 175. 000kN/m²
Passive Earth Pressure

(4) Summary of Forces on the Wall

Elev (m)	Active side (kPa) $P_a + P_w$	Passive side(kPa) P_p
5.50 4.50	0.000+ 0.000= 0.000 0.000+ 0.000= 0.000	——— ———
4.50 3.55	5.820+ 0.000= 5.820 10.800+ 0.000= 10.800	——— ———
3.55 3.00	10.800+ 0.000= 10.800 12.400+ 5.555= 17.955	——— ———
3.00 0.43	12.400+ 5.555= 17.955 19.879+ 31.512= 51.391	——— ———
0.43 -2.00	19.879+ 31.512= 51.391 26.950+ 31.512= 58.462	——— ———
-2.00 -3.00	62.600+ 31.512= 94.112 69.600+ 31.512= 101.112	30.000 37.000
-3.00 -4.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	37.000 44.000
-4.00 -5.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	44.000 39.000
-5.00 -11.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	39.000 63.000
-11.00 -12.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	95.000 99.000
-12.00 -13.50	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	99.000 105.000
-13.50 -16.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	170.000 180.000
-16.00 -20.00	7.000+ 31.512= 38.512 7.000+ 31.512= 38.512	155.000 175.000

2-2 Deflection Curve Method

(1) Calculation of embedded length

The elastic equations are solved under the external force conditions obtained in 2-1 with the conditions that the displacement and deflection angle is zero at the tie setting point and the toe of the pipe wall.

For this purpose, the pipe wall is assumed to be simply supported at the tie setting point and the toe level of the pipe wall and the deflection angle at the toe of the pipe wall is calculated by changing the embedded length of the pipe wall. Once the embedded length of the pipe wall with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of the pipe wall shall be 1.2 times (i.e. factor of safety) the minimum embedded length.

Seabed elevation: -2.000 m

Toe of pipe wall (m)	Deflection angle θ×EI	Reaction at Tie (kN/m)	Reaction at Toe (kN/m)
-2.000	-239.109	112.012	126.370
-3.000	-446.199	138.417	164.077
-4.000	-686.260	161.798	138.708
-5.000	-899.495	178.897	118.621
-6.000	-1095.816	191.976	103.054
-7.000	-1271.134	201.990	86.552
-8.000	-1414.513	209.412	68.642
-9.000	-1512.401	214.558	49.008
-10.000	-1548.812	217.640	27.438
-11.000	-1505.437	218.822	3.768
-12.000	-1286.949	217.145	-53.043
-13.000	-794.823	211.898	-110.284
-14.000	43.246	202.997	-200.371

The above results suggest that the toe level of the pipe wall by which the deflection angle at the toe of the pipe wall becomes zero would be in between -13.00 and -14.00. Such depth was obtained by the iterative calculation as follows.

Toe of pipe wall (m)	Deflection angle at toe (deg)	Reaction at tie (kN/m)	Reaction at toe (kN/m)
-13.961	0.000	203.449	-195.669

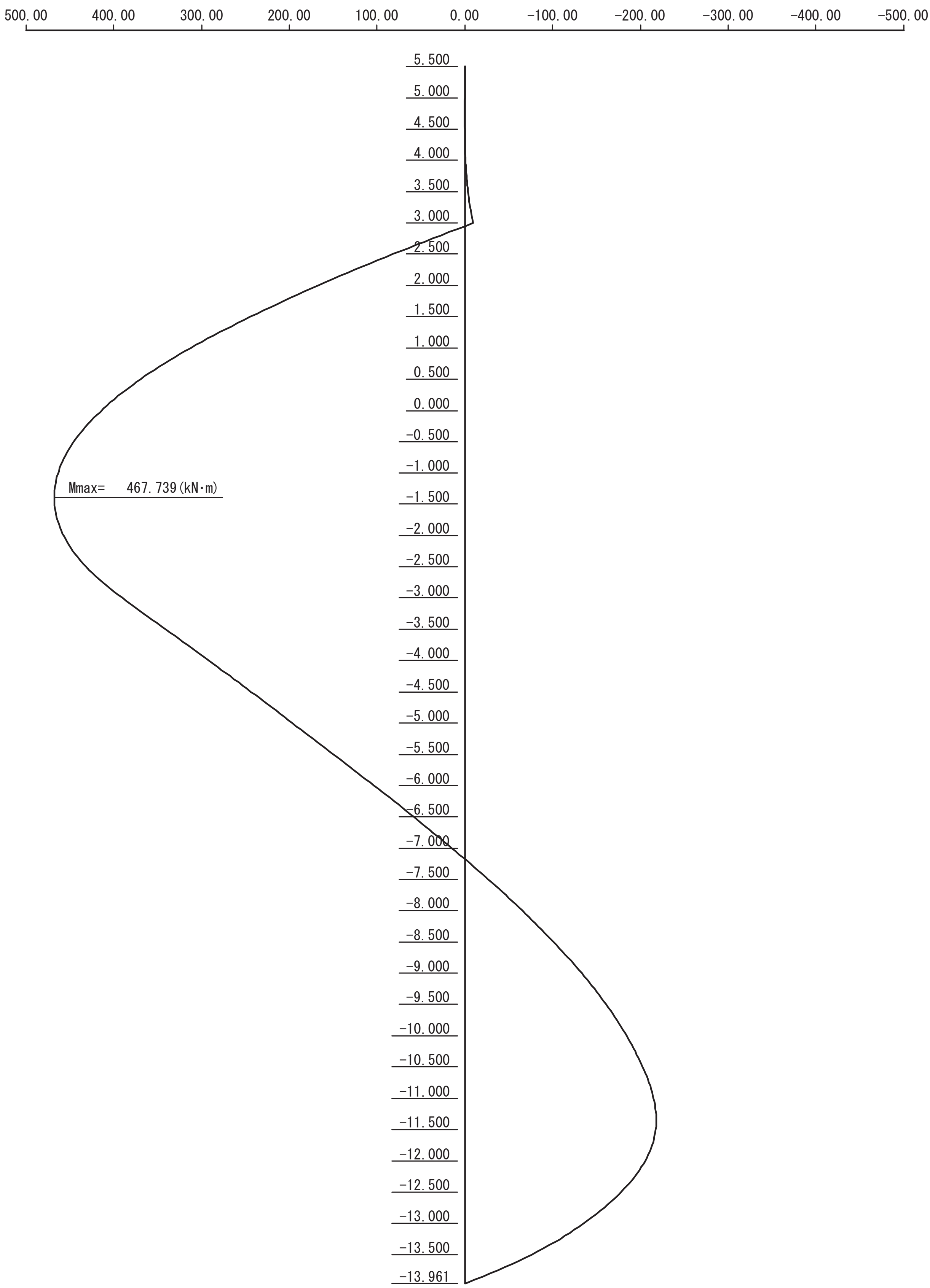
Embedded length of the pipe wall : L = 1.2 × (-2.000 + 13.961) = 14.353 m
Toe elevation : D = -2.000 – 14.353 = -16.353 m
Reaction force at tie setting point : 203.449 kN/m

(2) Calculation of maximum bending moment

Elev (m)	Bending moment (kN-m/m)	Shear force (kN/m)
5.500	0.000	0.000
5.000	0.000	0.000
4.500	0.000	0.000
4.000	-0.837	-3.565
3.550	-3.375	-7.894
3.050	-8.944	-14.921
3.000	-9.712	-15.802
2.500	81.596	177.043
2.000	166.789	163.187
1.500	244.241	146.078
1.000	312.325	125.717
0.500	369.416	102.103
0.430	376.439	98.537
-0.070	419.223	72.478
-0.570	448.795	45.691
-1.070	464.793	18.177
-1.570	466.851	-10.064
-2.000	457.196	-34.934
-2.500	431.715	-66.990
-3.000	390.206	-99.046
-3.500	340.639	-98.927
-4.000	291.570	-97.058
-4.500	243.623	-94.939
-5.000	196.423	-94.070
-5.500	149.532	-93.326
-6.000	103.263	-91.582
-6.500	58.117	-88.838
-7.000	14.592	-85.094
-7.500	-26.811	-80.350
-8.000	-65.592	-74.606
-8.500	-101.250	-67.862
-9.000	-133.287	-60.118
-9.500	-161.202	-51.374
-10.000	-184.495	-41.630
-10.500	-202.665	-30.886
-11.000	-215.214	-19.142
-11.500	-217.641	9.602
-12.000	-205.446	39.346
-12.500	-178.128	70.090
-13.000	-135.189	101.834
-13.500	-76.128	134.578
-13.961	0.000	195.669

Maximum bending moment : 467.739 kN-m/m
Elevation of maximum bending moment : -1.393 m
Depth of 1st steady point (moment=0) : -7.173 m

Bending moment diagram – Deflection Curve Method



2-3 Free Earth Support Method

(1) Calculation of embedded length

The embedded length of the pipe wall is obtained so that the following formula is satisfied.

M_p = FOS×M_a

where;

M_p is the moment due to the passive earth pressure about tie setting point (kN-m/m)

Ma is the moment due to the active earth pressure and the residual water pressure about the tie setting point (kN-m/m)

FOS =1.2

1) Calculation of FOS×M_a

NO	Elev (m)	Calculation			S (kN/m)	L (m)	M (kN-m/m)	FOS×M_a (kN-m/m)
—	5.50	1/2x	0.000x	1.000	0.000	-2.167	0.000	
—	4.50	1/2x	0.000x	1.000	0.000	-1.833	0.000	0.000
1	4.50	1/2x	5.820x	0.950	2.764	-1.183	-3.270	
2	3.55	1/2x	10.800x	0.950	5.130	-0.867	-4.448	-9.262
3	3.55	1/2x	10.800x	0.550	2.970	-0.367	-1.090	
4	3.00	1/2x	17.955x	0.550	4.938	-0.183	-0.904	-11.655
5	3.00	1/2x	17.955x	2.570	23.072	0.857	19.773	
6	0.43	1/2x	51.391x	2.570	66.037	1.713	113.121	147.818
7	0.43	1/2x	51.391x	2.430	62.440	3.380	211.047	
8	-2.00	1/2x	58.462x	2.430	71.031	4.190	297.620	758.218
9	-2.00	1/2x	94.112x	1.000	47.056	5.333	250.950	
10	-3.00	1/2x	101.112x	1.000	50.556	5.667	286.501	1403.159
11	-3.00	1/2x	38.512x	1.000	19.256	6.333	121.948	
12	-4.00	1/2x	38.512x	1.000	19.256	6.667	128.380	1703.553
13	-4.00	1/2x	38.512x	1.000	19.256	7.333	141.204	
14	-5.00	1/2x	38.512x	1.000	19.256	7.667	147.636	2050.161
15	-5.00	1/2x	38.512x	6.000	115.536	10.000	1155.360	
16	-11.00	1/2x	38.512x	6.000	115.536	12.000	1386.432	5100.311
17	-11.00	1/2x	38.512x	1.000	19.256	14.333	275.996	
18	-12.00	1/2x	38.512x	1.000	19.256	14.667	282.428	5770.420
19	-12.00	1/2x	38.512x	1.500	28.884	15.500	447.702	
20	-13.50	1/2x	38.512x	1.500	28.884	16.000	462.144	6862.235
21	-13.50	1/2x	38.512x	2.500	48.140	17.333	834.411	
22	-16.00	1/2x	38.512x	2.500	48.140	18.167	874.559	8912.999
23	-16.00	1/2x	38.512x	4.000	77.024	20.333	1566.129	
24	-20.00	1/2x	38.512x	4.000	77.024	21.667	1668.879	12795.009

where; S is the horizontal force (kN/m)

L is the distance of the horizontal force acting point to the tie point (m)

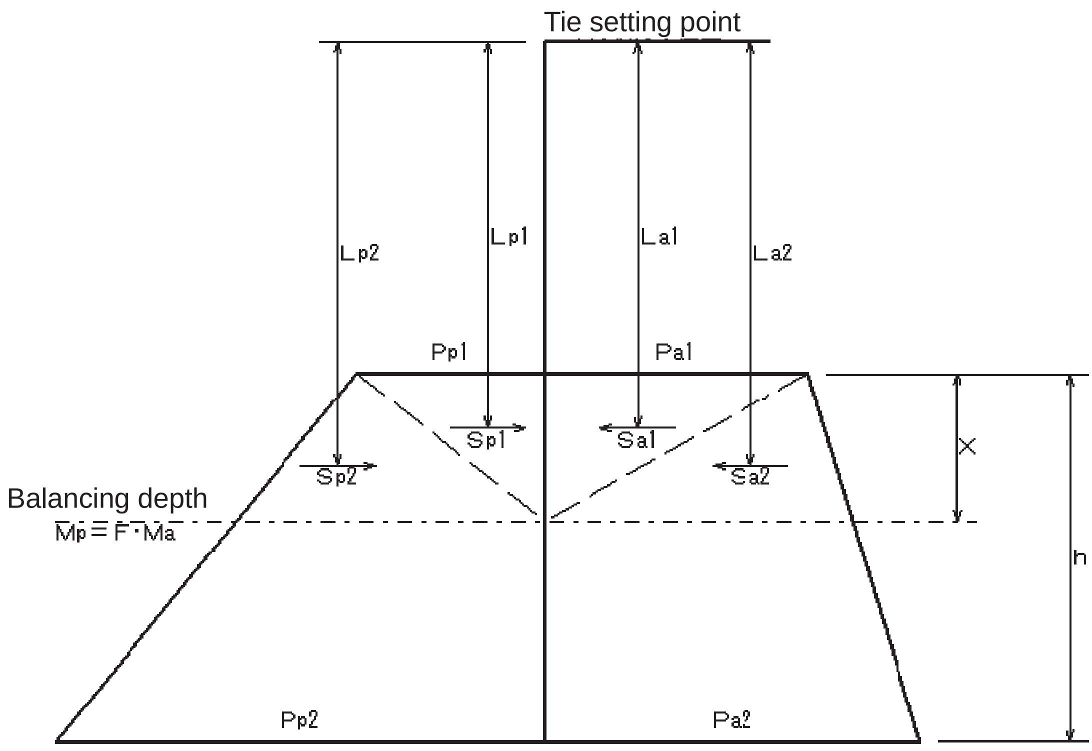
M_a is the moment about the tie setting point (kN-m/m)

2) Calculation of M_p

NO	Elev (m)	Calculation	S (kN/m)	L (m)	M (kN-m/m)	FOS×M_p (kN-m/m)
1	-2.00	1/2x 30.000x 1.000	15.000	5.333	79.995	
2	-3.00	1/2x 37.000x 1.000	18.500	5.667	104.840	184.835
3	-3.00	1/2x 37.000x 1.000	18.500	6.333	117.160	
4	-4.00	1/2x 44.000x 1.000	22.000	6.667	146.674	448.669
5	-4.00	1/2x 44.000x 1.000	22.000	7.333	161.326	
6	-5.00	1/2x 39.000x 1.000	19.500	7.667	149.506	759.501
7	-5.00	1/2x 39.000x 6.000	117.000	10.000	1170.000	
8	-11.00	1/2x 63.000x 6.000	189.000	12.000	2268.000	4197.501
9	-11.00	1/2x 95.000x 1.000	47.500	14.333	680.818	
10	-12.00	1/2x 99.000x 1.000	49.500	14.667	726.016	5604.335
11	-12.00	1/2x 99.000x 1.500	74.250	15.500	1150.875	
12	-13.50	1/2x 105.000x 1.500	78.750	16.000	1260.000	8015.210
13	-13.50	1/2x 170.000x 2.500	212.500	17.333	3683.262	
14	-16.00	1/2x 180.000x 2.500	225.000	18.167	4087.575	15786.047
15	-16.00	1/2x 155.000x 4.000	310.000	20.333	6303.230	
16	-20.00	1/2x 175.000x 4.000	350.000	21.667	7583.450	29672.727

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M_p is the moment about the tie setting point (kN-m/m)

3) Calculation of embedded length



Horizontal force and moment (upper triangle)

$$S_{a(p)1} = \frac{P_{a(p)1}X}{2}, \quad L_{a(p)1} = L + \frac{1}{3}X$$

$$M_{a(p)1'} = S_{a(p)1} \times L_{a(p)1}$$

Horizontal force and moment (lower triangle)

$$S_{a(p)2} = \frac{\left[P_{a(p)1} + \dfrac{P_{a(p)2} - P_{a(p)1}}{h} X\right] X}{2} \ , \quad L_{a(p)2} = L + \frac{2}{3} X$$

$$M_{a(p)2'} = S_{a(p)2} \times L_{a(p)2}$$

Moment due to forces above the balancing depth

$$M_{a(p)} = M_{a(p)1'} + M_{a(p)2'} + M_{a1}$$

Where;

$M_{a(p)}$: the moment due to active (passive) side pressure above the balancing depth (kN-m/m)

$M_{a(p)1}$: the moment due to active (passive) side pressure above the top elevation of the soil layer (kN-m/m)

$M_{a(p)1'}$: the moment due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)

$M_{a(p)2'}$: the moment due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN-m/m)

$S_{a(p)1}$: the horizontal force due to upper triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)

$S_{a(p)2}$: the horizontal force due to lower triangle of the active (passive) side pressure above the balancing depth in the soil layer (kN/m)

$L_{a(p)1}$: the arm length of $S_{a(p)1}$ from the tie setting point (m)

$L_{a(p)2}$: the arm length of $S_{a(p)2}$ from the tie setting point (m)

$P_{a(p)1}$: the active (passive) side pressure at the top elevation of the soil layer (kPa)

$P_{a(p)1}$: the active (passive) side pressure at the bottom elevation of the soil layer (kPa)

h : the thickness of the soil layer (m)

L : the vertical distance from the tie setting point to the top elevation of the soil layer (m)

X : the vertical distance from the top elevation of the soil layer to the balancing depth (m)

The balancing depth is obtained by comparing the moments due to the active side pressure and the passive side pressure.

at -12.00 m $\quad$ FOS×M_{a1} = 5770.420 $\quad$ > M_{p1} = 5604.335
at -13.50 m $\quad$ FOS×M_{a2} = 6862.235 $\quad$ > M_{p2} = 8015.210

[Moment on active side]

$$S_{a1} = \frac{38.512X}{2} = 19.256X \ , \quad L_{a1} = 15.000 + \frac{1}{3}X$$

$$M_{a1'} = 6.419X^2 + 288.840X$$

$$S_{a2} = \frac{\left[38.512 + \frac{38.512 - 38.512}{2.500}X\right]X}{2} = 0.000X^2 + 19.256X \ , \quad L_{a2} = 15.000 + \frac{2}{3}X$$

$$M_{a2'} = 0.000X^3 + 12.837X^2 + 288.840X$$

$$M_a = 0.000X^3 + 19.256X^2 + 577.680X + 4808.684$$

[Moment on passive side]

$$S_{p1} = \frac{99.000X}{2} = 49.500X \ , \quad L_{p1} = 15.000 + \frac{1}{3}X$$

$$M_{p1'} = 16.500X^2 + 742.500X$$

$$S_{p2} = \frac{\left[99.000 + \frac{105.000 - 99.000}{1.500}X\right]X}{2} = 2.000X^2 + 49.500X \ , \quad L_{p2} = 15.000 + \frac{2}{3}X$$

$$M_{p2'} = 1.333X^3 + 63.000X^2 + 742.500X$$

$$M_p = 1.333X^3 + 79.500X^2 + 1485.000X + 5604.335$$

[Balancing depth]

$$FOS \cdot M_a = M_p$$

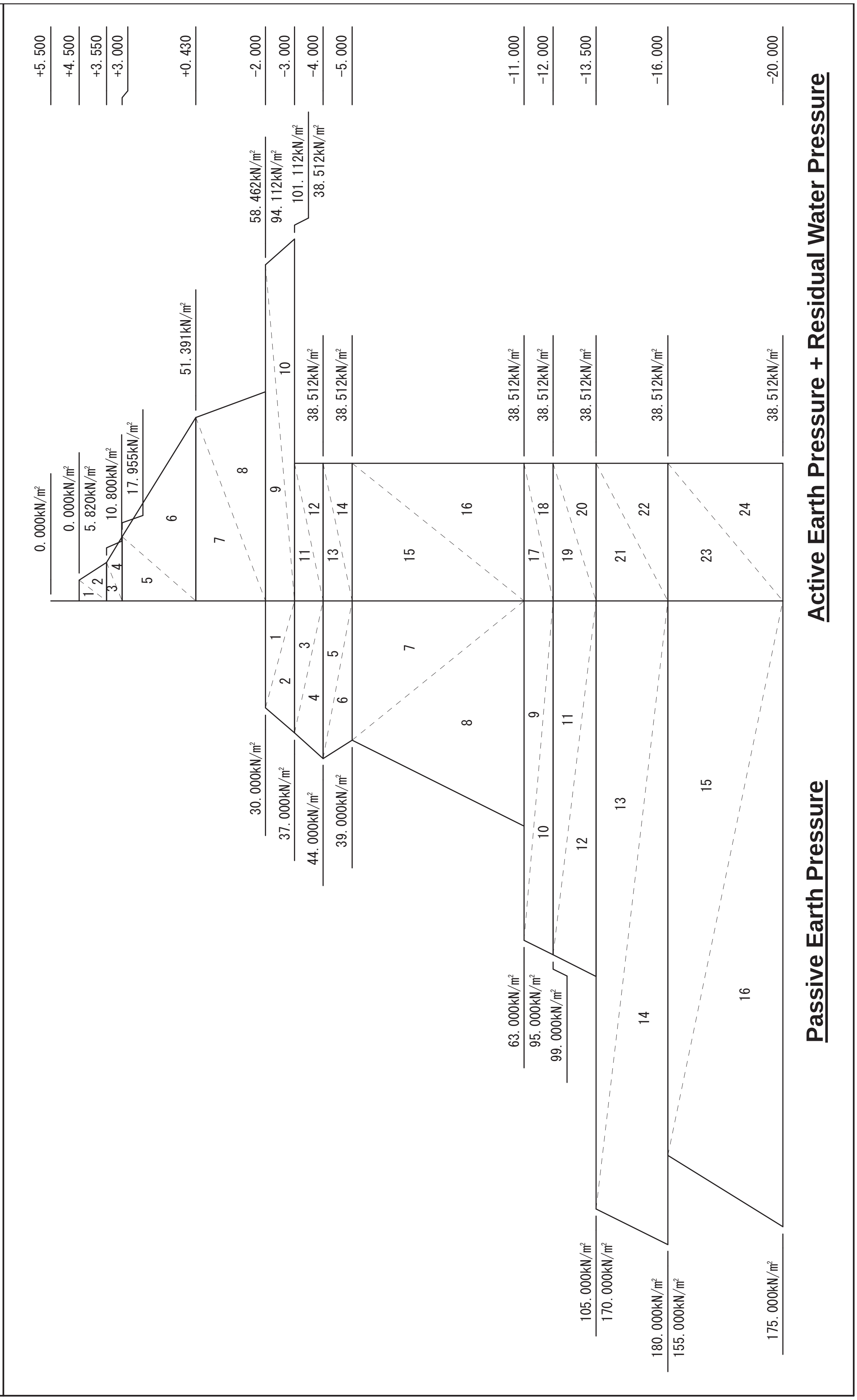
$$1.2 \times (0.000X^3 + 19.256X^2 + 577.680X + 4808.684)$$

$$= 1.333X^3 + 79.500X^2 + 1485.000X + 5604.335$$

X= 0.207 m

Accordingly, toe elevation of the pipe wall shall be as follows:
D = -12.000 – 0.207 = -12.207 m

Earth Pressure and Water Pressure



(2) Calculation of maximum bending moment

1) External forces

Elev (m)	$P_a + P_w$ (kN/m^2)	P_p (kN/m^2)	$P_a - P_p$ (kN/m^2)
5.50 4.50	0.000 0.000	——— ———	0.000 0.000
4.50 3.55	5.820 10.800	——— ———	5.820 10.800
3.55 3.00	10.800 17.955	——— ———	10.800 17.955
3.00 0.43	17.955 51.391	——— ———	17.955 51.391
0.43 -2.00	51.391 58.462	——— ———	51.391 58.462
-2.00 -3.00	94.112 101.112	30.000 37.000	64.112 64.112
-3.00 -4.00	38.512 38.512	37.000 44.000	1.512 -5.488
-4.00 -5.00	38.512 38.512	44.000 39.000	-5.488 -0.488
-5.00 -11.00	38.512 38.512	39.000 63.000	-0.488 -24.488
-11.00 -12.00	38.512 38.512	95.000 99.000	-56.488 -60.488
-12.00 -13.50	38.512 38.512	99.000 105.000	-60.488 -66.488
-13.50 -16.00	38.512 38.512	170.000 180.000	-131.488 -141.488
-16.00 -20.00	38.512 38.512	155.000 175.000	-116.488 -136.488

2) Virtual seabed level

The elevation at which the active side pressure equals to the passive side pressure is defined as the virtual seabed level.

at -3.00 m $P_{a1} = 38.512 \quad > \quad P_{p1} = 37.000$
at -4.00 m $P_{a2} = 38.512 \quad < \quad P_{p2} = 44.000$

$$X = EL_{top} - \frac{h(P_{p1} - P_{a1})}{(P_{a2} - P_{a1}) - (P_{p2} - P_{p1})}$$

Where;

EL_{top} : the top elevation of the soil layer in question (m)

P_{a1} : the active earth pressure plus residual water pressure at the top of the soil layer (kPa)

P_{a2} : the active earth pressure plus residual water pressure at the bottom of the soil layer (kPa)

P_{p1} : the passive earth pressure at the top of the soil layer (kPa)

P_{p2} : the passive earth pressure at the bottom of the soil layer (kPa)

h : the thickness of the soil layer (m)

$$X = -3.00 - \frac{1.00 \times (37.000 - 38.512)}{(38.512 - 38.512) - (44.000 - 37.000)} = -3.216m$$

Accordingly, the virtual seabed level is obtained as -3.216m.

3) Moment about tie setting point

No	Calculation	S (kN/m)	L (m)	M (kN-m/m)
1	1/2x 5.820x 0.950	2.764	-1.183	-3.270
2	1/2x 10.800x 0.950	5.130	-0.867	-4.448
3	1/2x 10.800x 0.550	2.970	-0.367	-1.090
4	1/2x 17.955x 0.550	4.938	-0.183	-0.904
5	1/2x 17.955x 2.570	23.072	0.857	19.773
6	1/2x 51.391x 2.570	66.037	1.713	113.121
7	1/2x 51.391x 2.430	62.440	3.380	211.047
8	1/2x 58.462x 2.430	71.031	4.190	297.620
9	1/2x 64.112x 1.000	32.056	5.333	170.955
10	1/2x 64.112x 1.000	32.056	5.667	181.661
11	1/2x 1.512x 0.216	0.163	6.072	0.990
Total		302.657	———	985.455

where; S is the horizontal force (kN/m)
L is the distance of the horizontal force acting point to the tie point (m)
M is the moment about the tie setting point (kN-m/m)

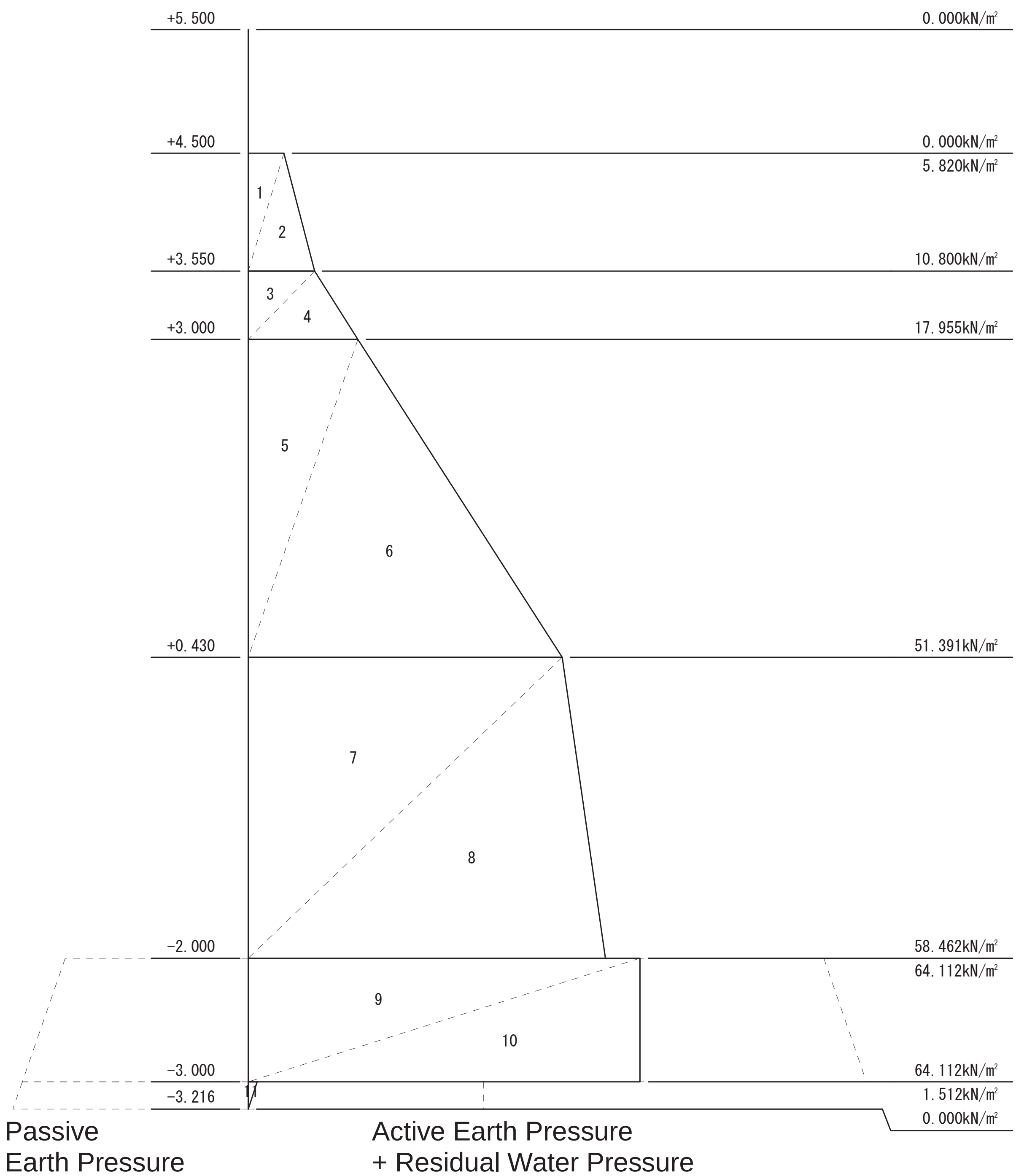
4) Reaction forces

Distance between supports : L_T = 3.000 – (-3.216) = 6.216 m

Reaction at virtual seabed : $R_0 = \frac{\Sigma M}{L_T} = \frac{985.455}{6.216} = 158.535 kN/m$

Reaction at tie setting point : $A_p = \Sigma S - R_0 = 302.657 - 158.535 = 144.122 kN/m$

External Force Diagram



5) Calculation of shear force zero point

Elev (m)	Horizontal Force S(kN/m)	∑S (kN/m)	Reaction at Tie A_p (kN/m)	Shear Force Q(kN/m)
5.50 4.50	0.000 0.000	0.000		0.000
4.50 3.55	2.764 5.130	7.894		-7.894
3.55 3.00	2.970 4.938	15.802	144.122	128.320
3.00 0.43	23.072 66.037	104.911	144.122	39.211
0.43 -2.00	62.440 71.031	238.382	144.122	-94.260
-2.00 -3.00	32.056 32.056	302.494	144.122	-158.372
-3.00 -3.22	0.163 0.000	302.657	144.122	-158.535

Shear force $Q = A_p - \sum S$

The above table suggests that the shear force zero point exists in between 0.430m and -2.000m.

$$Q = 39.211 - \frac{[51.391 + (51.391 + 2.910X)]X}{2} = 0$$

X = 0.747 m

Shear force zero point : DL = 0.430 – 0.747 = -0.317m

6) Calculation of moment

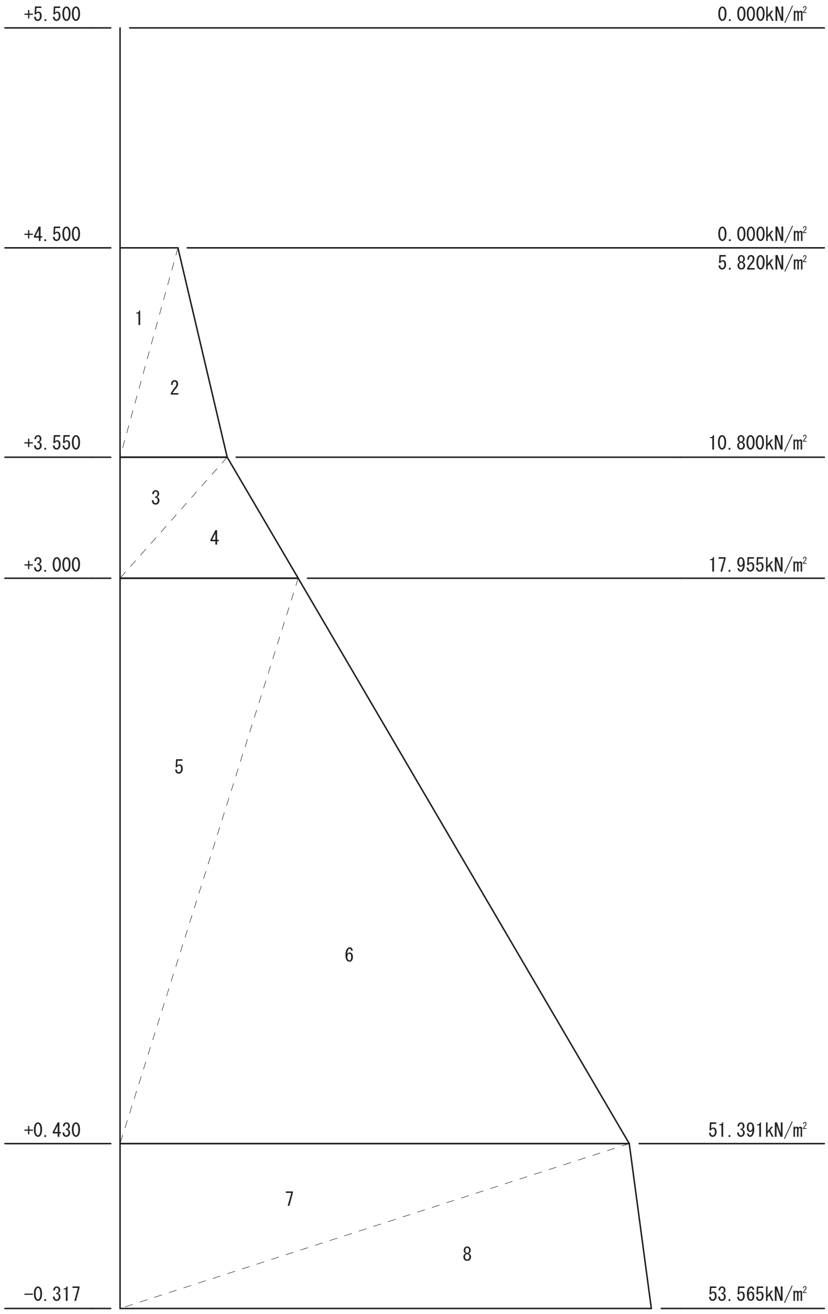
No	Calculation	S (kN/m)	L (m)	M (kN-m/m)
1	1/2x 5.820x 0.950	-2.764	4.500	-12.438
2	1/2x 10.800x 0.950	-5.130	4.184	-21.464
3	1/2x 10.800x 0.550	-2.970	3.684	-10.941
4	1/2x 17.955x 0.550	-4.938	3.500	-17.283
5	1/2x 17.955x 2.570	-23.072	2.460	-56.757
6	1/2x 51.391x 2.570	-66.037	1.604	-105.923
7	1/2x 51.391x 0.747	-19.195	0.498	-9.559
8	1/2x 53.565x 0.747	-20.007	0.249	-4.982
Total		———	———	-239.347

where; S is the horizontal force (kN/m)
L is the distance to the shear force zero point (m)
M is the moment about the shear force zero point (kN-m/m)

7) Maximum bending moment

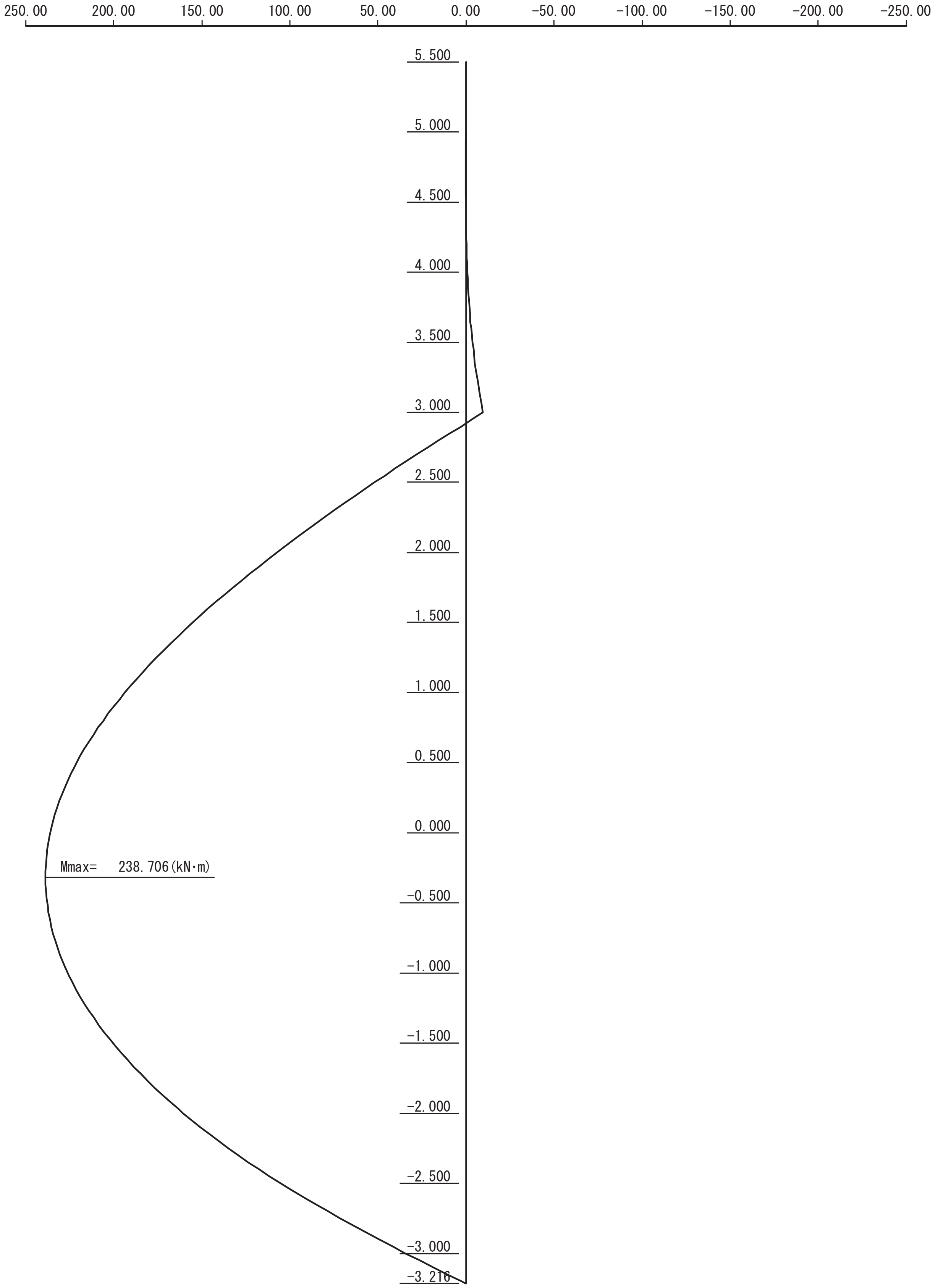
- Distance of the shear zero point to the tie setting point
  h = 3.000 – (-0.317) = 3.317 m
- Maximum bending moment
  $M_{max} = A_p \times h + \sum M = 144.122 \times 3.317 - 239.347 = 238.706$ kN-m/m

External Force Diagram



Active Earth Pressure
+ Residual Water Pressure

Bending moment diagram – Free Earth Support Method



2-4 Determination of Pipe Wall Section

(1) Section properties

Dimensions and joint type : ϕ800 × t10 (P-T joint)

Modulus of elasticity : E = 200.0 kN/mm^2
Moment of inertia : I = 193647 cm^4
Section modulus : Z = 4841 cm^3

Section property (per 1m) before corrosion
- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 197599 cm^4/m
- Section modulus : Z = 4940 cm^3/m

Section property (per 1m) after corrosion
- Design life time : 50 years
- Effect of cathodic protection : 90%
- Corrosion rate : 0.030 mm/year (0.3mm/year × 10%)
- Corrosion allowance : t = 0.030 × 50 years = 1.50 mm

- Spacing of pipes : Pipe 800mm + Joint 180mm = 980mm
- Moment of inertia : I = 166997 cm^4/m
- Section modulus : Z = 4191 cm^3/m

(2) Embedded depth of pipe wall
Toe level of the pipe wall is obtained as follows:
- Deflection curve method : -16.353 m --- adopted
- Free earth support method : -12.207 m

Therefore, the minimum length of the pipe wall is;
L = 3.500 – (-16.353) = 19.853m → 20.000 m

Accordingly the design toe level of the pipe wall is;
EL = +3.500 – 20.000 = -16.500 m

(3) Stress on pipe wall section
Maximum bending moment on the pipe wall is as follows:
- Deflection curve method : 467.739 kN-m/m --- adopted
- Free earth support method : 238.706 kN-m/m

$$\sigma = \frac{M_{\max}}{Z} = \frac{467.739\times10^6}{4666\times10^3} = 111.6MPa \quad \le \quad \sigma_a = 140MPa \quad .... OK$$

3. Tie Wire

3-1 Tension Force on Tie Wire

$$T = A_p \cdot L \cdot \sec\theta_1 \cdot \sec\theta_2$$

Where;

- T is the tension force on tie wire (kN/wire)
- A_p is the reaction force of the pipe wall at tie setting point (kN/m)
- L is the spacing of the tie wire (m)
- θ_1 is the vertical angle of the tie wire to horizontal (deg.)
- θ_2 is the plan angle of the tie wire to the direction perpendicular to the revetment line (deg.)

The reaction force is obtained as follows:

- Deflection curve method : 203.449 kN-m/m --- adopted
- Free earth support method : 144.122 kN-m/m

T = 203.449 × 1.96 × sec(0.000) × sec (0.000) = 398.760 (kN/wire)

3-2 Requirement of Tie Wire

Factor of safety = 3.8

Required tensile strength of tie wire = 398.760 × 3.8 = 1515.288 kN/wire

Tie wire shall have minimum tensile strength of <u>1516 kN</u>.

4. Study of Waling Beam

4-1 Maximum Bending Moment

$$M_{maz} = \frac{T \cdot L}{10.0}$$

Where;

M_{max} is the maximum bending moment on the waling beam (kN-m)
T is the tension force on tie wire (kN/wire)
L is the spacing of the tie wire (m)

$$M_{maz} = \frac{398.760 \times 1.960}{10.0} = 78.157 kN - m$$

4-2 Waling Beam of Seaside Wall

Provide 2×[250×90×11.0×14.5

Steel grade : SS400
Section modulus : Z = 374.0 cm^3

$$\sigma = \frac{M_{\max}}{2 \cdot Z} \le \sigma_a$$

$$\sigma = \frac{M_{\max}}{2 \cdot Z} = \frac{78.157 \times 10^6}{2 \times 374.0 \times 10^3} = 104.5 MPa \quad \le \quad \sigma_a = 140 MPa \quad .... \ OK$$

Phụ lục 7-9

Tính toán khả năng chịu lực của cọc ván thép

Bearing Capacity Check

1) Block-1

Block-1

Self Weight of Cope Concrete/SPSP and Skin Friction on SPSP

Dead weight of coping concrete

Formula
V = 1.5 x 1.5 x 1/2(1.5 + 1.0) x 2.0 = 4.75 m3/m W = 4.75 x 24 kN/m3 = 114 kN/m

↓ Wc= 114.0 kN/m

Pile weight

Dimensions		Unit	Elevation		Length	Weight
Dia	Thk	weight	Top	Bottom		per pile
mm	mm	kg/m	m CD	m CD	m	kN
800	14	271.4	3.5	-15.5	19.0	50.6

↓ Wp= 51.6 kN/m

Negative friction on land side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Sand Fill	5.50	2.00	3.50	10.00		20.00	0.98 x h =	3.43	68.60
Sand Fill	2.00	-2.00	4.00	10.00		20.00	π/2x0.8x h=	5.03	100.53
Layer-2	-2.00	-8.00	6.00		15.00	15.00	π/2x0.8x h=	7.54	113.10
Layer-3b	-8.00	-10.00	2.00		25.00	25.00	π/2x0.8x h=	2.51	62.83
Layer-4	-10.00	-15.00	5.00		50.00	50.00	π/2x0.8x h=	6.28	314.16
Layer-5	-15.00	-15.50	0.50		40.00	40.00	π/2x0.8x h=	0.63	25.13
								Total	684.35

↓ Fin= 698.32 kN/m

Skin friction on sea side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Layer-2	-5.00	-8.00	3.00		15.00	15.00	π/2x0.8x h=	3.77	56.55
Layer-3b	-8.00	-10.00	2.00		25.00	25.00	π/2x0.8x h=	2.51	62.83
Layer-4	-10.00	-15.00	5.00		50.00	50.00	π/2x0.8x h=	6.28	314.16
Layer-5	-15.00	-15.50	0.50		40.00	40.00	π/2x0.8x h=	0.63	25.13
								Total	458.67

↑ Fout= 468.03 kN/m

Total downward load

= Wc + Wp + Fin = 863.9 kN/m > Fout … Therefore, SPSP with cope concrete will settle by the consolidation of the soil between SPSP and DMM after construction.

Bearing Capacity Check

Bearing capacity

Ru = 300 x N x Ap

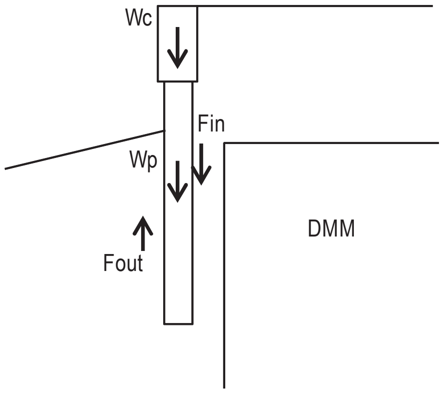
= 300 x 40 x π/4 x 0.8^2 = 6,031.9 kN/pile

Ra = Ru / 2.5 = $\boxed{2,412.7}$ kN/pile

Design load

P = Wc + Wp + Fin - Fout = 395.9 kN/m

$P_{\_4piles}$ = P x 0.98m x 4piles = $\boxed{1,551.9}$ kN/pile < Ra ... OK



Stress Check for Bearing Pile

Pile diameter	D =	800	mm
Wall thickness	t =	19	mm
Corrosion loss	Δt =	1.5	mm
Outer dia after corrosion	OD =	797	mm
Inner dia after corrosion	ID =	762	mm (no change)
Area	A =	42,855	mm2
Moment of inertia	I =	3,256,605,327	mm4
Section modulus	Z =	8,172,159	mm3
Maximum bending moment	M =	786.6	kNm
Axial compression force	P =	1,551.9	kN
Stress due to bending moment	M/Z =	96.3	MPa
Stress due to axial force	P/A =	36.2	MPa
Maximum fibre stress	M/Z + P/A =	$\boxed{132.5}$	MPa < 140 MPa ... OK

2

2) Block-a

Block-a

Self Weight of Cope Concrete/SPSP and Skin Friction on SPSP

Dead weight of coping concrete

Formula
V = 1.5 x 1.5 x 1/2(1.5 + 1.0) x 2.0 = 4.75 m3/m W = 4.75 x 24 kN/m3 = 114 kN/m

↓ Wc= 114.0 kN/m

Pile weight

Dimensions		Unit	Elevation		Length	Weight
Dia	Thk	weight	Top	Bottom		per pile
mm	mm	kg/m	m CD	m CD	m	kN
800	10	194.8	3.5	-13.5	17.0	32.5

↓ Wp= 33.2 kN/m

Negative friction on land side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Sand Fill	5.50	2.00	3.50	10.00		20.00	0.98 x h =	3.43	68.60
Sand Fill	2.00	-2.00	4.00	10.00		20.00	π/2x0.8x h=	5.03	100.53
Layer-2	-2.00	-7.50	5.50		15.00	15.00	π/2x0.8x h=	6.91	103.67
Layer-4	-7.50	-13.50	6.00		50.00	50.00	π/2x0.8x h=	7.54	376.99
								Total	649.79

↓ Fin= 663.06 kN/m

Skin friction on sea side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Layer-2	-2.00	-7.50	5.50		15.00	15.00	π/2x0.8x h=	6.91	103.67
Layer-4	-7.50	-13.50	6.00		50.00	50.00	π/2x0.8x h=	7.54	376.99
								Total	480.66

↑ Fout= 490.47 kN/m

Total downward load

= Wc + Wp + Fin = 810.2 kN/m > Fout … Therefore, SPSP with cope concrete will settle by the consolidation of the soil between SPSP and DMM after construction.

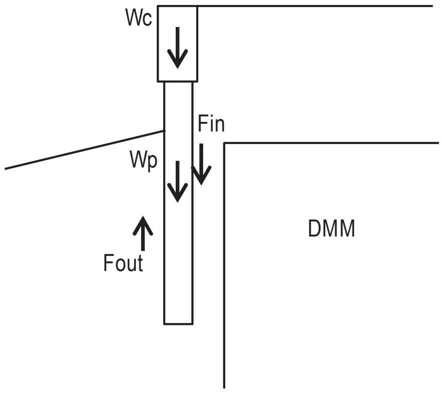
Bearing Capacity Check

Bearing capacity

Ru = 300 x N x Ap

= 300 x 40 x π/4 x 0.8^2 = 6,031.9 kN/pile

Ra = Ru / 2.5 = $\boxed{2{,}412.7}$ kN/pile



Design load

P = Wc + Wp + Fin - Fout = 319.7 kN/m

$P_{\_4piles}$ = P x 0.98m x 4piles = $\boxed{1{,}253.4}$ kN/pile < Ra ... OK

Stress Check for Bearing Pile

Pile diameter	D =	800	mm
Wall thickness	t =	12	mm
Corrosion loss	Δt =	1.5	mm
Outer dia after corrosion	OD =	797	mm
Inner dia after corrosion	ID =	776	mm (no change)
Area	A =	25,944	mm2
Moment of inertia	I =	2,006,424,227	mm4
Section modulus	Z =	5,034,942	mm3
Maximum bending moment	M =	457.1	kNm
Axial compression force	P =	1,253.4	kN
Stress due to bending moment	M/Z =	90.8	MPa
Stress due to axial force	P/A =	48.3	MPa
Maximum fibre stress	M/Z + P/A =	$\boxed{139.1}$	MPa < 140 MPa ... OK

3) Block-b

Block-b

Self Weight of Cope Concrete/SPSP and Skin Friction on SPSP

Dead weight of coping concrete

Formula
V = 1.5 x 1.5 x 1/2(1.5 + 1.0) x 2.0 = 4.75 m3/m W = 4.75 x 24 kN/m3 = 114 kN/m

↓ Wc= 114.0 kN/m

Pile weight

Dimensions		Unit	Elevation		Length	Weight
Dia	Thk	weight	Top	Bottom		per pile
mm	mm	kg/m	m CD	m CD	m	kN
800	10	194.8	3.5	-16.5	20.0	38.2

↓ Wp= 39.0 kN/m

Negative friction on land side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Sand Fill	5.50	2.00	3.50	10.00		20.00	0.98 x h =	3.43	68.60
Sand Fill	2.00	-2.00	4.00	10.00		20.00	π/2x0.8x h=	5.03	100.53
Layer-2	-2.00	-9.00	7.00		15.00	15.00	π/2x0.8x h=	8.80	131.95
Layer-3b	-9.00	-13.00	4.00		25.00	25.00	π/2x0.8x h=	5.03	125.66
Layer-4	-13.00	-16.00	3.00		50.00	50.00	π/2x0.8x h=	3.77	188.50
Layer-5	-16.00	-16.50	0.50		40.00	40.00	π/2x0.8x h=	0.63	25.13
								Total	640.37

↓ Fin= 653.44 kN/m

Skin friction on sea side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Layer-2	-2.00	-9.00	7.00		15.00	15.00	π/2x0.8x h=	8.80	131.95
Layer-3b	-9.00	-13.00	4.00		25.00	25.00	π/2x0.8x h=	5.03	125.66
Layer-4	-13.00	-16.00	3.00		50.00	50.00	π/2x0.8x h=	3.77	188.50
Layer-5	-16.00	-16.50	0.50		40.00	40.00	π/2x0.8x h=	0.63	25.13
								Total	471.24

↑ Fout= 480.86 kN/m

Total downward load

= Wc + Wp + Fin = 806.4 kN/m   > Fout … Therefore, SPSP with cope concrete will settle by the consolidation of the soil between SPSP and DMM after construction.

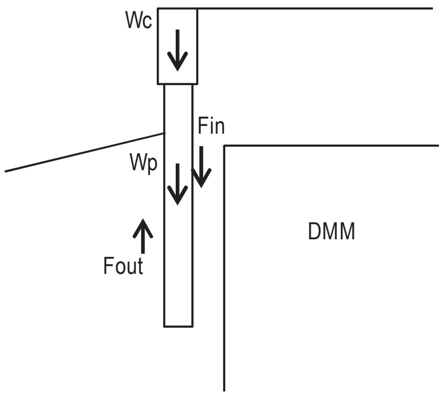
Bearing Capacity Check

Bearing capacity

Ru = 300 x N x Ap

= 300 x 40 x π/4 x 0.8^2 = 6,031.9 kN/pile

Ra = Ru / 2.5 = $\boxed{2,412.7}$ kN/pile



Design load

P = Wc + Wp + Fin - Fout = 325.6 kN/m

$P_{\_4piles}$ = P x 0.98m x 4piles = $\boxed{1,276.3}$ kN/pile < Ra ... OK

Stress Check for Bearing Pile

Pile diameter	D =	800	mm
Wall thickness	t =	14	mm
Corrosion loss	Δt =	1.5	mm
Outer dia after corrosion	OD =	797	mm
Inner dia after corrosion	ID =	772	mm (no change)
Area	A =	30,807	mm2
Moment of inertia	I =	2,370,603,868	mm4
Section modulus	Z =	5,948,818	mm3
Maximum bending moment	M =	524.7	kNm
Axial compression force	P =	1,276.3	kN
Stress due to bending moment	M/Z =	88.2	MPa
Stress due to axial force	P/A =	41.4	MPa
Maximum fibre stress	M/Z + P/A =	$\boxed{129.6}$	MPa < 140 MPa ... OK

4) Block-c

Block-c

Self Weight of Cope Concrete/SPSP and Skin Friction on SPSP

Dead weight of coping concrete

Formula
V = 1.5 x 1.5 x 1/2(1.5 + 1.0) x 2.0 = 4.75 m3/m W = 4.75 x 24 kN/m3 = 114 kN/m

↓ Wc= 114.0 kN/m

Pile weight

Dimensions		Unit	Elevation		Length	Weight
Dia	Thk	weight	Top	Bottom		per pile
mm	mm	kg/m	m CD	m CD	m	kN
800	10	194.8	3.5	-15.0	18.5	35.4

↓ Wp= 36.1 kN/m

Negative friction on land side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Sand Fill	5.50	2.00	3.50	10.00		20.00	0.98 x h =	3.43	68.60
Sand Fill	2.00	-2.00	4.00	10.00		20.00	π/2x0.8x h=	5.03	100.53
Layer-2	-2.00	-8.00	6.00		15.00	15.00	π/2x0.8x h=	7.54	113.10
Layer-3a	-8.00	-9.50	1.50	4.00		8.00	π/2x0.8x h=	1.88	15.08
Layer-4	-9.50	-15.00	5.50		50.00	50.00	π/2x0.8x h=	6.91	345.58
								Total	642.88

↓ Fin= 656.00 kN/m

Skin friction on sea side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Layer-2	-2.00	-8.00	6.00		15.00	15.00	π/2x0.8x h=	7.54	113.10
Layer-3a	-8.00	-9.50	1.50	4.00		8.00	π/2x0.8x h=	1.88	15.08
Layer-4	-9.50	-15.00	5.50		50.00	50.00	π/2x0.8x h=	6.91	345.58
								Total	473.75

↑ Fout= 483.42 kN/m

Total downward load

= Wc + Wp + Fin = 806.1 kN/m   > Fout … Therefore, SPSP with cope concrete will settle by the consolidation of the soil between SPSP and DMM after construction.

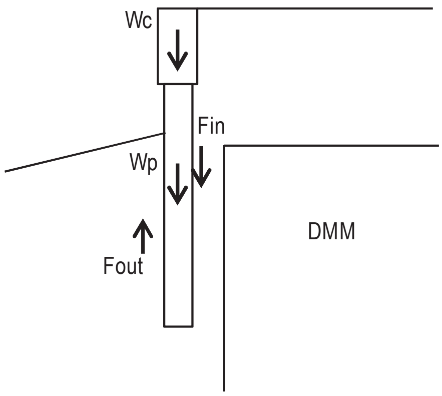
Bearing Capacity Check

Bearing capacity

$Ru = 300 \times N \times Ap$

$= 300 \times 40 \times \pi/4 \times 0.8^2$ = 6,031.9 kN/pile

$Ra = Ru / 2.5$ = $\boxed{2,412.7}$ kN/pile



Design load

$P = Wc + Wp + Fin - Fout$ = 322.7 kN/m

$P_{\_4piles} = P \times 0.98m \times 4piles$ = $\boxed{1,264.8}$ kN/pile < Ra ... OK

Stress Check for Bearing Pile

Pile diameter	D =	800	mm
Wall thickness	t =	14	mm
Corrosion loss	Δt =	1.5	mm
Outer dia after corrosion	OD =	797	mm
Inner dia after corrosion	ID =	772	mm (no change)
Area	A =	30,807	mm2
Moment of inertia	I =	2,370,603,868	mm4
Section modulus	Z =	5,948,818	mm3
Maximum bending moment	M =	509.3	kNm
Axial compression force	P =	1,264.8	kN
Stress due to bending moment	M/Z =	85.6	MPa
Stress due to axial force	P/A =	41.1	MPa
Maximum fibre stress	M/Z + P/A =	$\boxed{126.67}$	MPa < 140 MPa ... OK

5) Block-d

Block-d

Self Weight of Cope Concrete/SPSP and Skin Friction on SPSP

Dead weight of coping concrete

Formula
V = 1.5 x 1.5 x 1/2(1.5 + 1.0) x 2.0 = 4.75 m3/m W = 4.75 x 24 kN/m3 = 114 kN/m

↓ Wc= 114.0 kN/m

Pile weight

Dimensions		Unit	Elevation		Length	Weight
Dia	Thk	weight	Top	Bottom		per pile
mm	mm	kg/m	m CD	m CD	m	kN
800	10	194.8	3.5	-17.5	21.0	40.1

↓ Wp= 41.0 kN/m

Negative friction on land side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Sand Fill	5.50	2.00	3.50	10.00		20.00	0.98 x h =	3.43	68.60
Sand Fill	2.00	-2.00	4.00	10.00		20.00	π/2x0.8x h=	5.03	100.53
Layer-2	-2.00	-11.00	9.00		15.00	15.00	π/2x0.8x h=	11.31	169.65
Layer-3b	-11.00	-13.50	2.50		25.00	25.00	π/2x0.8x h=	3.14	78.54
Layer-4	-13.50	-16.00	2.50		50.00	50.00	π/2x0.8x h=	3.14	157.08
Layer-5	-16.00	-17.50	1.50		40.00	40.00	π/2x0.8x h=	1.88	75.40
								Total	649.79

↓ Fin= 663.06 kN/m

Skin friction on sea side surface of SPSP

	Elev		Layer	Soil Condition		f	As		F
	Top	Bottom	Thk	SPT-N	Cu	2N or Cu			per pile
	mCD	mCD	m		kPa	kPa	m2		kN
Layer-2	-2.00	-11.00	9.00		15.00	15.00	π/2x0.8x h=	11.31	169.65
Layer-3b	-11.00	-13.50	2.50		25.00	25.00	π/2x0.8x h=	3.14	78.54
Layer-4	-13.50	-16.00	2.50		50.00	50.00	π/2x0.8x h=	3.14	157.08
Layer-5	-16.00	-17.50	1.50		40.00	40.00	π/2x0.8x h=	1.88	75.40
								Total	480.66

↑ Fout= 490.47 kN/m

Total downward load

= Wc + Wp + Fin = 818.0 kN/m > Fout … Therefore, SPSP with cope concrete will settle by the consolidation of the soil between SPSP and DMM after construction.

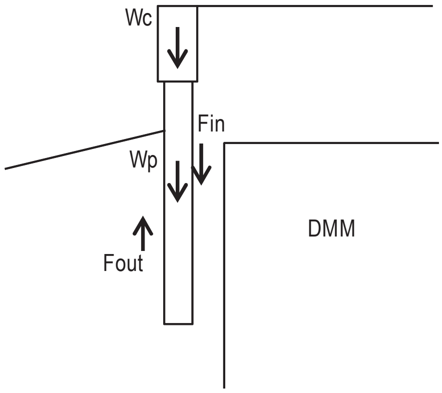
Bearing Capacity Check

Bearing capacity

$Ru = 300 \times N \times Ap$

$= 300 \times 40 \times \pi/4 \times 0.8^2 =$ 6,031.9 kN/pile

$Ra = Ru / 2.5 =$ $\boxed{2,412.7}$ kN/pile



Design load

P = Wc + Wp + Fin - Fout = 327.5 kN/m

$P_{\_4piles}$ = P x 0.98m x 4piles = $\boxed{1,283.9}$ kN/pile < Ra … OK

Stress Check for Bearing Pile

Pile diameter	D =	800	mm
Wall thickness	t =	14	mm
Corrosion loss	Δt =	1.5	mm
Outer dia after corrosion	OD =	797	mm
Inner dia after corrosion	ID =	772	mm (no change)
Area	A =	30,807	mm2
Moment of inertia	I =	2,370,603,868	mm4
Section modulus	Z =	5,948,818	mm3
Maximum bending moment	M =	577.49	kNm
Axial compression force	P =	1,283.9	kN
Stress due to bending moment	M/Z =	97.1	MPa
Stress due to axial force	P/A =	41.7	MPa
Maximum fibre stress	M/Z + P/A =	$\boxed{138.75}$	MPa < 140 MPa … OK