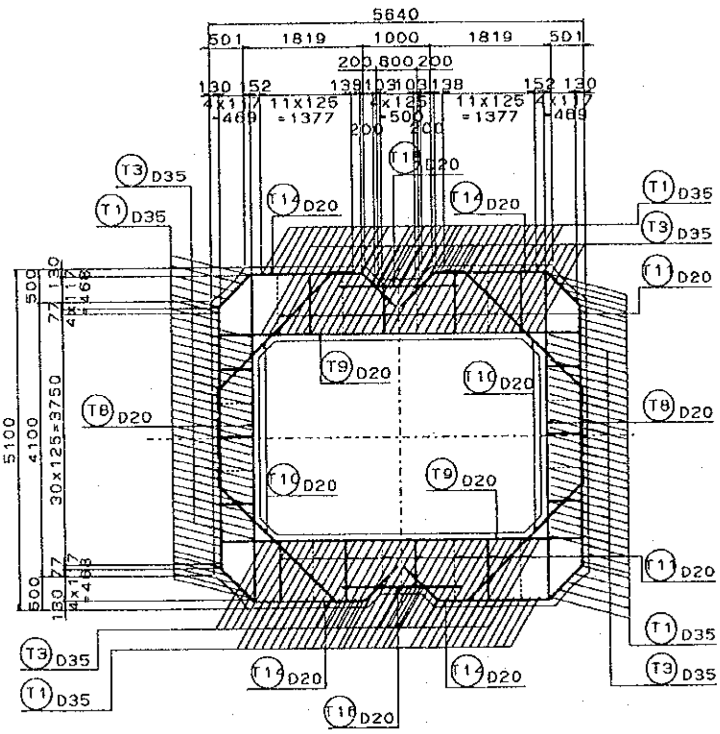
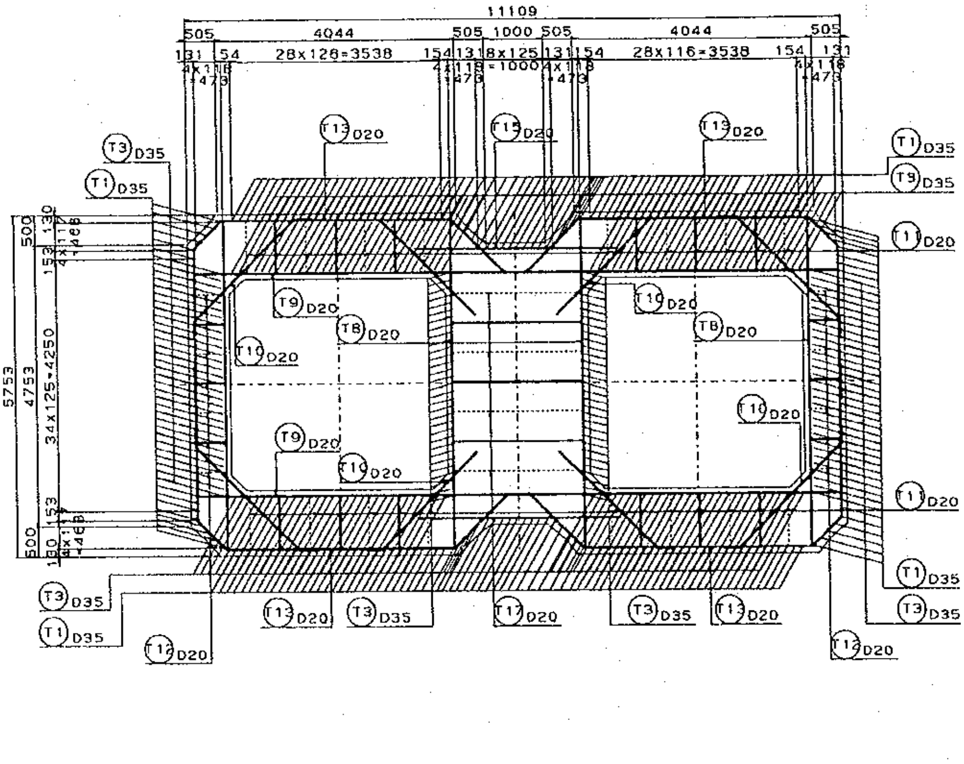
3.9.3 Cross Section

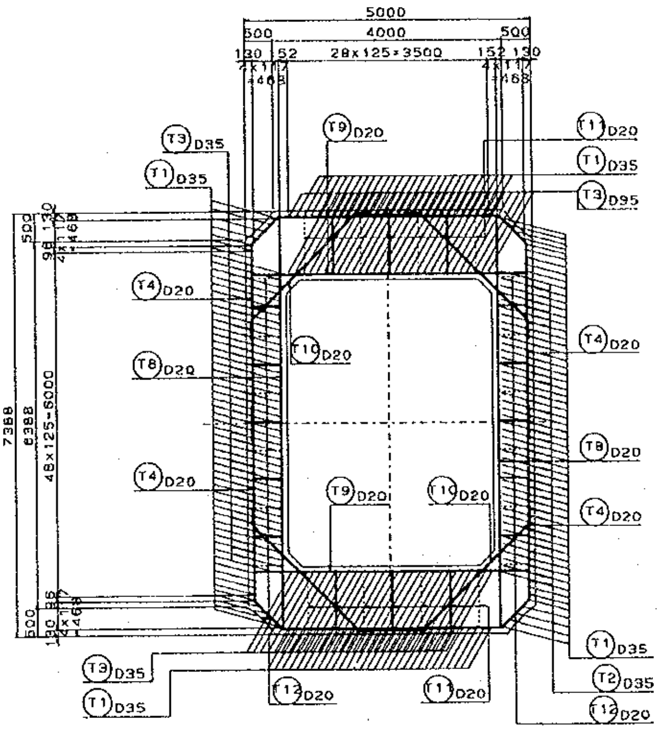
PYLON SECTION A-A



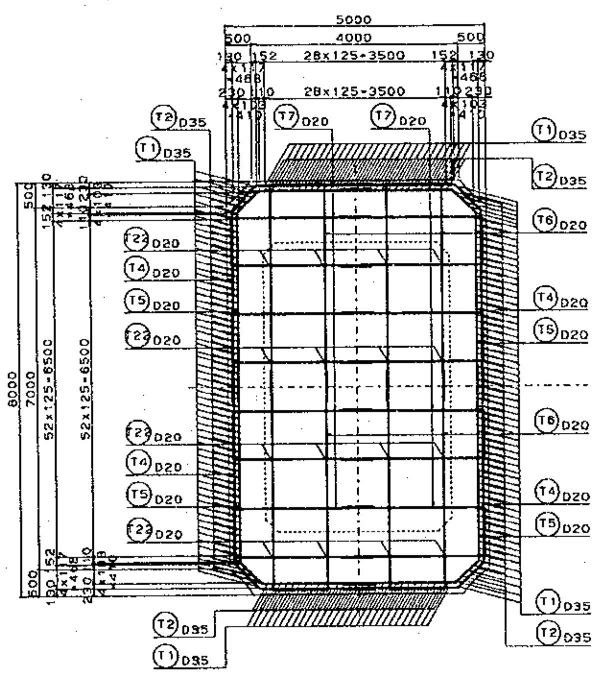
PYLON SECTION B-B



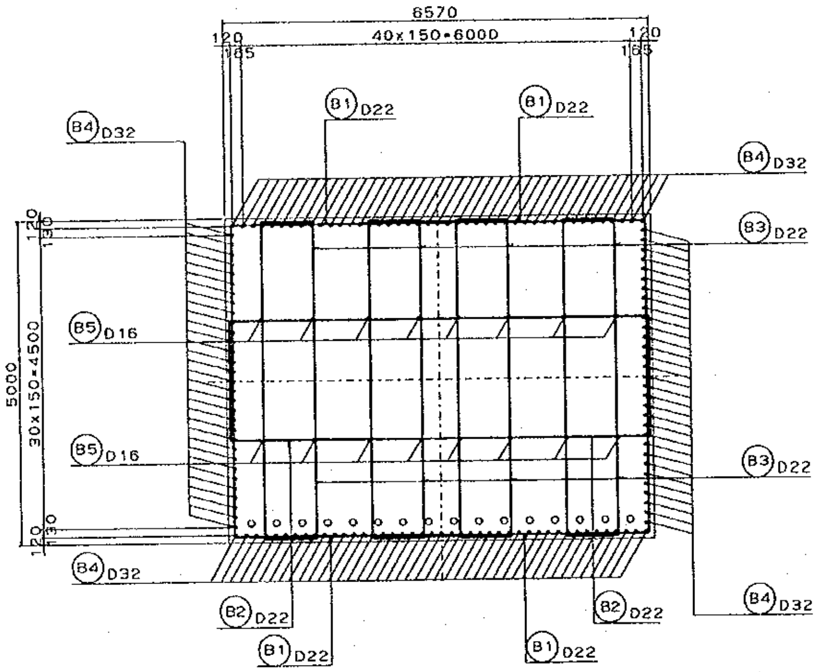
PYLON SECTION C-C



PYLON SECTION D-D



CROSS BEAM



6570
40x150=6000
120
165
120
165
B1 D22
B1 D22
B4 D32
B4 D32
B3 D22
B5 D16
B5 D16
B3 D22
5000
30x150=4500
120
130
120
130
B4 D32
B2 D22
B1 D22
B2 D22
B1 D22
B4 D32

3.9.4 Check from Load and Resistance Factor Design of Column of Pylon

Determination of Internal Forces for ULS - Strength I

Longitudinal direction

			LL												Total	
	DC	DW	Mmax	Mmin	Smax	Smin	Nmax	Nmin	WS	WL	TU	CR	SH	TG		ULT. strength factor
Strength I	1.25	1.5	1.75	1.75	1.75	1.75	1.75	1.75	0	0	1.2	1.2	1.2	0	kNm/kN	
Section A-A																
Mmax	0	0							3,391						0	32.511
Nref	-12,674	-1,429							0						-17,986	
Mmin	0	0							-3,391						0	
Nref	-12,674	-1,429							0						-17,986	
Section B-B																
Mmax	-549,286	46,604	81,930						4,824		5,222	53		3,219	-466,994	2.253
Nref	-102,292	-16,467	-8,675						-6,101		117	-3		-208	-167,610	
Mmin	-549,286	46,604		-44,303					-4,824		-5,222				-700,498	1.166
Nref	-102,292	-16,467		-5,234					6,101		-117				-161,865	
Section C-C																
Mmax	-145,655	42,055	43,832						6,305	435	16,572	171	8		-22,179	2.509
Nref	-151,144	-14,799	-10,308						5,533	-15	28	-2	0		-229,136	
Mmin	-145,655	42,055		-12,980					-6,305	-435	-16,572			-3,638	-161,588	2.323
Nref	-151,144	-14,799		-1,227					-5,533	15	-28			-113	-213,309	
Section D-D																
Mmax	-86,956	41,446	57,428						392,361	2,766	32,346	193	12		93,034	2.615
Nref	-187,483	-16,742	-9,638						-4,775	443	121	1	0		-276,187	
Mmin	-86,956	41,446		-27,063					-392,351	-2,766	-32,346			-6,012	-132,701	2.583
Nref	-187,483	-16,742		-3,097					4,775	-443	-121			-56	-265,032	

Determination of Internal Forces for ULS - Strength I

Transversal direction

	DC+DW	LL	WS	WL	Total
Strength I	1.5	1.75	0	0	kNm/kN
Section A-A					
Mmax	0	35	3,662	1	61
Nref	Taken from longitudinal section results				
Mmin	0	-35	-3,662	-1	-61
Nref	Taken from longitudinal section results				
Section B-B					
Mmax	0	3,937	174,764	92	6,890
Nref	Taken from longitudinal section results				
Mmin	0	-3,837	-174,764	-92	-6,715
Nref	Taken from longitudinal section results				
Section C-C					
Mmax	-31,498	319	91,060	10	-46,689
Nref	Taken from longitudinal section results				
Mmin	-31,498	-637	-109,440	-10	-48,362
Nref	Taken from longitudinal section results				
Section D-D					
Mmax	-193,035	544	117,462	2,934	-288,601
Nref	Taken from longitudinal section results				
Mmin	-193,035	-2,198	-116,721	-2,934	-293,399
Nref	Taken from longitudinal section results				

Determination of Internal Forces for ULS - Strength III

Longitudinal direction

			LL												Total	ULT. strength factor
	DC	DW	Mmax	Mmin	Smax	Smin	Nmax	Nmin	WS	WL	TU	CR	SH	TG		
Strength III	1.25	1.5	0	0	0	0	0	0	1.4	0	1.2	1.2	1.2	0	kNm/kN	
Section A-A																
Mmax	0	0							3,391						4,747	28.112
Nref	-12,674	-1,429							0						-17,986	
Mmin	0	0							-3,391						-4,747	
Nref	-12,674	-1,429							0						-17,986	
Section B-B																
Mmax	-549,286	46,604	81,930						4,824		5,222	53		3,219	-603,618	1.391
Nref	-102,292	-16,467	-8,675						-6,101		117	-3		-208	-160,970	
Mmin	-549,286	46,604		-44,303					-4,824		-5,222				-629,722	1.208
Nref	-102,292	-16,467		-5,234					6,101		-117				-144,165	
Section C-C																
Mmax	-145,655	42,055	43,832						6,305	435	16,572	171	8		-90,058	2.519
Nref	-151,144	-14,799	-10,308						5,533	-15	28	-2	0		-203,351	
Mmin	-145,655	42,055		-12,980					-6,305	-435	-16,572			-3,638	-147,700	1.877
Nref	-151,144	-14,799		-1,227					-5,533	15	-28			-113	-218,908	
Section D-D																
Mmax	-86,956	41,446	57,428						392,361	2,766	32,346	193	12		541,841	2.209
Nref	-187,483	-16,742	-9,638						-4,775	443	121	1	0		-266,005	
Mmin	-86,956	41,446		-27,063					-392,351	-2,766	-32,346			-6,012	-634,633	1.235
Nref	-187,483	-16,742		-3,097					4,775	-443	-121			-56	-252,927	

Determination of Internal Forces for ULS - Strength III

Transversal direction

	DC+DW	LL	WS	WL	Total
Strength III	1.5	0	1.4	0	kNm/kN
Section A-A					
Mmax	0	35	3,662	1	5,127
Nref	Taken from longitudinal section results				
Mmin	0	-35	-3,662	-1	-5,127
Nref	Taken from longitudinal section results				
Section B-B					
Mmax	0	3,937	174,764	92	244,670
Nref	Taken from longitudinal section results				
Mmin	0	-3,837	-174,764	-92	-244,670
Nref	Taken from longitudinal section results				
Section C-C					
Mmax	-31,498	319	91,060	10	80,237
Nref	Taken from longitudinal section results				
Mmin	-31,498	-637	-109,440	-10	-200,463
Nref	Taken from longitudinal section results				
Section D-D					
Mmax	-193,035	544	117,462	2,934	-125,106
Nref	Taken from longitudinal section results				
Mmin	-193,035	-2,198	-116,721	-2,934	-452,962
Nref	Taken from longitudinal section results				

Determination of Internal Forces for ULS - Strength V

Longitudinal direction

			LL												Total	ULT. strength factor
	DC	DW	Mmax	Mmin	Smax	Smin	Nmax	Nmin	WS	WL	TU	CR	SH	TG		
Strength V	1.25	1.5	1.35	1.35	1.35	1.35	1.35	1.35	0.4	1	1.2	1.2	1.2	0	kNm/kN	
Section A-A																
Mmax	0	0							3,391						1,356	31.192
Nref	-12,674	-1,429							0						-17,986	
Mmin	0	0							-3,391						-1,356	
Nref	-12,674	-1,429							0						-17,986	
Section B-B																
Mmax	-549,286	46,604	81,930						4,824		5,222	53		3,219	-497,836	2.043
Nref	-102,292	-16,467	-8,675						-6,101		117	-3		-208	-166,580	
Mmin	-549,286	46,604		-44,303					-4,824		-5,222				-684,707	1.175
Nref	-102,292	-16,467		-5,234					6,101		-117				-157,331	
Section C-C																
Mmax	-145,655	42,055	43,832						6,305	435	16,572	171	8		-36,755	2.685
Nref	-151,144	-14,799	-10,308						5,533	-15	28	-2	0		-222,815	
Mmin	-145,655	42,055		-12,980					-6,305	-435	-16,572			-3,638	-159,353	2.227
Nref	-151,144	-14,799		-1,227					-5,533	15	-28			-113	-215,017	
Section D-D																
Mmax	-86,956	41,446	57,428						392,361	2,766	32,346	193	12		229,773	2.619
Nref	-187,483	-16,742	-9,638						-4,775	443	121	1	0		-273,799	
Mmin	-86,956	41,446		-27,063					-392,351	-2,766	-32,346			-6,012	-281,583	2.119
Nref	-187,483	-16,742		-3,097					4,775	-443	-121			-56	-262,326	

Determination of Internal Forces for ULS - Strength V

Transversal direction

	DC+DW	LL	WS	WL	Total
Strength V	1.5	1.35	0.4	1	kNm/kN
Section A-A					
Mmax	0	35	3,662	1	1,513
Nref	Taken from longitudinal section results				
Mmin	0	-35	-3,662	-1	-1,513
Nref	Taken from longitudinal section results				
Section B-B					
Mmax	0	3,937	174,764	92	75,313
Nref	Taken from longitudinal section results				
Mmin	0	-3,837	-174,764	-92	-75,178
Nref	Taken from longitudinal section results				
Section C-C					
Mmax	-31,498	319	91,060	10	-10,382
Nref	Taken from longitudinal section results				
Mmin	-31,498	-637	-109,440	-10	-91,893
Nref	Taken from longitudinal section results				
Section D-D					
Mmax	-193,035	544	117,462	2,934	-238,899
Nref	Taken from longitudinal section results				
Mmin	-193,035	-2,198	-116,721	-2,934	-342,142
Nref	Taken from longitudinal section results				

Determination of Internal Forces for ULS - Extreme Event I

Longitudinal direction

			LL													Total	ULT. strength factor
	DC	DW	Mmax	Mmin	Smax	Smin	Nmax	Nmin	WS	WL	TU	CR	SH	TG	EQ		
Extreme I	1.25	1.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0	0	0	0	1	kNm/kN	
Section A-A																	
Mmax	0	0							3,391						3,035	3,035	29.556
Nref	-12,674	-1,429							0						-104	-18,090	
Mmin	0	0							-3,391						-3,035	-3,035	29.870
Nref	-12,674	-1,429							0						104	-17,882	
Section B-B																	
Mmax	-549,286	46,604	81,930						4,824		5,222	53		3,219	127,524	-448,213	2.298
Nref	-102,292	-16,467	-8,675						-6,101		117	-3		-208	63	-156,840	
Mmin	-549,286	46,604		-44,303					-4,824		-5,222				-127,524	-766,377	1.000
Nref	-102,292	-16,467		-5,234					6,101		-117				-63	-155,246	
Section C-C																	
Mmax	-145,655	42,055	43,832						6,305	435	16,572	171	8		401,343	304,273	1.971
Nref	-151,144	-14,799	-10,308						5,533	-15	28	-2	0		2,236	-214,047	
Mmin	-145,655	42,055		-12,980					-6,305	-435	-16,572			-3,638	-401,343	-526,819	1.415
Nref	-151,144	-14,799		-1,227					-5,533	15	-28			-113	-2,236	-213,978	
Section D-D																	
Mmax	-86,956	41,446	57,428						392,361	2,766	32,346	193	12		851,952	834,140	1.430
Nref	-187,483	-16,742	-9,638						-4,775	443	121	1	0		2,271	-262,015	
Mmin	-86,956	41,446		-27,063					-392,351	-2,766	-32,346			-6,012	-851,952	-912,010	1.006
Nref	-187,483	-16,742		-3,097					4,775	-443	-121			-56	-2,271	-263,286	

Determination of Internal Forces for ULS - Extreme Event I

Transversal direction

	DC+DW	LL	WS	WL	EQ	Total
Extreme I	1.5	0.5	0	0	1	kNm/kN
Section A-A						
Mmax	0	35	3,662	1	3,126	3,144
Nref	Taken from longitudinal section results					
Mmin	0	-35	-3,662	-1	-3,126	-3,144
Nref	Taken from longitudinal section results					
Section B-B						
Mmax	0	3,937	174,764	92	55,466	57,435
Nref	Taken from longitudinal section results					
Mmin	0	-3,837	-174,764	-92	-55,466	-57,385
Nref	Taken from longitudinal section results					
Section C-C						
Mmax	-31,498	319	91,060	10	66,931	19,844
Nref	Taken from longitudinal section results					
Mmin	-31,498	-637	-109,440	-10	-66,778	-114,344
Nref	Taken from longitudinal section results					
Section D-D						
Mmax	-193,035	544	117,462	2,934	116,879	-172,402
Nref	Taken from longitudinal section results					
Mmin	-193,035	-2,198	-116,721	-2,934	-116,944	-407,596
Nref	Taken from longitudinal section results					

Determination of Internal Forces for SLS - Service I

Longitudinal direction

			LL												Total
	DC	DW	Mmax	Mmin	Smax	Smin	Nmax	Nmin	WS	WL	TU	CR	SH	TG	
Service I	1	1	1	1	1	1	1	1	0.3	1	1	1	1	0.5	kNm/kN
Section A-A															
Mmax	0	0							3,391						1,017
Nref	-12,674	-1,429							0						-14,103
Mmin	0	0							-3,391						-1,017
Nref	-12,674	-1,429							0						-14,103
Section B-B															
Mmax	-549,286	46,604	81,930						4,824		5,222	53		3,219	-412,420
Nref	-102,292	-16,467	-8,675						-6,101		117	-3		-208	-129,254
Mmin	-549,286	46,604		-44,303					-4,824		-5,222				-553,654
Nref	-102,292	-16,467		-5,234					6,101		-117				-122,280
Section C-C															
Mmax	-145,655	42,055	43,832						6,305	435	16,572	171	8		-40,691
Nref	-151,144	-14,799	-10,308						5,533	-15	28	-2	0		-174,580
Mmin	-145,655	42,055		-12,980					-6,305	-435	-16,572			-3,636	-137,298
Nref	-151,144	-14,799		-1,227					-5,533	15	-28			-113	-168,899
Section D-D															
Mmax	-86,956	41,446	57,428						392,361	2,766	32,346	193	12		164,943
Nref	-187,483	-16,742	-9,638						-4,775	443	121	1	0		-214,731
Mmin	-86,956	41,446		-27,063					-392,351	-2,766	-32,346			-6,012	-228,396
Nref	-187,483	-16,742		-3,097					4,775	-443	-121			-56	-206,482

Determination of Internal Forces for SLS - Service I

Transversal direction

	DC+DW	LL	WS	WL	Total
Service I	1	1	0.3	1	kNm/kN
Section A-A					
Mmax	0	35	3,662	1	1,135
Nref	Taken from longitudinal section results				
Mmin	0	-35	-3,662	-1	-1,135
Nref	Taken from longitudinal section results				
Section B-B					
Mmax	0	3,937	174,764	92	56,458
Nref	Taken from longitudinal section results				
Mmin	0	-3,837	-174,764	-92	-56,358
Nref	Taken from longitudinal section results				
Section C-C					
Mmax	-31,498	319	91,060	10	-3,851
Nref	Taken from longitudinal section results				
Mmin	-31,498	-637	-109,440	-10	-64,977
Nref	Taken from longitudinal section results				
Section D-D					
Mmax	-193,035	544	117,462	2,934	-154,318
Nref	Taken from longitudinal section results				
Mmin	-193,035	-2,198	-116,721	-2,934	-233,183
Nref	Taken from longitudinal section results				

Determination of Stresses @ Extreme Fibers (Service I)

Stresses caused by Flexure in Longitudinal Direction

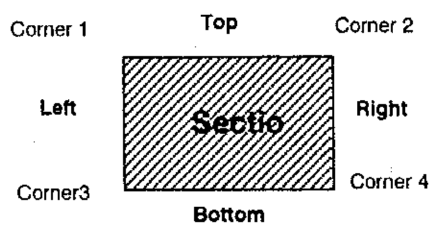
Description	Area	Ineritia moment	Ztop	Zbot	Mmax	Nref	Sig. top	Sig. bot	Mmin	Nref	Sig. top	Sig. bot
	[m2]	[m4]	[cm]	[cm]	[kNm]	[kN]	[N/mm2]	[N/mm2]	[kNm]	[kN]	[N/mm2]	[N/mm2]
Section A-A	17.56	63.80	262.50	262.50	1017	-14103	-0.76	-0.84	-1017	-14103	-0.84	-0.76
Section B-B	36.97	150.61	292.40	292.40	-412420	-129254	-11.50	4.51	-553654	-122280	-14.06	7.44
Section C-C	17.54	116.65	362.50	362.50	-40691	-174580	-11.22	-8.69	-137298	-168899	-13.90	-5.36
Section D-D	40.44	215.68	400.00	400.00	164943	-214731	-2.25	-8.37	-228396	-206482	-9.34	-0.87

Stresses caused by Flexure in Transversal Direction

Description	Area	Ineritia moment	Ztop	Zbot	Mmax	Nref	Sig. left	Sig. right	Mmin	Nref	Sig. left	Sig. right
	[m2]	[m4]	[cm]	[cm]	[kNm]	[kN]	[N/mm2]	[N/mm2]	[kNm]	[kN]	[N/mm2]	[N/mm2]
Section A-A	17.56	84.26	325.00	325.00	1135	-14103	-0.76	-0.85	-1135	-14103	-0.85	-0.76
Section B-B	36.97	380.70	555.50	555.50	56458	-129254	-2.67	-4.32	-56358	-122280	-4.13	-2.49
Section C-C	17.54	56.96	252.75	252.75	-3851	-174580	-10.12	-9.78	-64977	-168899	-12.51	-6.75
Section D-D	40.44	86.11	252.75	252.75	-154318	-214731	-9.84	-0.78	-233183	-206482	-11.95	1.74

Normal Stresses caused by Biaxial Flexure at the Corner Points

	Mmax, Nref				Mmin, Nref			
Description	Sig. at Cor. 1	Sig. at Cor. 2	Sig. at Cor. 3	Sig. at Cor. 4	Sig. at Cor. 1	Sig. at Cor. 2	Sig. at Cor. 3	Sig. at Cor. 4
Section A-A	-1.52	-1.61	-1.60	-1.69	-1.69	-1.60	-1.61	-1.52
Section B-B	-14.18	-15.82	1.84	0.19	-18.19	-16.54	3.31	4.96
Section C-C	-21.34	-21.00	-18.81	-18.47	-26.41	-20.64	-17.88	-12.11
Section D-D	-12.09	-3.03	-18.21	-9.15	-21.29	-7.60	-12.82	0.87



3.10 Design of Stay Cable

As for determination of Stay Cable Unit, those are considered action of tensile force on stay cable, whether tensile force should be less than 56% of tensile strength while short term loading, and 45% of tensile strength for long term loading. At examination of cable unit, apply statical load resulting from 2-Dimensional analysis. On the other hand, live load is applied from 3-Dimensional analysis.

3.10.1 Section Analysis of Stay Cable

(1) Property of stay cables

Adjustment force of stay cables

Cable Name		Nos. of Strand	Introduce Tension(kN) (1-plane)
SN-1	SS-1	60	5500
SN-2	SS-2	60	5900
SN-3	SS-3	60	6250
SN-4	SS-4	55	5950
SN-5	SS-5	55	5100
SN-6	SS-6	55	6500
SN-7	SS-7	55	6850
SN-8	SS-8	50	6600
SN-9	SS-9	50	6350
SN-10	SS-10	50	5900
SN-11	SS-11	50	5750
SN-12	SS-12	55	6350
SN-13	SS-13	60	6300
SN-14	SS-14	50	5600
SN-15	SS-15	45	5050
SN-16	SS-16	45	4600
SN-17	SS-17	37	4350
SN-18	SS-18	37	4150
SN-19	SS-19	37	3750
SN-20	SS-20	37	3550
SN-21	SS-21	37	4000
SN-22	SS-22	37	4000
SN-23	SS-23	37	3250
SN-24	SS-24	37	3600
SN-25	SS-25	45	3850
SN-26	SS-26	50	4150
SN-27	SS-27	50	4400
SN-28	SS-28	55	4600
SN-29	SS-29	55	4950
SN-30	SS-30	60	5200
SN-31	SS-31	60	5450
SN-32	SS-32	70	5700
SN-33	SS-33	70	5850
SN-34	SS-34	70	6000
SN-35	SS-35	37	2825
SN-36	SS-36	30	1825
SN-37	SS-37	30	2125
SN-38	SS-38	30	2525
SN-39	SS-39	37	2875
SN-40	SS-40	37	3125
SN-41	SS-41	45	3575
SN-42	SS-42	50	3725

(2) Axial Force at Stay Cables During Construction (1-Plane)

Side Span

Cable No.	SN(SS)-1	SN(SS)-2	SN(SS)-3	SN(SS)-4	SN(SS)-5	SN(SS)-6	SN(SS)-7	SN(SS)-8	SN(SS)-9	SN(SS)-10	SN(SS)-11	SN(SS)-12	SN(SS)-13	SN(SS)-14	SN(SS)-15	SN(SS)-16	SN(SS)-17	SN(SS)-18	SN(SS)-19	SN(SS)-20	SN(SS)-21
Stage-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4000
Stage-5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4202
Stage-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3550	3978
Stage-7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3869	4217
Stage-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3750	3503	3939
Stage-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4087	3742	4215
Stage-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4150	3759	3409	3908
Stage-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4509	4002	3722	4245
Stage-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4350	4288	3717	3379	3896
Stage-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4610	4450	3980	3739	4288
Stage-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4600	3837	3795	3443	3302	3951
Stage-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5612	4472	4329	3889	3679	4261
Stage-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5050	4642	3769	3707	3349	3223	3921
Stage-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6091	5532	4396	4250	3804	3602	4216
Stage-18	-	-	-	-	-	-	-	-	-	-	-	-	-	5600	5168	4546	3646	3571	3216	3114	3858
Stage-19	-	-	-	-	-	-	-	-	-	-	-	-	-	6491	5976	5396	4293	4146	3700	3505	4145
Stage-20	-	-	-	-	-	-	-	-	-	-	-	-	6300	5296	4883	4403	3616	3568	3213	3096	3820
Stage-21	-	-	-	-	-	-	-	-	-	-	-	-	7903	6308	5476	4641	3616	3470	3111	3057	3859
Stage-22	-	-	-	-	-	-	-	-	-	-	-	-	8126	6572	5786	4987	3886	3715	3316	3218	3970
Stage-23	-	-	-	-	-	-	-	-	-	-	-	6350	7029	5537	4810	4074	3242	3163	2855	2834	3664
Stage-24	-	-	-	-	-	-	-	-	-	-	-	7119	7864	6349	5616	4870	3818	3662	3270	3170	3915
Stage-25	-	-	-	-	-	-	-	-	-	-	5750	6369	7047	5561	4824	4072	3225	3130	2810	2798	3648
Stage-26	-	-	-	-	-	-	-	-	-	-	6539	7095	7867	6357	5607	4836	3773	3601	3200	3114	3884
Stage-27	-	-	-	-	-	-	-	-	-	5900	5678	6372	7141	5692	4928	4082	3166	3041	2727	2743	3629
Stage-28	-	-	-	-	-	-	-	-	-	6664	6385	7086	7962	6492	5700	4820	3685	3484	3091	3039	3852
Stage-29	-	-	-	-	-	-	-	-	6350	5866	5624	6356	7152	5718	4950	4077	3122	2975	2664	2701	3613
Stage-30	-	-	-	-	-	-	-	-	6749	6238	5991	6715	7556	6106	5328	4442	3381	3196	2845	2847	3720
Stage-31	-	-	-	-	-	-	-	6600	5992	5493	5258	5998	6747	5327	4568	3707	2860	2751	2478	2550	3496
Stage-32	-	-	-	-	-	-	-	6920	6205	5702	5462	6195	6967	5537	4772	3904	2999	2870	2577	2628	3553
Stage-33	-	-	-	-	-	-	6850	6006	5473	4969	4750	5514	6211	4813	4064	3216	2508	2451	2232	2351	3347
Stage-34	-	-	-	-	-	-	7508	6350	5593	5030	4829	5643	6394	4994	4219	3339	2584	2508	2276	2389	3379
Stage-35	-	-	-	-	-	-	7462	6332	5598	5046	4845	5649	6394	4993	4221	3347	2590	2512	2279	2391	3380
Stage-36	-	-	-	-	-	-	7492	6360	5617	5063	4860	5662	6407	5004	4230	3355	2595	2516	2282	2393	3380
Stage-37	-	-	-	-	-	6500	6631	5517	4979	4438	4250	5072	5748	4375	3621	2770	2183	2166	1996	2163	3210
Stage-38	-	-	-	-	-	6797	6898	5776	5173	4626	4433	5246	5941	4557	3796	2936	2299	2264	2075	2226	3254
Stage-39	-	-	-	-	5100	6143	6271	5162	4708	4173	3992	4822	5470	4109	3365	2524	2009	2019	1877	2067	3137
Stage-40	-	-	-	-	5409	6408	6527	5408	4891	4349	4162	4984	5647	4276	3523	2673	2113	2107	1947	2121	3175
Stage-41	-	-	-	5950	4652	5689	5841	4748	4391	3860	3690	4535	5153	3809	3074	2245	1813	1854	1742	1960	3057
Stage-42	-	-	-	6264	4909	5944	6088	4984	4564	4025	3848	4685	5317	3962	3218	2381	1908	1933	1804	2007	3089
Stage-43	-	-	6250	5485	4176	5244	5413	4331	4080	3559	3399	4254	4843	3517	2795	1980	1629	1700	1618	1860	2983
Stage-44	-	-	6595	5755	4435	5492	5648	4555	4245	3715	3548	4395	4994	3656	2924	2101	1712	1768	1671	1900	3009
Stage-45	-	5900	5808	5091	3795	4877	5058	3989	3826	3317	3169	4032	4591	3278	2570	1774	1490	1586	1526	1787	2927
Stage-46	-	6251	6115	5347	4038	5107	5276	4195	3977	3460	3303	4157	4725	3400	2684	1880	1562	1644	1571	1820	2948
Stage-47	5500	5633	5428	4741	3464	4575	4776	3716	3618	3115	2976	3850	4393	3092	2395	1610	1375	1491	1450	1727	2883
Stage-48	5244	5361	5182	4538	3268	4389	4599	3546	3492	2994	2861	3740	4275	2982	2291	1513	1309	1436	1407	1695	2862
Stage-49	5399	5512	5330	4664	3390	4506	4710	3653	3572	3071	2934	3811	4351	3055	2362	1579	1354	1473	1437	1717	2877
Stage-50	5412	5528	5349	4682	3410	4529	4737	3683	3597	3100	2965	3844	4395	3103	2412	1632	1393	1507	1463	1736	2886
Stage-51	5115	5231	5027	4346	3006	4079	4291	3261	3250	2646	2400	3303	4081	3408	3509	3455	3088	3171	2882	2791	3558
Stage-52	5936	6056	5858	5075	3742	4824	5046	4029	3852	3255	3012	3910	4775	4076	4145	4055	3522	3556	3198	3011	3662
Stage-53	5929	6056	5858	5073	3736	4812	5031	4012	3839	3245	3004	3905	4771	4072	4142	4052	3519	3551	3191	3003	3662
Maximum	5936	6251	6595	6264	5409	6797	7508	6920	6749	6664	6539	7119	8126	6572	6091	5612	4610	4509	4087	3869	4288

Axial Force at Stay Cables During Construction (1-Plane)

Midspan

Cable Name	SN(SS)-22	SN(SS)-23	SN(SS)-24	SN(SS)-25	SN(SS)-26	SN(SS)-27	SN(SS)-28	SN(SS)-29	SN(SS)-30	SN(SS)-31	SN(SS)-32	SN(SS)-33	SN(SS)-34	SN(SS)-35	SN(SS)-36	SN(SS)-37	SN(SS)-38	SN(SS)-39	SN(SS)-40	SN(SS)-41	SN(SS)-42
Stage-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-3	4000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-4	4189	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-5	3940	3250	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-6	4144	3595	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-7	3842	3163	3600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-8	4063	3365	3918	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-9	3756	2987	3461	3850	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-10	4035	3239	3636	4215	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-11	3676	2898	3375	3993	4150	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-12	4014	3205	3581	4126	4392	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-13	3595	2812	3296	3906	4296	4400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-14	3899	3099	3493	4024	4318	4546	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-15	3579	2801	3279	3870	4266	4580	4600	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-16	3877	3082	3486	4028	4312	4554	4716	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-17	3564	2771	3245	3828	4215	4549	4810	4950	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-18	3860	3050	3451	3994	4297	4551	4758	5048	-	-	-	-	-	-	-	-	-	-	-	-	-
Stage-19	3576	2797	3291	3892	4250	4520	4707	4956	5200	-	-	-	-	-	-	-	-	-	-	-	-
Stage-20	3877	3080	3498	4059	4343	4552	4680	4895	5307	-	-	-	-	-	-	-	-	-	-	-	-
Stage-21	3767	2939	3372	3987	4432	4877	5374	5975	7008	-	-	-	-	-	-	-	-	-	-	-	-
Stage-22	3679	2894	3360	3943	4272	4509	4651	4878	5298	5450	-	-	-	-	-	-	-	-	-	-	-
Stage-23	3958	3159	3553	4099	4358	4550	4655	4841	5233	5559	-	-	-	-	-	-	-	-	-	-	-
Stage-24	3699	2919	3378	3955	4272	4500	4622	4818	5210	5537	5700	-	-	-	-	-	-	-	-	-	-
Stage-25	3934	3139	3539	4083	4343	4533	4634	4805	5166	5481	5813	-	-	-	-	-	-	-	-	-	-
Stage-26	3686	2909	3371	3946	4262	4488	4608	4793	5161	5482	5823	5850	-	-	-	-	-	-	-	-	-
Stage-27	3909	3117	3521	4066	4327	4517	4617	4791	5139	5439	5770	5975	-	-	-	-	-	-	-	-	-
Stage-28	3670	2889	3350	3923	4247	4490	4638	4852	5214	5481	5756	5873	6000	-	-	-	-	-	-	-	-
Stage-29	3885	3092	3497	4039	4310	4517	4644	4845	5203	5458	5718	5826	6132	-	-	-	-	-	-	-	-
Stage-30	3769	2984	3413	3957	4240	4447	4558	4770	5164	5478	5813	6032	6453	2825	-	-	-	-	-	-	-
Stage-31	3980	3181	3556	4070	4300	4473	4564	4764	5153	5470	5795	6014	6440	2901	-	-	-	-	-	-	-
Stage-32	3918	3121	3505	4018	4253	4427	4513	4717	5109	5445	5806	6082	6581	3010	1825	-	-	-	-	-	-
Stage-33	4111	3303	3637	4122	4309	4450	4517	4709	5096	5435	5794	6063	6566	3006	1905	-	-	-	-	-	-
Stage-34	4067	3248	3572	4022	4193	4322	4376	4592	5025	5470	5985	6502	7280	3495	2564	-	-	-	-	-	-
Stage-35	4064	3246	3571	4022	4192	4322	4376	4593	5025	5470	5985	6502	7280	3494	2564	-	-	-	-	-	-
Stage-36	4067	3263	3606	4093	4284	4425	4486	4673	5049	5388	5754	6037	6569	3028	1959	2125	-	-	-	-	-
Stage-37	4229	3415	3717	4180	4331	4444	4488	4665	5037	5377	5745	6019	6553	3023	1956	2200	-	-	-	-	-
Stage-38	4180	3372	3689	4160	4322	4440	4482	4652	5007	5329	5677	5921	6435	2960	1892	2144	2525	-	-	-	-
Stage-39	4290	3476	3765	4221	4355	4453	4484	4646	4997	5319	5668	5907	6421	2954	1888	2141	2587	-	-	-	-
Stage-40	4247	3440	3744	4212	4359	4465	4498	4653	4989	5286	5603	5791	6256	2851	1761	1994	2427	2875	-	-	-
Stage-41	4360	3546	3821	4273	4392	4479	4500	4648	4979	5275	5591	5780	6243	2846	1758	1994	2431	2930	-	-	-
Stage-42	4321	3514	3803	4268	4401	4497	4523	4667	4987	5261	5544	5681	6088	2742	1619	1821	2225	2700	3125	-	-
Stage-43	4423	3610	3874	4324	4432	4510	4525	4662	4977	5250	5532	5667	6073	2737	1616	1820	2227	2706	3178	-	-
Stage-44	4389	3582	3859	4322	4444	4532	4556	4693	5004	5257	5510	5597	5943	2640	1477	1632	1988	2417	2790	3575	-
Stage-45	4469	3658	3914	4366	4469	4543	4558	4689	4996	5248	5498	5583	5929	2635	1472	1629	1988	2418	2796	3623	-
Stage-46	4441	3633	3900	4363	4476	4560	4583	4715	5022	5263	5495	5548	5850	2571	1375	1491	1805	2187	2470	3141	3725
Stage-47	4504	3694	3944	4398	4496	4568	4585	4712	5016	5256	5484	5534	5838	2565	1370	1488	1803	2188	2475	3153	3761
Stage-48	4534	3721	3965	4421	4519	4595	4622	4756	5073	5314	5534	5569	5837	2540	1308	1375	1625	1932	2074	2491	2949
Stage-49	4515	3703	3950	4403	4499	4574	4596	4729	5043	5292	5527	5587	5881	2582	1375	1475	1761	2107	2321	2855	3345
Stage-50	4443	3641	3906	4370	4483	4568	4597	4737	5058	5311	5550	5616	5920	2602	1399	1500	1789	2136	2357	2904	3396
Stage-51	3755	2960	3389	3937	4231	4439	4537	4722	5065	5326	5567	5632	5929	2603	1395	1492	1777	2120	2333	2866	3350
Stage-52	3834	3139	3643	4318	4640	4863	5021	5225	5677	5991	6303	6549	6954	3142	1985	2125	2443	2808	3140	3886	4333
Stage-53	3826	3131	3638	4317	4640	4863	5021	5225	5677	5991	6303	6549	6946	3128	1967	2107	2426	2793	3125	3869	4317
Maximum	4534	3721	3965	4421	4640	4877	5374	5975	7008	5991	6303	6549	7280	3495	2564	2200	2587	2930	3178	3886	4333

(3) Live Load with Impact

Table Tensile Force due to Live Load at Stay Cable

Cable No.		Tensile Force due to Live Load (kN)				Impact Factor
		Resulting From 3D Analysis		Resulting from 2D Analysis(Reference		
		Maximum	Minimum	Maximum	Minimum	
SN-1	(SS-1)	372	-10	712	-53	0.167
SN-2	(SS-2)	532	-6	722	-60	0.167
SN-3	(SS-3)	726	-3	733	-69	0.167
SN-4	(SS-4)	698	-6	647	-68	0.167
SN-5	(SS-5)	659	-15	653	-76	0.167
SN-6	(SS-6)	615	-28	672	-94	0.167
SN-7	(SS-7)	568	-61	712	-132	0.167
SN-8	(SS-8)	664	-104	755	-168	0.167
SN-9	(SS-9)	612	-117	608	-153	0.167
SN-10	(SS-10)	734	-147	623	-166	0.167
SN-11	(SS-11)	719	-139	618	-159	0.167
SN-12	(SS-12)	635	-96	582	-123	0.111
SN-13	(SS-13)	548	-20	629	-100	0.111
SN-14	(SS-14)	528	2	583	-82	0.111
SN-15	(SS-15)	518	0	575	-80	0.111
SN-16	(SS-16)	516	-5	584	-76	0.111
SN-17	(SS-17)	433	-14	457	-57	0.111
SN-18	(SS-18)	449	-29	447	-59	0.111
SN-19	(SS-19)	425	-62	420	-87	0.111
SN-20	(SS-20)	323	-87	366	-122	0.111
SN-21	(SS-21)	135	-53	258	-129	0.111
SN-22	(SS-22)	221	-11	241	-136	0.033
SN-23	(SS-23)	316	-10	340	-129	0.033
SN-24	(SS-24)	428	-8	389	-105	0.033
SN-25	(SS-25)	403	-10	518	-105	0.033
SN-26	(SS-26)	370	-16	519	-90	0.033
SN-27	(SS-27)	331	-24	512	-79	0.033
SN-28	(SS-28)	362	-52	559	-75	0.033
SN-29	(SS-29)	516	-90	555	-62	0.033
SN-30	(SS-30)	518	-102	647	-58	0.033
SN-31	(SS-31)	621	-127	674	-47	0.033
SN-32	(SS-32)	613	-119	720	-39	0.033
SN-33	(SS-33)	579	-89	877	-37	0.033
SN-34	(SS-34)	491	-45	970	-31	0.033
SN-35	(SS-35)	375	1	506	-13	0.033
SN-36	(SS-36)	252	-2	548	-11	0.033
SN-37	(SS-37)	172	-8	575	-11	0.033
SN-38	(SS-38)	218	-15	604	-13	0.033
SN-39	(SS-39)	244	-42	623	-16	0.033
SN-40	(SS-40)	185	-68	734	-23	0.033
SN-41	(SS-41)	164	-90	935	-40	0.033
SN-42	(SS-42)	64	-52	921	-57	0.033

Note : Tensile force due to live load shown in this table, which include tensile force caused by impact force.
Tensile force shown in this table, these value are indicated as 1 plane.

(4) Section Analysis of Stay Cable

Side Span

	Unit	SN-1 SS-1	SN-2 SS-2	SN-3 SS-3	SN-4 SS-4	SN-5 SS-5	SN-6 SS-6	SN-7 SS-7	SN-8 SS-8	SN-9 SS-9	SN-10 SS-10	SN-11 SS-11	SN-12 SS-12	SN-13 SS-13	SN-14 SS-14	SN-15 SS-15	SN-16 SS-16	SN-17 SS-17	SN-18 SS-18	SN-19 SS-19	SN-20 SS-20	SN-21 SS-21
Nos. of Strand		60	60	60	55	55	55	55	50	50	50	50	55	60	50	45	45	37	37	37	37	37
Property of Strand																						
Clasification		T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2
Tensile Strength	N/mm2	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860
Area of Strand	mm2	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7
Tensile Strength of Stay Cable																						
During Constructic 0.56fpu	kN	8668	8668	8668	7946	7946	7946	7946	7223	7223	7223	7223	7946	8668	7223	6501	6501	5345	5345	5345	5345	5345
After Construction 0.45fpu	kN	6966	6966	6966	6385	6385	6385	6385	5805	5805	5805	5803	6385	6966	5805	5224	5224	4295	4295	4295	4295	4295
Tensile Force																						
During Construction																						
Maximum Tensile Fo	kN	5936	6251	6595	6264	5409	6797	7508	6920	6749	6664	6539	7119	8126	6572	6091	5612	4610	4509	4087	3869	4288
After Construction																						
D	kN	5929	6056	5858	5073	3736	4812	5031	5031	4012	3245	3004	3905	4771	4072	4142	4052	3519	3551	3191	3003	3662
D + L + TU Max	kN	6347	6627	6617	5793	4411	5435	5600	5708	4643	4008	3761	4584	5372	4648	4701	4600	3970	4011	3620	3329	3806
D + L + TU Min	kN	5873	6010	5822	5045	3705	4775	4969	4914	3875	3068	2827	3766	4699	4026	4101	4015	3487	3511	3124	2913	3600
Remark		O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K
Stress Range due to Live Load	N/mm2	46	65	88	92	88	84	82	111	105	127	124	96	68	76	83	84	87	93	95	80	37

Midspan

	Unit	SN-22 SS-22	SN-23 SS-23	SN-24 SS-24	SN-25 SS-25	SN-26 SS-26	SN-27 SS-27	SN-28 SS-28	SN-29 SS-29	SN-30 SS-30	SN-31 SS-31	SN-32 SS-32	SN-33 SS-33	SN-34 SS-34	SN-35 SS-35	SN-36 SS-36	SN-37 SS-37	SN-38 SS-38	SN-39 SS-39	SN-40 SS-40	SN-41 SS-41	SN-42 SS-42
Nos of Strand		37	37	37	45	50	50	55	55	60	60	70	70	70	37	30	30	30	37	37	45	50
Property of Strand																						
Clasification		T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2	T15.2
Tensile Strength	N/mm2	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860	1860
Area of Strand	mm2	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7	138.7
Tensile Strength of Stay Cable																						
During Constructic 0.56fpu	kN	5345	5345	5345	6501	7223	7223	7946	7946	8668	8668	10113	10113	10113	5345	4334	4334	4334	5345	5345	6501	7223
After Construction 0.45fpu	kN	4295	4295	4295	5224	5805	5805	6385	6385	6966	6966	8126	8126	8126	4295	3483	3483	3483	4295	4295	5224	5805
Tensile Force																						
During Construction																						
Maximum Tensile Fo	kN	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288	4288
After Construction																						
D	kN	3826	3131	3638	4317	4640	4863	5021	5225	5677	5991	6303	6549	6946	3128	1967	2107	2426	2793	3125	3869	4317
D + L + TU Max	kN	4083	3471	4081	4730	5014	5195	5383	5741	6196	6615	6921	7137	7449	3509	2226	2285	2650	3043	3316	4039	4385
D + L + TU Min	kN	3779	3096	3615	4297	4620	4838	4968	5135	5574	5862	6179	6451	6889	3123	1959	2093	2405	2745	3051	3773	4261
Remark		O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K
Stress Range due to Live Load	N/mm2	45	64	85	66	56	51	54	79	74	90	75	69	55	73	61	43	56	56	49	41	17

3.10.2 Design of Control Device for Vibration at Stay Cable

(1) Judgement for necessity of The Control Device for Vibration for Stay Cable

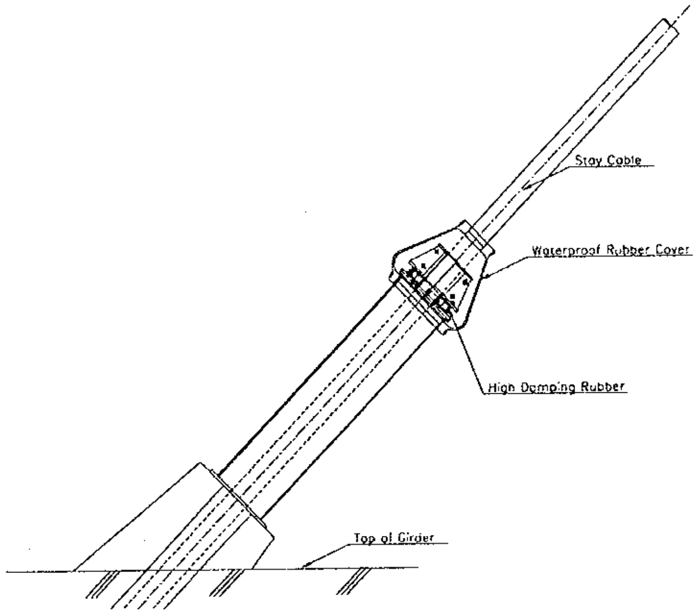
Stay cable unit is in the need of control device for vibration at stay cable under the condition as mentioned below.

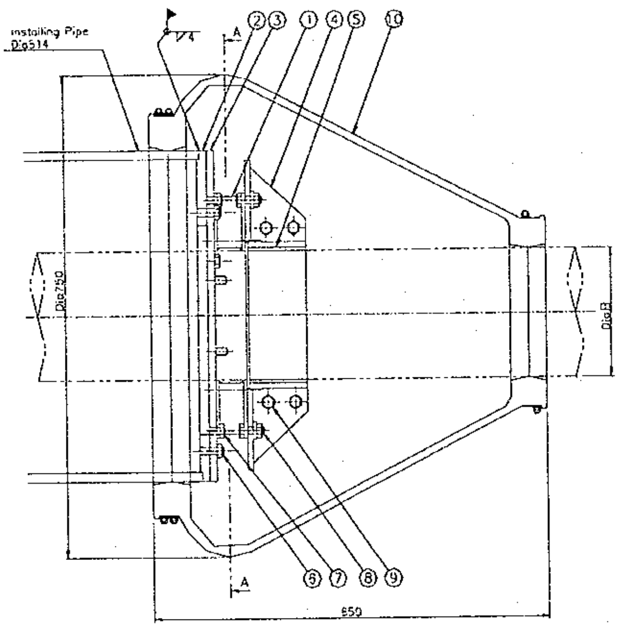
1) Natural frequency of stay cable is less than 3.0 Hz.
2) The scruton number is less than 60.

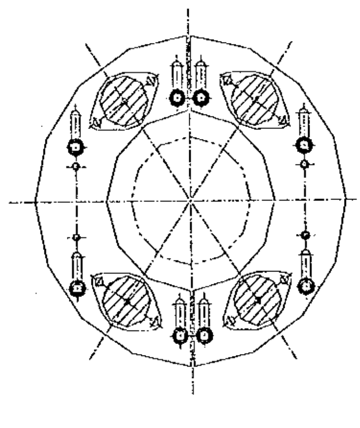
Result of Neccessity for Control Device

Stay Cable No.		Natural frequency(Hz)				Scruton Number	Judgement
		1st	2nd	3rd			
SN-01	(SS-01)	0.44	0.89	1.33	< 3Hz	18.44 < 60	Neccessaey
SN-02	(SS-02)	0.47	0.93	1.40	< 3Hz	18.44 < 60	Neccessaey
SN-03	(SS-03)	0.48	0.96	1.44	< 3Hz	18.44 < 60	Neccessaey
SN-04	(SS-04)	0.50	1.01	1.51	< 3Hz	15.94 < 60	Neccessaey
SN-05	(SS-05)	0.45	0.91	1.36	< 3Hz	15.94 < 60	Neccessaey
SN-06	(SS-06)	0.54	1.08	1.62	< 3Hz	15.94 < 60	Neccessaey
SN-07	(SS-07)	0.58	1.17	1.75	< 3Hz	15.94 < 60	Neccessaey
SN-08	(SS-08)	0.55	1.10	1.65	< 3Hz	15.94 < 60	Neccessaey
SN-09	(SS-09)	0.68	1.36	2.04	< 3Hz	12.74 < 60	Neccessaey
SN-10	(SS-10)	0.67	1.33	2.00	< 3Hz	12.74 < 60	Neccessaey
SN-11	(SS-11)	0.68	1.36	2.04	< 3Hz	12.74 < 60	Neccessaey
SN-12	(SS-12)	0.77	1.54	2.31	< 3Hz	12.74 < 60	Neccessaey
SN-13	(SS-13)	0.86	1.72	2.59	< 3Hz	14.57 < 60	Neccessaey
SN-14	(SS-14)	0.87	1.74	2.61	< 3Hz	14.57 < 60	Neccessaey
SN-15	(SS-15)	0.97	1.93	2.90	< 3Hz	14.57 < 60	Neccessaey
SN-16	(SS-16)	1.06	2.12	3.17	< 3Hz	14.57 < 60	Neccessaey
SN-17	(SS-17)	1.23	2.47	3.70	< 3Hz	11.82 < 60	Neccessaey
SN-18	(SS-18)	1.37	2.74	4.11	< 3Hz	11.82 < 60	Neccessaey
SN-19	(SS-19)	1.46	2.93	4.39	< 3Hz	11.82 < 60	Neccessaey
SN-20	(SS-20)	1.62	3.25	4.87	< 3Hz	11.82 < 60	Neccessaey
SN-21	(SS-21)	2.13	4.26	6.39	< 3Hz	11.82 < 60	Neccessaey
SN-22	(SS-22)	2.22	4.45	6.67	< 3Hz	11.82 < 60	Neccessaey
SN-23	(SS-23)	1.70	3.41	5.11	< 3Hz	11.82 < 60	Neccessaey
SN-24	(SS-24)	1.61	3.23	4.84	< 3Hz	11.82 < 60	Neccessaey
SN-25	(SS-25)	1.41	2.82	4.23	< 3Hz	14.57 < 60	Neccessaey
SN-26	(SS-26)	1.31	2.62	3.93	< 3Hz	14.57 < 60	Neccessaey
SN-27	(SS-27)	1.21	2.43	3.64	< 3Hz	14.57 < 60	Neccessaey
SN-28	(SS-28)	1.07	2.15	3.22	< 3Hz	15.94 < 60	Neccessaey
SN-29	(SS-29)	1.00	2.00	3.01	< 3Hz	15.94 < 60	Neccessaey
SN-30	(SS-30)	0.90	1.79	2.69	< 3Hz	18.44 < 60	Neccessaey
SN-31	(SS-31)	0.85	1.70	2.55	< 3Hz	18.44 < 60	Neccessaey
SN-32	(SS-32)	0.81	1.62	2.44	< 3Hz	18.44 < 60	Neccessaey
SN-33	(SS-33)	0.74	1.48	2.21	< 3Hz	14.08 < 60	Neccessaey
SN-34	(SS-34)	0.71	1.41	2.12	< 3Hz	14.08 < 60	Neccessaey
SN-35	(SS-35)	0.64	1.29	1.93	< 3Hz	14.49 < 60	Neccessaey
SN-36	(SS-36)	0.48	0.96	1.45	< 3Hz	14.49 < 60	Neccessaey
SN-37	(SS-37)	0.47	0.94	1.41	< 3Hz	14.49 < 60	Neccessaey
SN-38	(SS-38)	0.48	0.96	1.44	< 3Hz	14.49 < 60	Neccessaey
SN-39	(SS-39)	0.49	0.98	1.47	< 3Hz	14.49 < 60	Neccessaey
SN-40	(SS-40)	0.45	0.90	1.36	< 3Hz	11.82 < 60	Neccessaey
SN-41	(SS-41)	0.43	0.87	1.30	< 3Hz	14.57 < 60	Neccessaey
SN-42	(SS-42)	0.44	0.88	1.31	< 3Hz	14.57 < 60	Neccessaey

(2) Detail of Control Device for Vibration at Stay Cable







Section AA
<Rubber Damper:4pieces>

No.	PART NAME
①	High Damping Rubber Damper
②	Fixing Flange
③	Adgustable Flange
④	Cable Flange
⑤	Rubber Pad
⑥	Nut
⑦	Nut
⑧	Bolt・Nut
⑨	Bolt・Nut
⑩	Waterproof Rubber Cover

(4) Design Calculation of Control Device for cable vibrationn

Table Design Calculation of Control Device for cable vibrationn

Cable No.	Property of Stay Cables: Length L (m)	Dia Dc (mm)	Tension T (KN)	Unit Weigth w (tf/m)	Equipped Height H (m)	Equipped Position Xi (m)	Position Ratio Xi/L	Natural Frequency fn 1st	fn 2nd	fn 3rd	Rubber Dumper: Spring Constant (suitable value) Kopt (kgf/cm)	Spring Constant (for Design) Kdes (kgf/cm)	Reduction factor (tan δ)	Dimension	Nos.	Logarithmic Decrement δD 1st	δD 2nd	δD 3rd	Scruton Number: Sc(C) without Dumper	Sc(D) Dumper
SN(SS)-1	291.281	200	5907	0.0889	5.00	13.930	0.048	0.443	0.885	1.328	335.3	175	0.5	80-10-40	2	0.0337	0.0329	0.0317	18.4	124.2
SN(SS)-2	279.035	200	6036	0.0889	5.00	13.695	0.049	0.467	0.934	1.401	349.0	175	0.5	80-10-40	2	0.0339	0.0331	0.0318	18.4	125.1
SN(SS)-3	266.814	200	5836	0.0889	5.00	13.449	0.050	0.480	0.960	1.441	344.1	175	0.5	80-10-40	2	0.0351	0.0342	0.0328	18.4	129.5
SN(SS)-4	254.622	200	5054	0.0768	5.00	13.190	0.052	0.504	1.007	1.511	304.3	175	0.5	80-10-40	2	0.0382	0.0372	0.0356	15.9	121.8
SN(SS)-5	242.465	200	3708	0.0768	4.00	10.931	0.045	0.453	0.906	1.359	267.5	175	0.5	80-10-40	2	0.0348	0.0341	0.0330	15.9	110.9
SN(SS)-6	230.346	200	4774	0.0768	4.00	10.690	0.046	0.541	1.082	1.623	352.6	175	0.5	80-10-40	2	0.0318	0.0312	0.0301	15.9	101.5
SN(SS)-7	218.273	200	4979	0.0768	4.00	10.436	0.048	0.583	1.166	1.750	377.2	175	0.5	80-10-40	2	0.0317	0.0310	0.0298	15.9	101.0
SN(SS)-8	206.252	200	3944	0.0768	4.00	10.169	0.049	0.549	1.099	1.648	307.2	175	0.5	80-10-40	2	0.0362	0.0353	0.0339	15.9	115.2
SN(SS)-9	194.296	200	4275	0.0614	4.00	9.888	0.051	0.679	1.358	2.037	343.0	175	0.5	80-10-40	2	0.0355	0.0346	0.0332	12.7	90.5
SN(SS)-10	182.416	200	3622	0.0614	3.50	8.720	0.048	0.666	1.331	1.997	328.4	175	0.5	80-10-40	2	0.0340	0.0332	0.0320	12.7	86.6
SN(SS)-11	170.628	200	3303	0.0614	3.50	8.437	0.049	0.680	1.359	2.039	310.1	175	0.5	80-10-40	2	0.0361	0.0353	0.0338	12.7	92.0
SN(SS)-12	158.936	200	3676	0.0614	3.50	8.139	0.051	0.770	1.540	2.309	358.4	175	0.5	80-10-40	2	0.0350	0.0341	0.0326	12.7	89.1
SN(SS)-13	147.888	200	4566	0.0702	2.50	6.273	0.042	0.862	1.724	2.587	572.3	350	0.5	80-10-40	4	0.0319	0.0313	0.0304	14.6	92.8
SN(SS)-14	135.596	200	3923	0.0702	2.50	6.022	0.044	0.872	1.743	2.615	513.3	350	0.5	80-10-40	4	0.0347	0.0341	0.0330	14.6	101.2
SN(SS)-15	124.204	200	4054	0.0702	2.50	5.757	0.046	0.967	1.935	2.902	556.0	350	0.5	80-10-40	4	0.0353	0.0346	0.0333	14.6	102.9
SN(SS)-16	112.998	200	4013	0.0702	2.50	5.484	0.049	1.058	2.116	3.174	579.1	350	0.5	80-10-40	4	0.0365	0.0356	0.0342	14.6	106.2
SN(SS)-17	102.054	200	3616	0.0570	2.50	5.205	0.051	1.234	2.468	3.702	551.2	350	0.5	80-10-40	4	0.0391	0.0381	0.0365	11.8	92.5
SN(SS)-18	91.395	200	3566	0.0570	2.50	4.923	0.054	1.368	2.737	4.105	576.4	350	0.5	80-10-40	4	0.0407	0.0395	0.0377	11.8	96.2
SN(SS)-19	81.078	200	3215	0.0570	2.50	4.648	0.057	1.465	2.929	4.394	552.5	350	0.5	80-10-40	4	0.0441	0.0427	0.0404	11.8	104.3
SN(SS)-20	70.856	200	3022	0.0570	2.50	4.395	0.062	1.625	3.250	4.875	551.9	350	0.5	80-10-40	4	0.0479	0.0461	0.0432	11.8	113.3
SN(SS)-21	59.642	200	3675	0.0570	2.50	4.184	0.070	2.129	4.258	6.387	711.2	350	0.5	80-10-40	4	0.0487	0.0464	0.0427	11.8	115.1
SN(SS)-22	58.115	200	3810	0.0570	2.50	4.195	0.072	2.225	4.449	6.674	737.0	350	0.5	80-10-40	4	0.0492	0.0468	0.0428	11.8	116.5
SN(SS)-23	68.534	200	3111	0.0570	2.50	4.426	0.065	1.705	3.409	5.114	565.7	350	0.5	80-10-40	4	0.0495	0.0475	0.0443	11.8	117.0
SN(SS)-24	78.070	200	3620	0.0570	2.50	4.713	0.060	1.614	3.228	4.842	615.5	350	0.5	80-10-40	4	0.0446	0.0430	0.0405	11.8	105.4
SN(SS)-25	87.794	200	4313	0.0702	2.50	5.033	0.057	1.412	2.823	4.235	684.4	350	0.5	80-10-40	4	0.0402	0.0389	0.0369	14.6	117.2
SN(SS)-26	97.934	200	4634	0.0702	2.50	5.367	0.055	1.312	2.623	3.935	687.8	350	0.5	80-10-40	4	0.0383	0.0372	0.0354	14.6	111.6
SN(SS)-27	108.419	200	4860	0.0702	2.50	5.705	0.053	1.213	2.427	3.640	677.0	350	0.5	80-10-40	4	0.0370	0.0360	0.0344	14.6	107.8
SN(SS)-28	119.208	200	5025	0.0768	2.50	6.041	0.051	1.073	2.146	3.218	659.7	350	0.5	80-10-40	4	0.0360	0.0351	0.0336	15.9	114.8
SN(SS)-29	130.217	200	5232	0.0768	2.50	6.371	0.049	1.002	2.004	3.006	650.1	350	0.5	80-10-40	4	0.0350	0.0342	0.0328	15.9	111.5
SN(SS)-30	141.451	200	5704	0.0889	2.50	6.690	0.047	0.895	1.791	2.686	673.8	350	0.5	80-10-40	4	0.0332	0.0325	0.0313	18.4	122.5
SN(SS)-31	152.871	200	6019	0.0889	3.00	7.870	0.051	0.851	1.702	2.553	607.1	350	0.5	80-10-40	4	0.0380	0.0370	0.0354	18.4	140.2
SN(SS)-32	164.281	200	6331	0.0889	3.00	8.215	0.050	0.812	1.625	2.437	610.8	350	0.5	80-10-40	4	0.0368	0.0359	0.0344	18.4	135.7
SN(SS)-33	175.815	240	6576	0.0977	3.00	8.544	0.049	0.738	1.476	2.213	609.1	350	0.5	80-10-40	4	0.0357	0.0349	0.0336	14.1	100.6
SN(SS)-34	187.467	240	6849	0.0977	3.00	8.856	0.047	0.706	1.412	2.119	611.1	350	0.5	80-10-40	4	0.0347	0.0339	0.0327	14.1	97.6
SN(SS)-35	199.217	165	3131	0.0475	3.00	9.154	0.046	0.644	1.288	1.933	269.9	175	0.5	80-10-40	2	0.0354	0.0346	0.0334	14.5	102.4
SN(SS)-36	211.051	165	1967	0.0475	5.00	13.628	0.065	0.482	0.964	1.446	116.2	124	0.5	80-40-40	2	0.0545	0.0523	0.0488	14.5	158.0
SN(SS)-37	224.725	165	2107	0.0475	5.00	14.013	0.062	0.469	0.937	1.406	120.7	124	0.5	80-40-40	2	0.0527	0.0507	0.0475	14.5	152.6
SN(SS)-38	234.919	165	2425	0.0475	5.00	14.377	0.061	0.481	0.962	1.442	135.3	124	0.5	80-40-40	2	0.0515	0.0496	0.0466	14.5	149.2
SN(SS)-39	246.937	165	2792	0.0475	5.00	14.720	0.060	0.491	0.982	1.472	151.9	124	0.5	80-40-40	2	0.0493	0.0476	0.0449	14.5	142.9
SN(SS)-40	259.004	200	3123	0.0570	5.00	15.045	0.058	0.452	0.904	1.356	165.9	124	0.5	80-40-40	2	0.0471	0.0456	0.0431	11.8	111.4
SN(SS)-41	271.112	200	3865	0.0702	3.50	11.808	0.044	0.433	0.865	1.298	257.7	175	0.5	80-10-40	2	0.0340	0.0334	0.0323	14.6	99.0
SN(SS)-42	283.258	200	4313	0.0702	3.50	12.029	0.042	0.438	0.875	1.313	281.9	175	0.5	80-10-40	2	0.0321	0.0315	0.0306	14.6	93.5

3.10.3 Study on the Increase of Stay Cable Stress

The purpose of the study herein is the comfirmation of safety for the increase of temporary cable stress in the case that cable is broken or exchanged of the stay cable.

(1) Tensile Force of Stay Cable (1Plane)

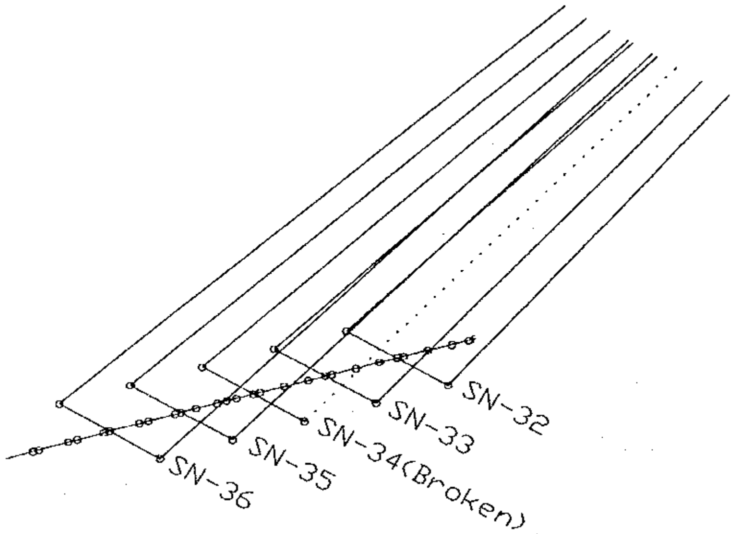
Unit : kN

Stay Cable		Nos of Strand	Dead Load at end of creep	Due to Live Load Max	Min	Range Max-Min	Remarks
SN-1	(SS-01)	60	5929	712	-53	765	P12
SN-2	(SS-02)	60	6056	722	-60	782	
SN-3	(SS-03)	60	5858	733	-69	802	
SN-4	(SS-04)	55	5073	647	-68	715	
SN-5	(SS-05)	55	3736	653	-76	729	
SN-6	(SS-06)	55	4812	672	-94	766	P13
SN-7	(SS-07)	55	5031	712	-132	844	
SN-8	(SS-08)	50	5031	755	-168	923	
SN-9	(SS-09)	50	4012	608	-153	761	
SN-10	(SS-10)	50	3245	623	-166	789	
SN-11	(SS-11)	50	3004	618	-159	777	
SN-12	(SS-12)	55	3905	582	-123	705	P14
SN-13	(SS-13)	60	4771	629	-100	729	
SN-14	(SS-14)	50	4072	583	-82	665	
SN-15	(SS-15)	45	4142	575	-80	655	
SN-16	(SS-16)	45	4052	584	-76	660	
SN-17	(SS-17)	37	3519	457	-57	514	
SN-18	(SS-18)	37	3551	447	-59	506	
SN-19	(SS-19)	37	3191	420	-87	507	
SN-20	(SS-20)	37	3003	366	-122	488	
SN-21	(SS-21)	37	3662	258	-129	387	
SN-22	(SS-22)	37	3826	241	-136	377	
SN-23	(SS-23)	37	3131	340	-129	469	
SN-24	(SS-24)	37	3638	389	-105	494	
SN-25	(SS-25)	45	4317	518	-105	623	
SN-26	(SS-26)	50	4640	519	-90	609	
SN-27	(SS-27)	50	4863	512	-79	591	
SN-28	(SS-28)	55	5021	559	-75	634	
SN-29	(SS-29)	55	5225	555	-62	617	
SN-30	(SS-30)	60	5677	647	-58	705	
SN-31	(SS-31)	60	5991	674	-47	721	
SN-32	(SS-32)	70	6303	720	-39	759	
SN-33	(SS-33)	70	6549	877	-37	914	
SN-34	(SS-34)	70	6946	970	-31	1001	
SN-35	(SS-35)	37	3128	506	-13	519	
SN-36	(SS-36)	30	1967	548	-11	559	
SN-37	(SS-37)	30	2107	575	-11	586	
SN-38	(SS-38)	30	2426	604	-13	617	
SN-39	(SS-39)	37	2793	623	-16	639	
SN-40	(SS-40)	37	3125	734	-23	757	
SN-41	(SS-41)	45	3869	935	-40	975	
SN-42	(SS-42)	50	4317	921	-57	978	

Study Case : SN-34(SS-34) is beaking (Left Side)

(2) Analysis Model

Examination of stay cable, in the case that the one of cable is broken, the analysis model is consider as local model.



(3) Calculation Result

Tensile Force of Stay Cable

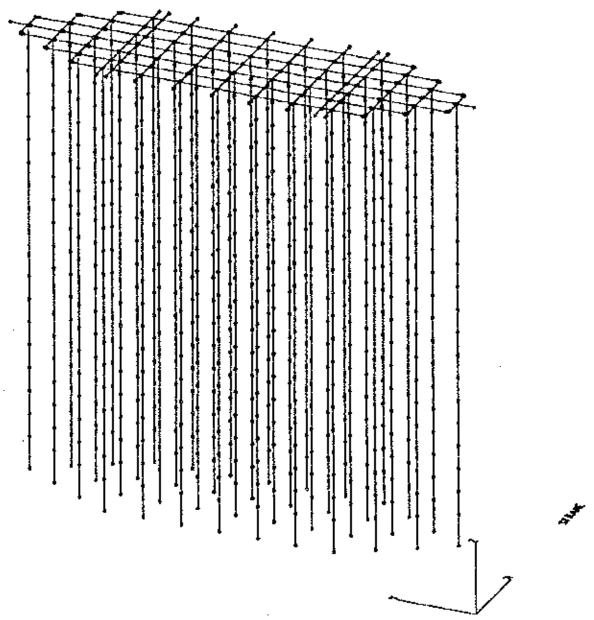
Stay Cable		Nos of Strand	Dead Load at end of creep	Re-distribution of Dead Load	Due to Live Load		D.L + L.L		Allowable Tensile Force (0.56fpu)
					Max	Min	Max	Min	
Left Side	SN-32 (SS-32)	70	6303	8536	986	153	9522	8689	10113 OK
	SN-33 (SS-33)	70	6549	8301	1153	16	9455	8317	10113 OK
	SN-34 (SS-34)	70	6946	Broken	Broken	Broken	Broken	Broken	-
	SN-35 (SS-35)	37	3128	4083	827	-7	4910	4075	5345 OK
	SN-36 (SS-36)	30	1967	3163	709	14	3872	3177	4334 OK
Right Side	SN-32 (SS-32)	70	6303	6761	735	-139	7497	6622	10113 OK
	SN-33 (SS-33)	70	6549	6634	833	-49	7466	6585	10113 OK
	SN-34 (SS-34)	70	6946	6450	965	-27	7415	6424	10113 OK
	SN-35 (SS-35)	37	3128	3322	586	0	3908	3322	5345 OK
	SN-36 (SS-36)	30	1967	2606	527	10	3134	2616	4334 OK

3.11 Design of Pile-Cap

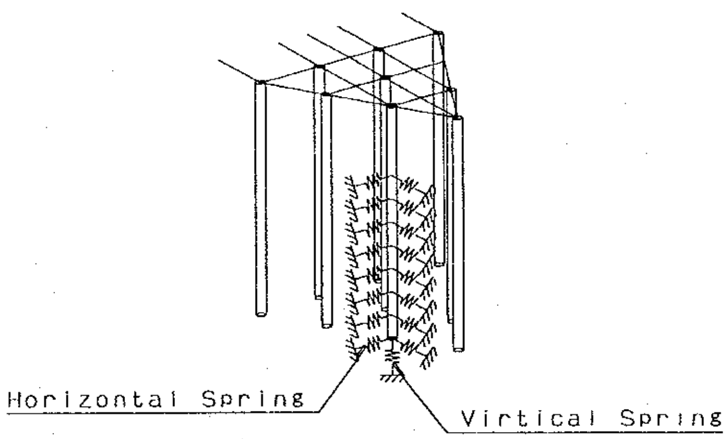
3.11.1 Space Frame Analysis

(1) Explanation of Analysis model

Structural model of pilecap , pile cap structure divide as beam element into 13 rows for longitudinal direction and 7 lines for transverse direction, basis the disposition of piles and bottom of column of pylon. And spring constant given for each node Analysis model of pile cap is as shown below.



General View of Space Frame Model of Pile Cap



Detail of Modeling of Ground Spring

Fig Space Frame Model of Pile Cap

(2) Spring Constant of Pile

Value of Spring constant of pile are taken from design calculation of composite pile. The substance of calculation of spring constant refer to design calculation of pile. Horizontal spring constant and vertical spring constant are mentioned below.

Table Horizontal spring constant of pile at Northern Pylon

POINT	Northern Pylon					Southern Pylon				
	depth (m)	A (m2)	I (m2)	kh:(kN/m) Ordinary	kh:(kN/m) Earthquake	depth (m)	A (m2)	I (m2)	kh:(kN/m) Ordinary	kh:(kN/m) Earthquake
①	5	9.863	7.431	0	0	7.1	9.863	7.431	0	0
②	10	9.863	7.431	0	0	12.1	9.863	7.431	0	0
③	15	9.863	7.431	0	0	17.1	9.863	7.431	0	0
④	20	9.863	7.431	0	0	22.1	9.863	7.431	0	0
⑤	25	9.863	7.431	80542	161094	27.1	9.863	7.431	0	0
⑥	30	9.863	7.431	161094	322188	32.1	9.863	7.431	80542	161094
⑦	35	9.863	7.431	161094	322188	37.1	9.863	7.431	161094	322188
⑧	40	9.863	7.431	161094	322188	42.1	9.863	7.431	161094	322188
⑨	45	9.863	7.431	161094	322188	47.1	9.863	7.431	161094	322188
⑩	50	7.069	3.976	235889	471788	52.1	9.863	7.431	161094	322188
⑪	55	7.069	3.976	324600	649200	57.1	7.069	3.976	261975	523950
⑫	60	7.069	3.976	324600	649200	62.1	7.069	3.976	415194	830388
⑬	65	7.069	3.976	324600	649200	67.1	7.069	3.976	415194	830388
⑭	70	7.069	3.976	787474	1574948	72.1	7.069	3.976	874704	1749418
⑮	75	7.069	3.976	1090951	2181901	77.1	7.069	3.976	1090951	2181901
⑯	80	7.069	3.976	1090951	2181901	82.1	7.069	3.976	1090951	2181901
⑰	85	7.069	3.976	1527327	3054654	87.1	7.069	3.976	1069131	2138262
⑱	90	7.069	3.976	498227	996464	92.1	7.069	3.976	1080036	2160081
⑲	97	7.069	3.976	763663	1527327	97	7.069	3.976	459412	918834

Table Vertical spring constant

	KV (kN/m)	Remark
Northern Pylon	12988398	
Southern Pylon	11985541	

Vertical spring constant is common value for calculate internal forces as Ordinaly and Earthquake

(3) Material

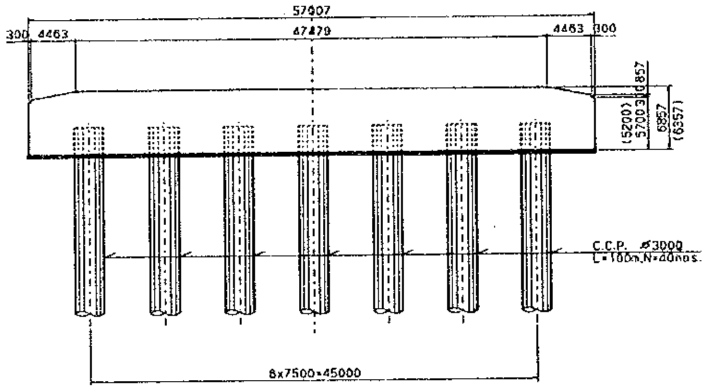
Concrete

	fc' (MPa)	Ec (MPa)	G (MPa)	Ct	Remark
Pile Cap	30	26300	10900	10.8/deg	Class D
Pile	30	26300	10900	x1.0E-6	Class D

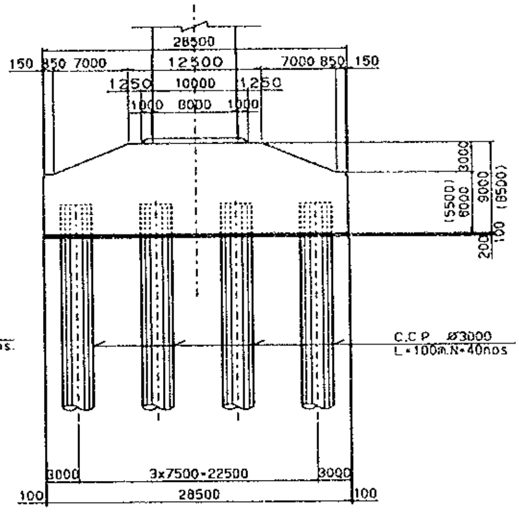
fc'= Compressive strength of concrete at 28 days (LRFD 5.4.2.1)
Ec= Elasticity Modules of concrete (LRFD 5.4.2.4)
G= Shear Modules (LRFD 5.4.2.5)
Ct= Coefficient of thermal expansion and contraction (LRFD 5.4.2.2)

(4) Design Section

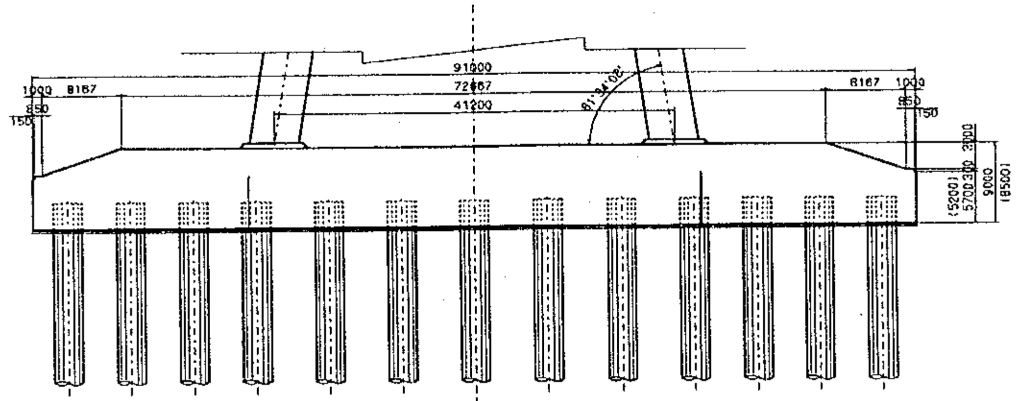
Section 1-1,3-3



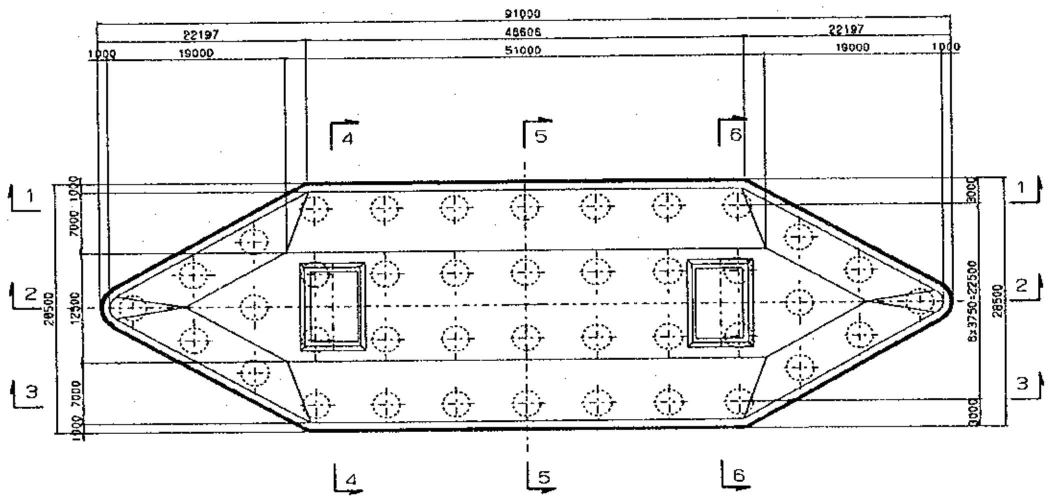
Section 4-4,5-5,6-6



Section 2-2



Plan



Indicate into ( ) is Dimension at Southern Pylon

Fig Detail of Pile Cap

3.11.2 Calculation result

(1) Loading

For calculation of internal forces at pilecap, loading shall be considered with effect due to dead load of superstructure, thermal effect, wind load, earthquake, and collision force due to vessels.
Summary of Loadings is mentioned below.

Case No	Load Name
LC-1	Pilecap
LC-2	Pile
LC-3	Girder + Surfacing
LC-4	Live Load M-Max
LC-5	Temperature Gradient
LC-6	Uniform Temperature (+10 deg)
LC-7	Uniform Temperature (-10 deg)
LC-8	Uniform Temperature at Pylon (+10 deg)
LC-9	Uniform Temperature at Pylon (-10 deg)
LC-10	Shrinkage at Pylon
LC-11	Wind Load for Longitudinal Direction (L->R)
LC-12	Wind Load for Longitudinal Direction (R->L)
LC-13	Wind Load for Transverse Direction (L->R)
LC-14	Wind Load for Transverse Direction (R->L)
LC-15	Wind Load on Live Load
LC-16	Water Load (Stream Pressure)
LC-17	Earthquake for Longitudinal Direction (L->R)
LC-18	Earthquake for Longitudinal Direction (R->L)
LC-19	Earthquake for Transverse Direction (L->R)
LC-20	Earthquake for Transverse Direction (R->L)
LC-21	EQ;Pilecap for Longitudinal Direction (L->R)
LC-22	EQ;Pilecap for Longitudinal Direction (R->L)
LC-23	EQ;Pilecap for Transverse Direction (L->R)
LC-24	EQ;Pilecap for Transverse Direction (R->L)
LC-25	EQ;Pile for Longitudinal Direction (L->R)
LC-26	EQ;Pile for Longitudinal Direction (R->L)
LC-27	EQ;Pile for Transverse Direction (L->R)
LC-28	EQ;Pile for Transverse Direction (R->L)
LC-29	Vessel Collision for Longitudinal Direction
LC-30	Vessel Collision for Transverse Direction
LC-31	Breaking Force (L->R)
LC-32	Breaking Force (R->L)

(2) Load Combination

As for load combination, that according to LRFD(Article 3.4.1).
As concern sectional force check at pile-cap resulting from 3D-analysis, load combination for examination, that is mentioned below.

Summary of Load Combination

Case No.	Contents	Remark
Case-1	1+2+3+4+6+8+10+16	Strength 1
Case-2	1+2+3+4+7+9+10+16	
Case-3	1+2+3+4+6+8+10+11+15+16	Strength 5 for Longitudinal Direction
Case-4	1+2+3+4+6+8+10+12+15+16	
Case-5	1+2+3+4+6+8+10+11+15+16	
Case-6	1+2+3+4+6+8+10+12+15+16	
Case-7	1+2+3+4+6+8+10+13+15+16	Strength 5 for Transverse Direction
Case-8	1+2+3+4+6+8+10+14+15+16	
Case-9	1+2+3+4+6+8+10+13+15+16	
Case-10	1+2+3+4+6+8+10+14+15+16	
Case-11	1+2+3+4+16+17+21+25	Earthquake for Longitudinal Direction
Case-12	1+2+3+4+16+18+22+26	
Case-13	1+2+3+4+16+19+23+27	Earthquake for Transverse Direction
Case-14	1+2+3+4+16+20+24+28	
Case-15	1+2+3+4+16+29	Vessel Collision for Longitudinal
Case-16	1+2+3+4+16+30	Vessel Collision for Transverse

(3) Sectional Force

Northern Pylon

	Section 1-1			Section 2-2			Section 3-3			Section 4-4			Section 5-5			Section 6-6		
	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)
LC-1	-57	27742	-36855	-92	-18700	100780	-57	-27742	-36855	-938	1288	38578	-1248	156	36283	-940	-17426	38577
LC-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LC-3	-1137	83059	-19648	-217	-170608	1145860	-202	-61267	-14123	-2607	-99184	657619	-713	16510	-374163	-2606	-105703	657620
LC-4	231	-1791	1182	-682	-17913	135738	-293	-8761	-2815	-125	-4790	31769	-35	797	-18076	-127	-5107	31768
LC-5	237	-3246	2667	-580	-5194	39510	-237	-3148	-2644	1	56	-345	0	-12	250	2	84	-531
LC-6	333	-4444	3739	-807	-7157	54156	-331	-4332	-3707	2	78	-520	0	-13	296	1	83	-522
LC-7	-333	4444	-3739	807	7157	-54156	331	4332	3707	-2	-78	520	0	13	-296	-1	-83	522
LC-8	-2	300	-36	-4	-198	2304	-2	-300	-36	-4544	-717	12937	-4582	188	2798	-58	716	-9657
LC-9	2	-300	36	4	198	-2304	2	300	36	4544	717	-12937	4582	-188	-2798	58	-716	9657
LC-10	0	-295	35	2	204	-2305	0	295	35	4547	714	-12930	4579	-184	-2800	57	-716	9652
LC-11	5961	-59470	76547	-14860	-106079	734158	-5996	-62899	-77345	27	-2392	16776	67	405	-8411	-69	-2384	14246
LC-12	-5961	59470	-76547	14860	106079	-734158	5996	62899	77345	-27	2392	-16776	-67	-405	8411	69	2384	-14246
LC-13	251	-30747	6793	653	81955	-564436	327	31479	7759	6919	45762	-186187	-875	-7767	140224	6546	29507	-59427
LC-14	-250	30700	-6786	-652	-81922	564075	-327	-31432	-7758	-6336	-30125	37373	558	11039	-145648	-7267	-51999	207736
LC-15	0	0	0	0	-1	4	0	0	0	-166	-58	-2930	33	16	583	-155	385	-5836
LC-16	0	-23	3	1	23	-232	0	23	3	-128	146	-592	-292	129	-516	-403	60	-483
LC-17	7002	-82850	75053	-17083	-134829	1008880	-6985	-81460	-74650	27	960	-6398	12	-159	3614	31	1027	-6347
LC-18	-7002	82847	-75047	17083	134824	-1008872	6985	81460	74645	-26	-960	6398	-12	159	-3614	-31	-1027	6346
LC-19	55	-313	768	-137	-559	3047	-55	-345	-754	4220	-18610	281855	-653	-4970	-10557	6127	17134	-9495
LC-20	-18	293	-156	46	498	-3991	19	300	167	-5771	-10646	-6795	1066	-1331	20638	-4561	24986	-265690
LC-21	3076	-32016	151662	-2191	-52484	49077	-3074	-32025	-151604	1	-2	-11	1	0	-3	1	-1	1
LC-22	-3076	32016	-151662	2191	52484	-49077	3074	32025	151604	-1	2	11	-1	0	3	-1	1	-1
LC-23	0	22	4	0	-16	149	-1	-22	-8	-817	9086	-44829	289	10251	-31984	2744	9209	51386
LC-24	0	-22	-4	0	16	-149	1	22	8	817	-9086	44829	-289	-10251	31984	-2744	-9209	-51386
LC-25	34	-5188	26720	-74	-8514	6366	-32	-5192	-26706	0	-1	-1	0	0	-1	0	0	0
LC-26	-34	5188	-26720	74	8514	-6366	32	5192	26706	0	1	1	0	0	1	0	0	0
LC-27	-1	6	1	-1	-3	45	0	-7	-3	43	2392	-11511	33	2737	-8571	-46	2429	11108
LC-28	1	-6	-1	1	3	-45	0	7	3	-43	-2392	11511	-33	-2737	8571	46	-2429	-11108
LC-29	-32	15740	-80180	51	25826	-21356	32	15740	80180	0	0	0	0	0	0	0	0	0
LC-30	0	0	0	0	0	0	0	0	0	-396	-14773	67975	106	-16724	53015	398	-14776	-67975
LC-31	0	-73	-45	0	-66	783	0	-48	54	0	18	-124	0	-3	71	0	20	-122
LC-32	0	73	45	0	66	-783	0	48	-54	0	-18	124	0	3	-71	0	-20	122

Southern Pylon

	Section 1-1			Section 2-2			Section 3-3			Section 4-4			Section 5-5			Section 6-6		
	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)
LC-1	-231	-18529	74187	-549	11811	-613	-355	14837	47231	-407	6597	1740	-457	-3357	11705	-461	3845	11532
LC-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LC-3	-1315	-116794	736152	-1595	7511	189639	-886	28803	192609	-1355	79119	203770	-1044	608	-30278	-1156	50610	-38571
LC-4	-258	-2230	14484	-84	-317	4	38	-1441	-5418	40	72	-460	-14	177	-433	28	58	-190
LC-5	-333	-3087	20385	-109	-429	22	50	-1955	-7514	51	132	-598	-19	252	-605	35	96	-275
LC-6	-290	-2650	17375	-96	-367	60	43	-1668	-6331	44	120	-471	-17	212	-519	31	89	-239
LC-7	436	3976	-26064	145	552	-91	-65	2502	9498	-66	-181	707	26	-319	779	-47	-133	358
LC-8	-594	-202	2583	-1834	-275	3034	-1196	169	3	1092	-845	-7171	-1517	-65	-67	-3010	592	3305
LC-9	594	202	-2583	1834	275	-3034	1196	-169	-3	-1092	845	7171	1517	65	67	3010	-592	-3305
LC-10	592	199	-2582	1835	276	-3033	1195	-165	-1	-1092	845	7168	1516	62	66	3011	-590	-3302
LC-11	-6090	-39250	232983	-2571	-5994	585	300	-26813	-89414	1075	145	-7440	-180	2520	-7326	866	476	-3296
LC-12	3347	-42521	241294	-1952	11029	39563	-568	28139	148970	5536	30319	165866	492	-300	-15410	2097	32726	19146
LC-13	4049	52924	-328985	-1190	10314	-148897	-419	7628	-12912	-1093	-58320	-143794	2335	-2613	17975	-3150	-29449	-4921
LC-14	3347	-42521	241294	-1952	11029	39563	-568	28139	148970	5536	30319	165866	492	-300	-15410	2097	32726	19146
LC-15	103	562	-4030	-43	214	-438	1	226	925	176	430	2335	25	72	233	81	60	1200
LC-16	-112	47	-291	-151	138	-877	-136	43	-109	-131	94	-634	-164	73	-506	-169	96	-674
LC-17	-8400	-68800	443293	-2776	-9470	3417	1240	-42909	-158150	1281	3338	-10448	-477	5245	-13402	886	2512	-6272
LC-18	8556	69294	-444783	2833	9554	-3626	-1256	43261	158525	-1305	-3316	10382	485	-5230	13481	-905	-2522	6307
LC-19	5685	41257	-253750	-2880	20387	-46685	-928	22174	75577	-990	4246	-39453	2629	1958	26950	-3821	-23056	-5027
LC-20	5534	36756	-251291	-2476	12851	-19050	-122	11968	47488	6743	24051	84394	1453	4249	17777	2458	-5418	47592
LC-21	-2220	-30398	17710	-1133	-6302	17937	42	-23762	5915	475	-3484	9763	344	-3138	-3821	601	165	-1378
LC-22	2220	30398	-17710	1133	6302	-17937	-42	23762	-5915	-475	3484	-9763	-344	3138	3821	-601	-165	1378
LC-23	440	2119	19838	-792	9880	-51294	-17	8087	26141	-1181	6647	-34069	513	6795	-8703	-414	7242	-31914
LC-24	-440	-2119	-19838	792	-9880	51294	17	-8087	-26141	1181	-6647	34069	-513	-6795	8703	414	-7242	31914
LC-25	12	-5958	2266	77	-1204	4138	62	-4692	2353	-18	-725	2027	-9	-651	-803	-20	36	-298
LC-26	-12	5958	-2266	-77	1204	-4138	-62	4692	-2353	18	725	-2027	9	651	803	20	-36	298
LC-27	-8	643	4846	36	2864	-14226	-11	2324	7479	28	1961	-8856	4	2008	-3167	12	2123	-8715
LC-28	8	-643	-4846	-36	-2864	14226	11	-2324	-7479	-28	-1961	8856	-4	-2008	3167	-12	-2123	8715
LC-29	26	-15352	5873	180	-3098	10630	147	-12093	6024	-43	-1872	5237	-20	-1679	-2077	-46	94	-773
LC-30	36	-3335	-25352	-164	-14926	74278	51	-12105	-39030	-133	-10225	46265	-17	-10464	16469	-57	-11076	45533
LC-31	0	56	-546	0	11	47	0	50	290	-7	6	62	-8	-12	1	-13	5	-15
LC-32	0	-56	546	0	-11	-47	0	-50	-290	7	-6	-62	8	12	-1	13	-5	15

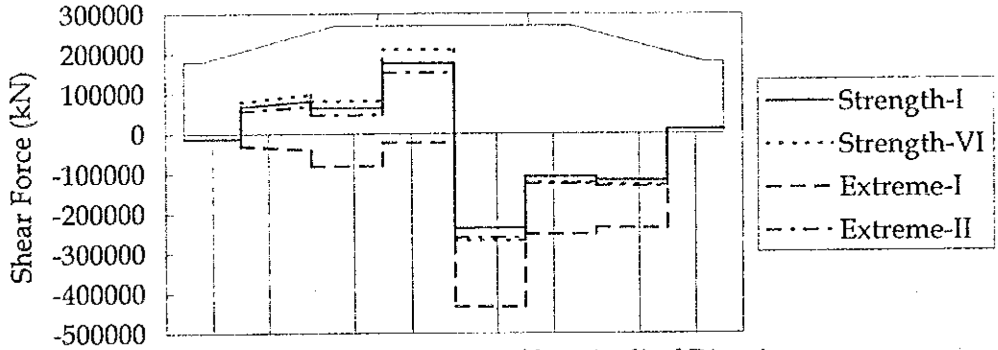
(4) Force Effect

Northern Pylon

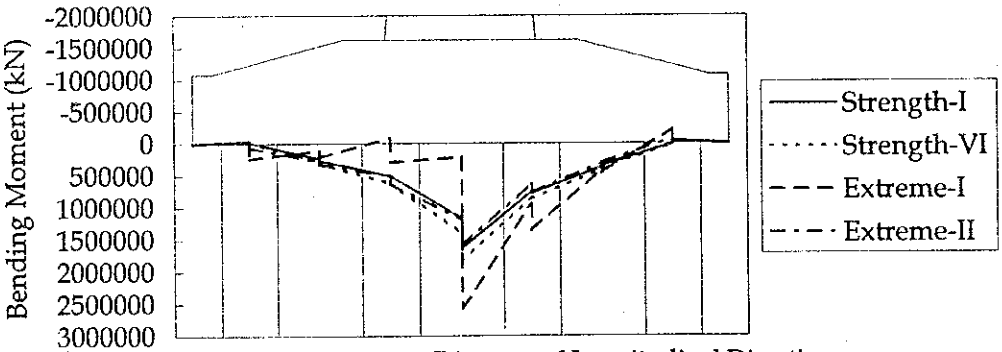
	Section 1-1			Section 2-2			Section 3-3			Section 4-4			Section 5-5			Section 6-6		
	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)
Case-1	-624	104562	-52563	-1906	-223401	1508233	-938	-104762	-57755	-3889	-106095	750944	-2316	18185	-369882	-4171	-131965	751045
Case-2	-955	108706	-56266	-1095	-216046	1451773	-605	-100130	-54012	653	-105456	738527	2266	18010	-372976	-4114	-132764	761224
Case-3	1668	81491	-22417	-7577	-258669	1747605	-3219	-126417	-87567	-3994	-105194	742017	-2242	18044	-365433	-4303	-130491	738200
Case-4	-3101	129067	-83654	4311	-173805	1160279	1577	-76098	-25691	-4016	-103280	728596	-2296	17720	-358704	-4248	-128583	726803
Case-5	1337	85635	-26120	-6766	-251314	1691145	-2886	-121785	-83824	548	-104555	729600	2340	17869	-368527	-4246	-131290	748379
Case-6	-3432	133211	-87357	5122	-166450	1103819	1910	-71466	-21948	526	-102641	716179	2286	17545	-361798	-4191	-129382	736982
Case-7	-616	92980	-50318	-1372	-183455	1228167	-690	-88666	-53526	-1238	-85932	660832	-2619	14776	-305979	-1657	-117734	708731
Case-8	-817	117559	-55750	-1894	-249006	1679572	-952	-113831	-59732	-6540	-116287	750256	-2046	22298	-420328	-7182	-150337	815596
Case-9	-947	97124	-54021	-561	-176100	1171707	-357	-84034	-49783	3304	-85293	648415	1963	14601	-309073	-1600	-118533	718910
Case-10	-1148	121703	-59453	-1083	-241651	1623112	-619	-109199	-55989	-1998	-115648	737839	2536	22123	-423422	-7125	-151136	825775
Case-11	8931	-11070	197941	-19900	-393295	2375789	-10291	-210344	-306190	-3708	-99179	705018	-2258	17033	-343789	-3981	-124587	705191
Case-12	-11088	229108	-309753	18602	-1580	247186	9480	27059	201420	-3763	-101111	717962	-2284	17354	-351080	-4045	-126659	718004
Case-13	-1025	108736	-55136	-787	-198013	1314724	-462	-92017	-53148	-290	-107277	937005	-2602	25212	-398546	4813	-96851	764597
Case-14	-1096	109286	-56070	-602	-196918	1307298	-386	-91314	-52205	-8733	-122269	761035	-1527	2875	-286241	-11272	-112275	383414
Case-15	-1111	124761	-136089	-598	-171609	1290127	-374	-75903	27798	-3736	-100145	711490	-2271	17194	-347434	-4013	-125623	711598
Case-16	-1079	109021	-55909	-649	-197435	1311483	-406	-91643	-52383	-4132	-114918	779465	-2165	470	-294419	-3615	-140399	643623

Southern Pylon

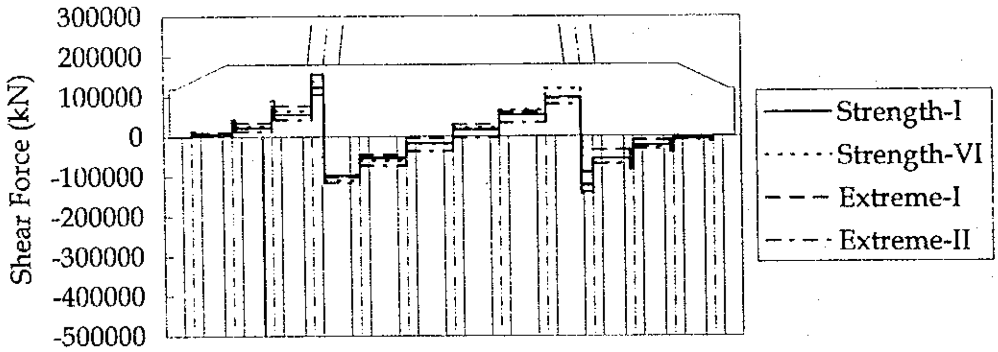
	Section 1-1			Section 2-2			Section 3-3			Section 4-4			Section 5-5			Section 6-6		
	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)	N (kN)	S (kN)	M (kNm)
Case-1	439	81210	-38354	-3398	-236012	1631040	-1503	-116053	-64189	-2832	-97894	703107	-1868	17010	-341303	-3147	-122509	703331
Case-2	169	84825	-42444	-2725	-229512	1583290	-1231	-111935	-60059	1697	-97245	690497	2696	16836	-344586	-3101	-123289	713316
Case-3	2077	62496	-11046	-7477	-264449	1815859	-3132	-133540	-91250	-3007	-97124	694405	-1862	16843	-337577	-3279	-121326	692410
Case-4	263	94890	-42328	-3332	-266486	1841498	-1495	-127272	-65257	-5274	-110496	721721	-1606	20962	-398801	-5842	-143799	787749
Case-5	1807	66111	-15136	-6804	-257949	1768109	-2860	-129422	-87120	1522	-96475	681795	2701	16669	-340860	-3233	-122105	702396
Case-6	-8	98505	-46418	-2659	-259986	1793748	-1223	-123154	-61127	-746	-109848	709111	2957	20788	-402084	-5796	-144579	797734
Case-7	463	69677	-36748	-3084	-202122	1396144	-1358	-102742	-60766	-536	-78892	615231	-2182	14439	-284768	-986	-110186	671982
Case-8	263	94890	-42328	-3332	-266486	1841498	-1495	-127272	-65257	-5274	-110496	721721	-1606	20962	-398801	-5842	-143799	787749
Case-9	193	73292	-40838	-2411	-195622	1348394	-1086	-98624	-56636	3993	-78243	602621	2381	14265	-288051	-940	-110966	681968
Case-10	-8	98505	-46418	-2659	-259986	1793748	-1223	-123154	-61127	-746	-109848	709111	2957	20788	-402084	-5796	-144579	797734
Case-11	9250	-39185	265010	-19933	-432889	2571596	-10202	-235494	-367792	-2821	-97236	698748	-1863	16898	-338817	-3131	-121817	698978
Case-12	-9176	212082	-354432	15145	-22504	574891	7999	13518	252046	-2853	-98788	709108	-1871	17157	-344734	-3166	-123463	709339
Case-13	125	85818	-43161	-2622	-228742	1578523	-1192	-111623	-59422	1025	-100506	913696	-2575	30010	-410100	5275	-89453	775349
Case-14	59	86492	-44222	-2454	-227627	1571376	-1123	-110949	-58362	-7829	-124721	774922	-865	-2319	-264544	-10425	-113676	352280
Case-15	123	67135	53034	-2586	-259371	1600917	-1188	-130300	-155618	-2837	-98012	703929	-1867	17028	-341775	-3149	-122640	704159
Case-16	93	86152	-43692	-2537	-228183	1574925	-1158	-111283	-58892	-3194	-115674	786815	-1772	-2996	-278730	-2793	-140301	621271



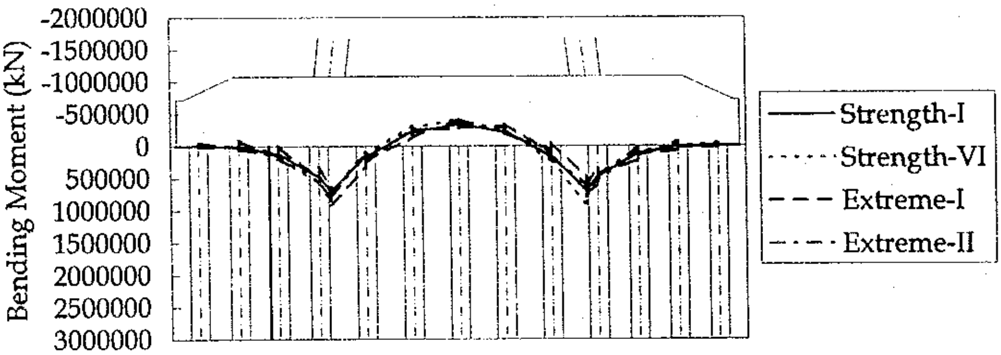
Total Shear Force Diagram of Longitudinal Direction



Total Bending Moment Diagram of Longitudinal Direction



Total Shear Force Diagram of Transverse Direction



Total Bending Moment Diagram of Transverse Direction

Fig Sectional Force Diagram of Pile Cap at Northern Pylon

3.11.3 Check from Load and Resistance Factor Design

(1) Check of Flexural Resistance

Pile Cap at Northern Pylon Longitudinal Direction

	Section 1-1		Section 2-2		Section 3-3	
	Moment (kNm/m)	Resistance Factor (kNm)	Moment (kNm/m)	Resistance Factor (kNm)	Moment (kNm/m)	Resistance Factor (kNm)
Strength 1	-56266	1722080	1508233	2806274	-57755	1722080
Strength 5	-87357		1747605		-87567	
Extreme 1	197941		2375789		201420	
Extreme 2	-136089		1290127		27798	

Pile Cap at Northern Pylon Transverse Direction

	Section 4-4		Section 5-5		Section 6-6	
	Moment (kNm/m)	Resistance Factor (kNm)	Moment (kNm/m)	Resistance Factor (kNm)	Moment (kNm/m)	Resistance Factor (kNm)
Strength 1	750944	1581899	-369882	1581899	761224	1581899
Strength 5	750256		-305979		825775	
Extreme 1	937005		-286241		764597	
Extreme 2	779465		-294419		643623	

Pile Cap at Southern Pylon Longitudinal Direction

	Section 1-1		Section 2-2		Section 3-3	
	Moment (kNm/m)	Resistance Factor (kNm)	Moment (kNm/m)	Resistance Factor (kNm)	Moment (kNm/m)	Resistance Factor (kNm)
Strength 1	-42444	1489222	1631040	2528508	-64189	1489222
Strength 5	-46418		1841498		-91250	
Extreme 1	265010		2571596		252046	
Extreme 2	53034		1600917		-155618	

Pile Cap at Southern Pylon Transverse Direction

	Section 4-4		Section 5-5		Section 6-6	
	Moment (kNm/m)	Resistance Factor (kNm)	Moment (kNm/m)	Resistance Factor (kNm)	Moment (kNm/m)	Resistance Factor (kNm)
Strength 1	703107	1245621	-344586	1245621	713316	1245621
Strength 5	721721		-402084		797734	
Extreme 1	913696		-264544		775349	
Extreme 2	786815		-278730		621271	

(2) Calculation of Frexural Resistance

Calculation of Flexural Resistance (Northern Pylon)

	Sign	Unit	Northern Pylon					
			Section 1-1	Section 2-2	Section 3-3	Section 4-4	Section 5-5	Section 6-6
Factored Flexural Resistance	M_r	Nmm	8.61E+11	1.403E+12	8.61E+11	1.582E+12	1.582E+12	1.582E+12
Resistance Factor	ϕ		0.9	0.9	0.9	0.9	0.9	0.9
Nominal Resistance	M_n	Nmm	9.567E+11	1.559E+12	9.567E+11	1.758E+12	1.758E+12	1.758E+12
Area of prestressing steel	A_{ps}	mm^2	0	0	0	0	0	0
Average stress in prestressing steel at nominal bending resistance	f_{ps}	MPa	0	0	0	0	0	0
Yield strength of prestressing steel	f_{py}	MPa	0	0	0	0	0	0
Specified tensile strength of prestressing steel	f_{pu}	MPa	0	0	0	0	0	0
	k		0	0	0	0	0	0
Distance from extreme compression fiber to the centroid of prestressing tendons	d_p	mm	0	0	0	0	0	0
Specified yield strength of reinforcing bars	f_y	MPa	390	390	390	390	390	390
Area of nonprestressed tension reinforcement	A_s	mm^2	377022	462156	377022	561116	561116	561116
Distance from extreme compression fiber to the centroid of nonprestressed tensile reinforcement	d_s	mm	6640	8783	6640	8236	8236	8236
Area of compression reinforcement	A'_s	mm^2	118618	144447	118618	44960	44960	44960
Distance from extreme compression fiber to centroid of compression reinforcement	d'_s	mm	150	150	150	194	194	194
Specified yield strength of compression reinforcement	f'_y	MPa	390	390	390	390	390	390
Specified compressive strength of concrete at 28 days, unless another age is specified	f'_c	MPa	30	30	30	30	30	30
Width of the compression face of the member	b	mm	18469	22755	18469	22653	22653	22653
Web width or diameter of a circular section	b_w	mm	0	0	0	0	0	0
Stress block factor	β_1		0.85	0.85	0.85	0.85	0.85	0.85
Distance from extreme compression fiber to the nutral axis assuming the tendon prestressing steel has yielded	c	mm	251.75	251.22	251.75	409.98	409.98	409.98
Compression flange depth of an I or T member	h_f	mm	251.75	251.22	251.75	409.98	409.98	409.98
Depth of the equivalent stress block	a ($=c\beta_1$)		213.99	213.54	213.99	348.48	348.48	348.48

Fomula : $M_n = A_{ps}f_{ps}(d_p-a/2)+A_sf_y(d_s-a/2)-A'_sf'_y(d'_s-a/2)+0.85f'_c(b-b_w)\beta_1h_f(a/2-h_f/2)$

$f_{ps} = f_{pu}(1-kc/d_p)$

$k = 2(1.04-f_{py}/f_{pu})$

$c = (A_{ps}f_{pu}+A_sf_y-A'_sf'_y-0.85\beta_1f'_c(b-b_w)h_f)/(0.85f'_c\beta_1b_w+kA_{ps}f_{pu}/d_p)$

Calculation of Flexural Resistance (Southern Pylon)

	Sign	Unit	Southern Pylon					
			Section 1-1	Section 2-2	Section 3-3	Section 4-4	Section 5-5	Section 6-6
Factored Flexural Resistance	M_r	Nmm	7.446E+11	1.264E+12	7.446E+11	1.246E+12	1.246E+12	1.246E+12
Resistance Factor	ϕ		0.9	0.9	0.9	0.9	0.9	0.9
Nominal Resistance	M_n	Nmm	8.273E+11	1.405E+12	8.273E+11	1.384E+12	1.384E+12	1.384E+12
Area of prestressing steel	A_{ps}	mm^2	0	0	0	0	0	0
Average stress in prestressing steel at nominal bending resistance	f_{ps}	MPa	0	0	0	0	0	0
Yield strength of prestressing steel	f_{py}	MPa	0	0	0	0	0	0
Specified tensile strength of prestressing steel	f_{pu}	MPa	0	0	0	0	0	0
	k		0	0	0	0	0	0
Distance from extreme compression fiber to the centroid of prestressing tendons	d_p	mm	0	0	0	0	0	0
Specified yield strength of reinforcing bars	f_y	MPa	390	390	390	390	390	390
Area of nonprestressed tension reinforcement	A_s	mm^2	356752	441886	356752	478237	478237	478237
Distance from extreme compression fiber to the centroid of nonprestressed tensile reinforcement	d_s	mm	6091	8284	6091	7753	7753	7753
Area of compression reinforcement	A'_s	mm^2	111922	139664	111922	46873	46873	46873
Distance from extreme compression fiber to centroid of compression reinforcement	d'_s	mm	185	150	185	221	221	221
Specified yield strength of compression reinforcement	f'_y	MPa	390	390	390	390	390	390
Specified compressive strength of concrete at 28 days, unless another age is specified	f'_c	MPa	30	30	30	30	30	30
Width of the compression face of the member	b	mm	17469	21755	17469	21653	21653	21653
Web width or diameter of a circular section	b_w	mm	0	0	0	0	0	0
Stress block factor	β_1		0.85	0.85	0.85	0.85	0.85	0.85
Distance from extreme compression fiber to the nutral axis assuming the tendon prestressing steel has yielded	c	mm	252.18	249.96	252.18	620.93	620.93	620.93
Compression flange depth of an I or T member	h_f	mm	252.18	249.96	252.18	620.93	620.93	620.93
Depth of the equivalent stress block	a (=cβ_1)		214.35	212.47	214.35	527.79	527.79	527.79

Fomula : $M_n = A_{ps}f_{ps}(d_p-a/2)+A_sf_y(d_s-a/2)-A'_sf'_y(d'_s-a/2)+0.85f'_c(b-b_w)\beta_1h_f(a/2-h_f/2)$

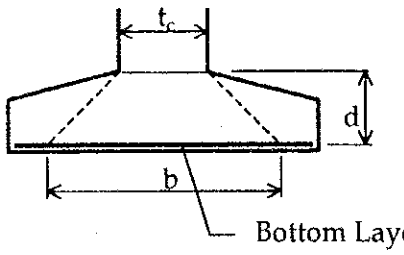
$f_{ps} = f_{pu}(1-kc/d_p)$

$k = 2(1.04-f_{py}/f_{pu})$

$c = (A_{ps}f_{pu}+A_sf_y-A'_sf'_y-0.85\beta_1f'_c(b-b_w)h_f)/(0.85f'_c\beta_1b_w+kA_{ps}f_{pu}/d_p)$

(3) Effective Width

Determination of amount of reinforcing bar, that calculated in accordance with effective width. The standpoint of effective width for calculation of flexural resistance is considered as follows.



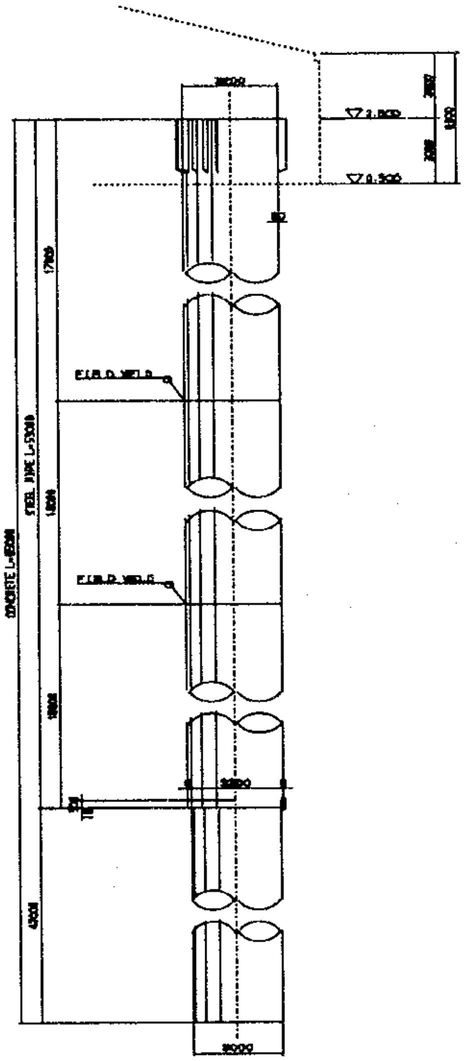
Effective width : l tc + 2*d

d : Distance from upper fiber to lower layer

t_c : Thickness of column

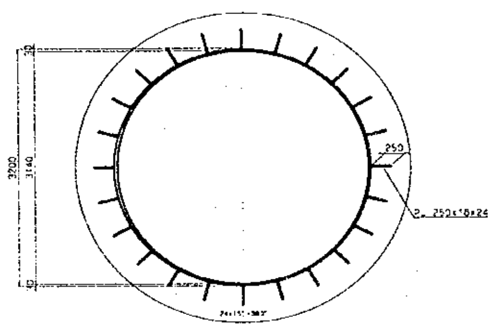
3.12 Design of Foundation for Pylon

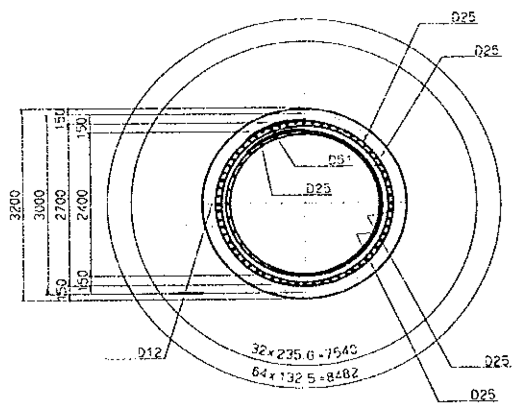
3.12.1 Detail of Hybrid Pile



Steel Casing

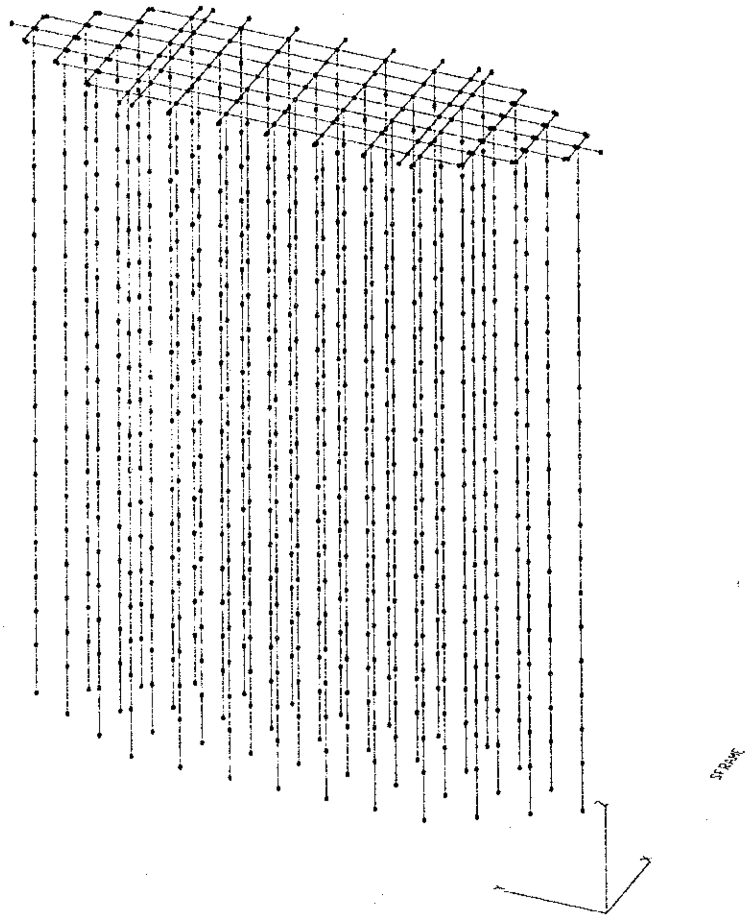
RC-Pile





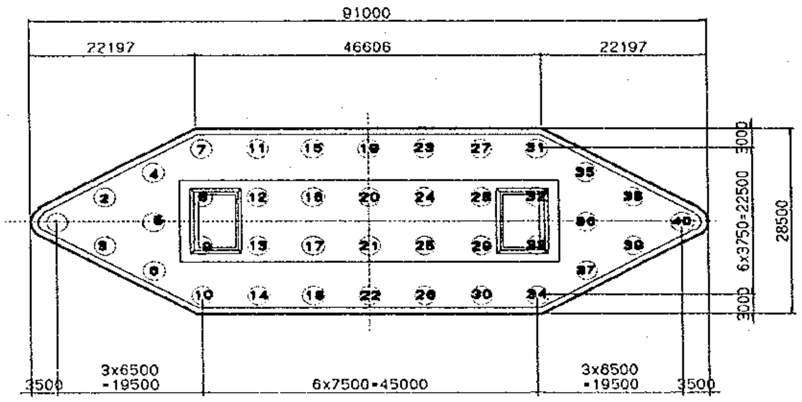
3.12.2 Calculation Model

Structure analysis of the foundation is done by Space frame .



Model of Space Frame

Pile Arrangement (Northern Pylon,Southern Pylon)



3.12.3 Load Combination for Foundation

List of Load Cases

Case No	Load Name
Case-1	Pilecap
Case-2	Pile
Case-3	Girder + Surfacing
Case-4	Live Load M-Max
Case-5	Temperature Gradient
Case-6	Uniform Temperature (+10 deg)
Case-7	Uniform Temperature (-10 deg)
Case-8	Uniform Temperature at Pylon (+10 deg)
Case-9	Uniform Temperature at Pylon (-10 deg)
Case-10	Shrinkage at Pylon
Case-11	Wind Load for Longitudinal Direction (L->R)
Case-12	Wind Load for Longitudinal Direction (R->L)
Case-13	Wind Load for Transverse Direction (L->R)
Case-14	Wind Load for Transverse Direction (R->L)
Case-15	Wind Load on Live Load
Case-16	Water Load (Stream Pressure)
Case-17	Earthquake for Longitudinal Direction (L->R)
Case-18	Earthquake for Longitudinal Direction (R->L)
Case-19	Earthquake for Transverse Direction (L->R)
Case-20	Earthquake for Transverse Direction (R->L)
Case-21	EQ;Pilecap for Longitudinal Direction (L->R)
Case-22	EQ;Pilecap for Longitudinal Direction (R->L)
Case-23	EQ;Pilecap for Transverse Direction (L->R)
Case-24	EQ;Pilecap for Transverse Direction (R->L)
Case-25	EQ;Pile for Longitudinal Direction (L->R)
Case-26	EQ;Pile for Longitudinal Direction (R->L)
Case-27	EQ;Pile for Transverse Direction (L->R)
Case-28	EQ;Pile for Transverse Direction (R->L)
Case-29	Vessel Collision for Longitudinal Direction
Case-30	Vessel Collision for Transverse Direction

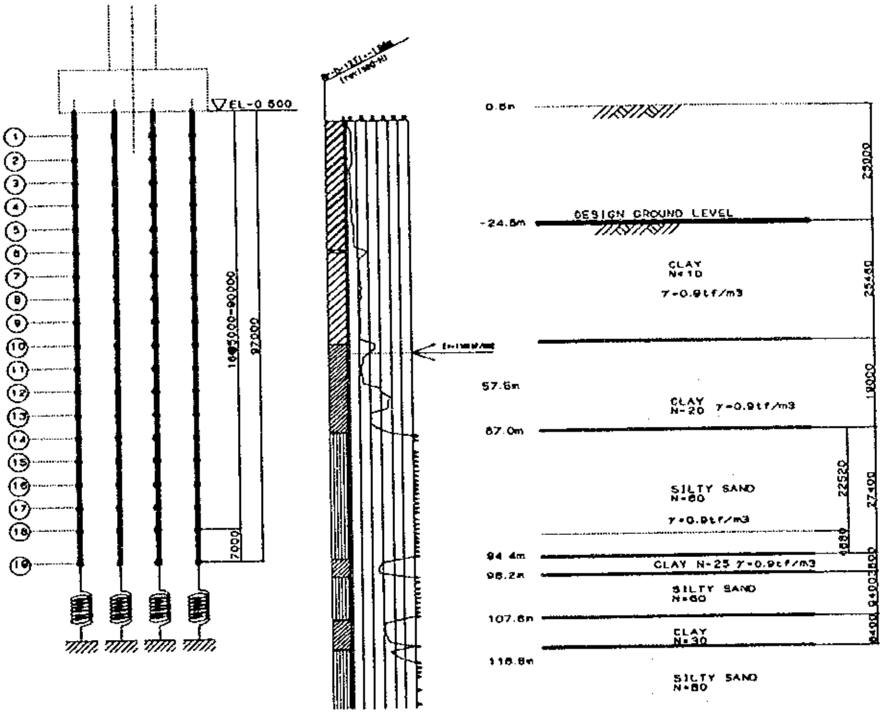
NOTE: "Case-4: Live Load M-Max" is the critical case for the foundation design with the maximum absolute value of Working Force caused by Live Load.

Summary for Load Combination

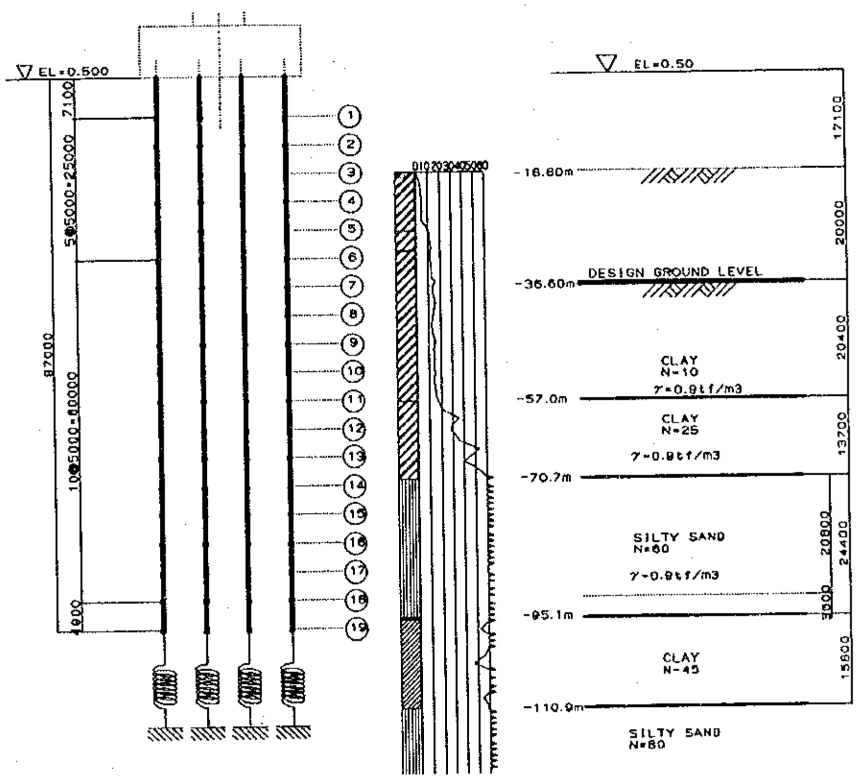
Combination Name		Contents	Remark
Combination1-1	Strength- I	1+2+3+4+6+8+10+16	Uniform Temperature
Combination1-2		1+2+3+4+7+9+10+16	
Combination2-1	Strength- V	1+2+3+4+6+8+10+11+15+16	Wind Load:Longitudinal Direction
Combination2-2		1+2+3+4+6+8+10+12+15+16	
Combination2-3		1+2+3+4+6+8+10+11+15+16	
Combination2-4		1+2+3+4+6+8+10+12+15+16	
Combination2-5	Strength- V	1+2+3+4+6+8+10+13+15+16	Wind Load:Transeverse Direction
Combination2-6		1+2+3+4+6+8+10+14+15+16	
Combination2-7		1+2+3+4+6+8+10+13+15+16	
Combination2-8		1+2+3+4+6+8+10+14+15+16	
Combination3-1	ExtremeEvent- I	1+2+3+4+16+17+21+25	Earthquake:Longitudinal Direction
Combination3-2		1+2+3+4+16+18+22+26	
Combination3-3	ExtremeEvent- I	1+2+3+4+16+19+23+27	Earthquake:Transeverse Direction
Combination3-4		1+2+3+4+16+20+24+28	
Combination4-1	ExtremeEvent- II	1+2+3+4+16+29	Vessel Collision:Longitudinal Direction
Combination4-2		1+2+3+4+16+30	Vessel Collision:Transeverse Direction
Combination5-1	Service- I	1+2+3+4+5+6+8+10+11+15+16	Wind Load:Longitudinal Direction
Combination5-2		1+2+3+4+5+6+8+10+12+15+16	
Combination5-3		1+2+3+4+5+6+8+10+11+15+16	
Combination5-4		1+2+3+4+5+6+8+10+12+15+16	
Combination5-5	Service- I	1+2+3+4+5+6+8+10+13+15+16	Wind Load:Transeverse Direction
Combination5-6		1+2+3+4+5+6+8+10+14+15+16	
Combination5-7		1+2+3+4+5+6+8+10+13+15+16	
Combination5-8		1+2+3+4+5+6+8+10+14+15+16	

3.12.4 Soil Condition of Pile

Northern Pylon



Southern Pylon



3.12.5 Vertical Spring Constant of Pile

Northern Pylon

Total length of pile = 97.0 m
stick out length of pile = 25.0 m

$$kv = \frac{1}{\frac{1}{kv1} + \frac{1}{kv2}}$$

kv: Equivalent Vertical Spring Constant

kv1: Kv of the part that stuck out in the water (Ap*Ec/h)

kv2: Kv of the part in the ground

$$Kv2 = \alpha \frac{Ap*Ep}{L}$$

$$\alpha = 0.031\ (\ l\ /\ D\ ) - 0.15$$

kv1= 1/4* π *3.2*^2*4.0*E6/25
= 1,130,976 tf/m

α = 0.031*(72.0/3)-0.15
0.5940

kv2= 0.5940*1/4* π *3.0^2*2.63*E6/72.0
= 153,371 tf/m

$$kv = \frac{1}{\frac{1}{kv1} + \frac{1}{kv2}}$$

$$= \frac{1}{\frac{1}{1{,}130{,}976} + \frac{1}{153{,}371}}$$

= 135,056 tf/m = 1,324,448 KN/m

Southern Pylon

Total length of pile = 97.0 m
stick out length of pile = 37.1 m

$$kv = \frac{1}{\frac{1}{kv1} + \frac{1}{kv2}}$$

kv: Equivalent Vertical Spring Constant

kv1: Kv of the part that stuck out in the water (Ap*Ec/h)

kv2: Kv of the part in the ground

$$Kv2 = \alpha \frac{Ap*Ep}{L}$$

$$\alpha = 0.031 (L / D) - 0.15$$

kv1= 1/4* π *3.2*^2*4*E6/37.1
= 867,115 tf/m

α = 0.031*(59.9/3)-0.15
= 0.46896667

kv2= 0.469*1/4* π *3.0^2*2.63*e6/59.9
= 145,547 tf/m

$$kv = \frac{1}{\frac{1}{kv1} + \frac{1}{kv2}}$$

$$= \frac{1}{\frac{1}{867,115} + \frac{1}{145,547}}$$

= 124,628 tf/m = 1,222,185 kN/m

3.12.6 Calculation of Horizontal Spring-constant for Pile

Northern Pylon

Layer Number	N-Value	kho: αE0(kgf/m3)		β	Bh=(D/β)^0.5(cm)	KH (kgf/cm3)	
		Ordinary	Earthquake			Ordinary	Earthquake
①	10	9.333	18.667	0.00094	218.8	2.103	4.206
②	20	18.667	37.333	0.00114	198.7	4.522	9.043
③	60	56.000	112.000	0.00154	170.9	15.184	30.369
④	25	23.333	46.667	0.00121	192.8	5.780	11.559
⑤	60	56.000	112.000	0.00154	170.9	15.184	30.369
⑥	30	28.000	56.000	0.00127	188.2	7.063	14.125
⑦	80	74.667	149.333	0.00167	164.2	20.870	41.741

Southern Pylon

Layer Number	N-Value	kho: αE0(kgf/m3)		β	Bh=(D/β)^0.5(cm)	KH (kgf/cm3)	
		Ordinary	Earthquake			Ordinary	Earthquake
①	10	9.333	18.667	0.00094	218.8	2.103	4.206
②	25	23.333	46.667	0.00121	192.8	5.780	11.559
③	60	56.000	112.000	0.00154	170.9	15.184	30.369
④	45	42.000	84.000	0.00142	178.0	11.047	22.094
⑤	80	74.667	149.333	0.00167	164.2	20.870	41.741

3.12.7 Calculation of Pile Capacity

NAME: *Northern Pylon*
PILE TYPE Hybrid Pile (Cast-in-situ-pile with Parmanent Casing)

Dia :	Upper Pile	3.200 m	(t=30mm)	
	Lower Pile	3.000 m		
Pile Length	Upper Pile	50.000 m		
	Lower Pile	47.000 m		
Stick out length of pile :		25.000 m		
Ulimate Soil End Bearing Capacity			300 tf/m2	2942 kN/m2

Skin Friction Capacity :

Layer Number	Depath:d (m)	Soil Type	N Value	fs (tf/m2)	Qs (tf)	Qs (kN)	Remarks
1	25.00	clay	10	5.0	1256.6	12323.4	Dia:3.2m
1	0.48	clay	10	10.0	45.2	443.6	Dia:3.0m
2	19.00	clay	20	15.0	2686.1	26341.3	〃
3	27.40	sand	60	20.0	5164.8	50649.3	〃
4	0.12	clay	25	15.0	17.0	166.4	〃
Total	72.00	-	-	-	9169.7	89924.1	

End Bearing Capacity : Qu	2120.6 (tf)	20795.8 (kN)
Replaced Effective Weight of Soil(Ws):	480.0 (tf)	4706.78 (kN)
Buoyant Weight of Pile(W):	1181.4 (tf)	11586 (kN)
Allowable Bearing Capacity(Qa):		
Service Limit State (FS=3)	2902.0 (tf)	28458.5 (kN)
Strength Limit State (FS=2)	4703.7 (tf)	46127.3 (kN)
Extreme Event Limit St: (FS=2)	4703.7 (tf)	46127.3 (kN)

NAME: ***Southern Pylon***

Pile Type Hybrid Pile (Cast-in-situ-pile with Parmanent Casing)

Dia :	Upper Pile	3.200	m	(t=30mm)
	Lower Pile	3.000	m	
Pile Length	Upper Pile	50.000	m	
	Lower Pile	47.000	m	
Stick out length of pile :		37.100	m	

Ulimate Soil End Bearing Capacity 300 tf/m2 2942 kN/m2

Skin Friction Capacity :

Layer Number	Depath:d (m)	Soil Type	N Value	fs (tf/m2)	Qs (tf)	Qs (kN)	Remarks
1	12.90	clay	10	10.0	1296.9	12717.8	Dia:3.2m
1	7.50	clay	10	10.0	706.9	6931.9	Dia:3.0m
2	13.70	clay	25	15.0	1936.8	18993.5	〃
3	24.40	sand	60	20.0	4599.3	45103.7	〃
4	1.40	clay	45	15.0	197.9	1940.9	〃
Total	59.90	-	-	-	8737.7	85687.9	

End Bearing Capacity : Qu	2120.6	(tf)	20795.8	(kN)
Replaced Effective Weight of Soil(Ws):	392.4	(tf)	3847.89	(kN)
Buoyant Weight of Pile(W):	0.0	(tf)	0	(kN)

Allowable Bearing Capacity(Qa):

Service Limit State	(FS=3)	2902.0	(tf)	28458.5	(kN)
Strength Limit State	(FS=2)	4703.7	(tf)	46127.3	(kN)
Extreme Event Limit Sta	(FS=2)	4703.7	(tf)	46127.3	(kN)

3.12.8 Calculation Result of Pile Reaction

Reaction of Pile (at pile top)
NORTHERN PYLON

Pile	Load Combination	Axial Force(Kn)		Shear-Force(kn)		Morment(knm)		Remarks
		max	min	Y	Z	Y	Z	
Pile NO.7	Strength- I	-23,329	-22,850	-76	-426	6,170	1,096	
	Strength- II	-	-	-	-	-	-	
	Strength- III	-	-	-	-	-	-	
	Strength- IV	-	-	-	-	-	-	
	Strength- V	-27,001	-19,412	-41	-789	10,530	356	<Qa=52200KN
	Extreme Event- I	-41,036	-5,373	-41	-2,648	37,937	288	<Qa=52200KN
	Extreme Event- II	-25,494	-22,371	-88	-1,132	16,751	1,381	
	Service- I	-26,438	-19,888	-101	-466	6,145	1,350	<Qa=32500KN
	Service- II	-	-	-	-	-	-	
	Service- III	-	-	-	-	-	-	
Pile NO.10	Strength- I	-22,827	-22,428	-90	424	-6,559	1,442	
	Strength- II	-	-	-	-	-	-	
	Strength- III	-	-	-	-	-	-	
	Strength- IV	-	-	-	-	-	-	
	Strength- V	-26,078	-18,142	-61	729	-10,744	827	
	Extreme Event- I	-38,622	-3,416	-55	2,524	-38,635	526	
	Extreme Event- II	-20,185	-18,730	1,285	337	-6,469	-23,377	
	Service- I	-25,147	-18,656	-79	652	-9,956	1,154	
	Service- II	-	-	-	-	-	-	
	Service- III	-	-	-	-	-	-	
Pile NO.1	Strength- I	-13,329	-13,174	-1,487	-8	-169	22,593	
	Strength- II	-	-	-	-	-	-	
	Strength- III	-	-	-	-	-	-	
	Strength- IV	-	-	-	-	-	-	
	Strength- V	-13,841	-12,175	-1,329	-298	4,244	20,506	
	Extreme Event- I	-16,580	-11,433	-3,038	963	-16,317	52,620	
	Extreme Event- II	-12,840	-9,565	-1,419	-671	9,325	21,553	
	Service- I	-13,609	-12,205	-1,341	-245	3,062	20,619	
	Service- II	-	-	-	-	-	-	
	Service- III	-	-	-	-	-	-	
Pile NO.40	Strength- I	-13,326	-13,174	1,554	-14	-103	-22,667	
	Strength- II	-	-	-	-	-	-	
	Strength- III	-	-	-	-	-	-	
	Strength- IV	-	-	-	-	-	-	
	Strength- V	-14,199	-13,016	1,841	256	-4,881	-28,458	
	Extreme Event- I	-14,251	-9,082	2,822	-767	10,424	-46,607	
	Extreme Event- II	-16,111	-12,836	2,739	-36	-742	-43,300	
	Service- I	-15,446	-12,607	1,610	-13	-770	-23,531	
	Service- II	-	-	-	-	-	-	
	Service- III	-	-	-	-	-	-	

Reaction of Pile (at pile top)
SOUTHERN PYLON

Pile	Load Combination	Axial Force(Kn)		Shear-Force(kn)		Morment(knm)		Remarks
		max	min	Y	Z	Y	Z	
Pile NO.7	Strength- I	-20,359	-19,856	-42	-148	4,839	1,127	
	Strength- II	-	-	-	-	-	-	
	Strength-III	-	-	-	-	-	-	
	Strength-IV	-	-	-	-	-	-	
	Strength- V	-23,481	-17,103	-25	-395	8,901	699	
	Extreme Event- I	-39,368	-1,897	-19	-2,265	46,381	481	
	Extreme Event- II	-19,591	-17,826	1,337	-175	5,345	-28,539	
	Service- I	-23,586	-17,291	-46	-160	5,026	1,353	
	Service- II	-	-	-	-	-	-	
	Service-III	-	-	-	-	-	-	
Pile NO.10	Strength- I	-23,843	-23,421	-44	114	-2,552	1,193	
	Strength- II	-	-	-	-	-	-	
	Strength-III	-	-	-	-	-	-	
	Strength-IV	-	-	-	-	-	-	
	Strength- V	-26,494	-20,985	-2	353	-6,554	216	<Qa=43500KN
	Extreme Event- I	-41,627	-4,535	-14	2,145	-42,717	325	<Qa=43500KN
	Extreme Event- II	-25,887	-22,126	-44	750	-15,451	1,189	
	Service- I	-26,195	-21,165	-30	74	-2,046	946	<Qa=26400KN
	Service- II	-	-	-	-	-	-	
	Service-III	-	-	-	-	-	-	
Pile NO.1	Strength- I	-12,415	-12,261	-496	-41	1,635	14,677	
	Strength- II	-	-	-	-	-	-	
	Strength-III	-	-	-	-	-	-	
	Strength-IV	-	-	-	-	-	-	
	Strength- V	-12,910	-11,262	-354	162	-2,523	12,211	
	Extreme Event- I	-16,680	-9,772	-2,065	608	-8,941	52,672	
	Extreme Event- II	-12,228	-8,324	-496	585	-10,527	14,669	
	Service- I	-12,790	-11,513	-386	106	-1,438	12,770	
	Service- II	-	-	-	-	-	-	
	Service-III	-	-	-	-	-	-	
Pile NO.40	Strength- I	-12,379	-12,225	553	-41	1,635	-14,553	
	Strength- II	-	-	-	-	-	-	
	Strength-III	-	-	-	-	-	-	
	Strength-IV	-	-	-	-	-	-	
	Strength- V	-13,478	-11,651	827	-267	6,102	-20,958	
	Extreme Event- I	-14,646	-9,361	1,942	-794	15,860	-47,721	
	Extreme Event- II	-16,096	-12,192	1,821	-57	1,850	-40,914	
	Service- I	-14,646	-11,790	595	-71	2,128	-15,686	
	Service- II	-	-	-	-	-	-	
	Service-III	-	-	-	-	-	-	

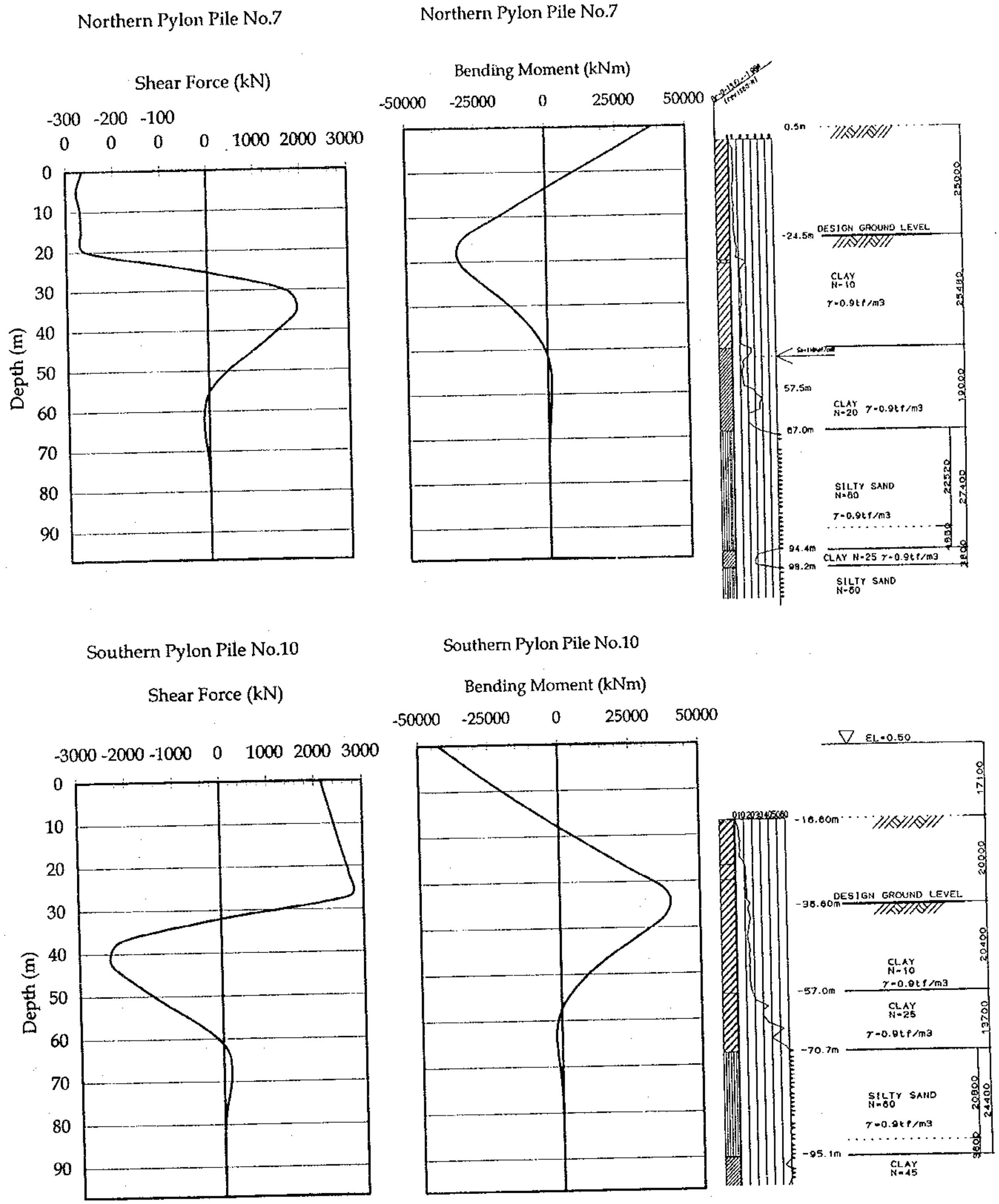
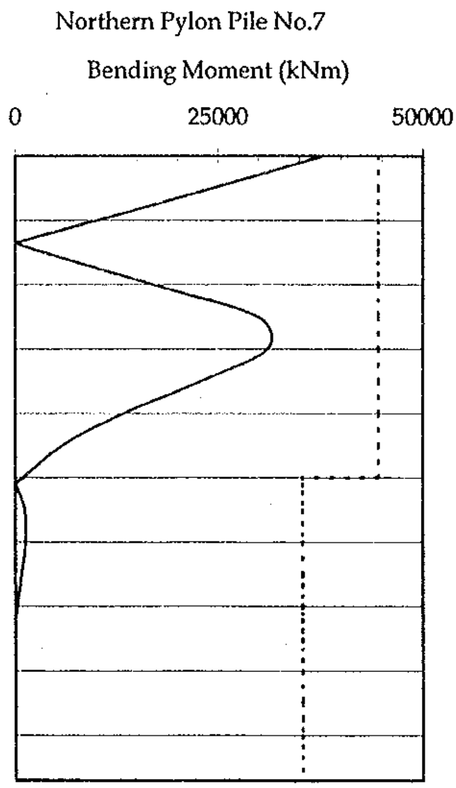
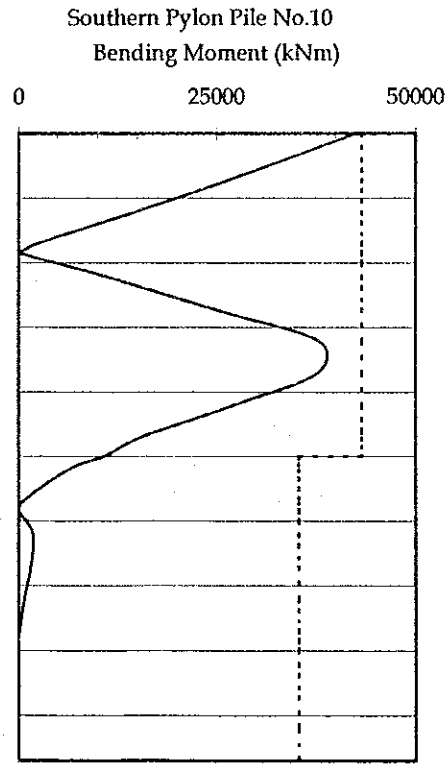


Fig Sectional Force Diagram of Pile

Force and Resistance of Bending Moment, Extreme Event-I
(Load Combination Including Seismic Force)





3.12.9 Calculation of Hibride Pile

Evaluate stiffness of hybrid pile as the member that composed concrete and steel pipe.

Axial force: distribute it by the ratio of the cross-section area of concrete and steel tube.
Bending morment: distribute it by the ratio of concrete and steel tube and geometrical moment of inertia.

section srea : A = Ac + nAs

geometrical moment of inertia.: I = Ic + nIs

n= Es / Ec = $2.0*10^7$ / $2.63*10^6$
= 7.605

Es = $2.00*10^7$ (steel pipe)
Ec= $2.63*10^6$ (RC)

Steel Pipe
ϕ 3200 t=30mm Thickness of the corrosion of the steel pipe in the future=2mm
As = 0.27867249 m^2
Is = 0.34962975 m^4

Reinforced Concrete
Ac = 7.74372984 m^2
Ic = 11.8292116 m^4

Distribution of Axial Force and Bending Moment
Axial Fore
steel pip Ns= 0.215
RC pile Nc= 0.785

Bending Moment
steel pip Ms= 0.184
RC pile Mc= 0.816

Calculation Result of Stress
Sectinal Force :

Pylon	Pile	Axial Force:max (KN)		Axial Force:min (KN)		Shear-Force(KN)		Morment(KNm)	
		Steel Pile	RC-pile	Steel Pile	RC-pile	Steel Pile	RC-pile	Steel Pile	RC-pile
North	No.7	8,817	32,219	1,233	4,219	569	2,079	6,962	30,976
South	No.10	8,867	32,400	974	3,561	461	1,684	7,839	34,879

Stress

Pylon	Pile	Steel Pipe(N/mm2)		RC-Pile(N/mm2)		Allowable sterss (N/mm2)		
		Tension	ompressic	Concrete	Re.-Bar	Steel Pipe	Concrete	Re-Bar
North	No.7	-27.40	63.46	13.74	177.89	182.50	16.00	220.00
South	No.10	-32.33	67.65	15.46	207.16			

3.13 Design of Supplementary Pier

3.13.1 Design Condition

(1) Type of Substructure

	Type of Substructure	Type of Foundation	Bearing Support
P12	Column Type Pier	12 Cast in situ Concrete Pile, dia. 1500mm	- Move
P13	Column Type Pier	12 Cast in situ Concrete Pile, dia. 1500mm	- Move
P14	Column Type Pier	12 Cast in situ Concrete Pile, dia. 1500mm	- Move
T1	A-shaped Tower		
T2	A-shaped Tower		
P15	Column Type Pier	18 Cast in situ Concrete Pile, dia. 2000mm	- Move
P16	Column Type Pier	16 Cast in situ Concrete Pile, dia. 2000mm	- Move
P17	Column Type Pier	16 Cast in situ Concrete Pile, dia. 2000mm	- Move

- Bearing Support Condition:
  - Move: Free for the longitudinal direction movement
  - Fix: Fix for the longitudinal direction movement

(2) Materials

1) Concrete

Grade	fc'	Typical use
B	40 MPa	PC box girder, PC I-Girder
C	35 MPa	Hollow Slab
D	30 MPa	In situ concrete : Bored pile
E	25MPa	In situ concrete : Pier, Abut, Pile cap
F	20 MPa	In situ concrete : Base concrete
G	15 MPa	In situ concrete : Lean Concrete, Plain Concrete

fc': Compressive strength of concrete at 28 days

Grade	fc'	Ec (MPa)	EXP
B	40MPa	33 990	10.8 x 1.0E-6 (/°C)
D	30MPa	29 440	
E	24MPa	26 330	

* Ec: Young's Modulus (AASHTO LRFD, 5.4.2.4), $Ec = 0.043\gamma_c^{1.5} \times \sqrt{fc'}$

γ_c: Density of concrete (kg/m^3)

EXP: Coefficient of thermal expansion and contraction

2) Reinforcement Steel

- Specified Yield Strength:

Plain Round: 240Mpa High Yield deformed: 390MPa

(3) Geological Conditions:

Layer Number & Type of Soil	Layer Notation	N-Value for Design	fsi (kN/m2)
(1) Lean Clay, soft	Rd	N= 0	-
(2) Clay, soft	C1	N= 1	10
(3) Lean Clay or Silty Sand	S/St	N= 20	10
(4) Lean Clay	C2	N= 12	20
(5) Lean Clay, stiff	St/C-1	N= 25	150
(6) Silty Sand, dense	S1	N= 60	200
(7) Lean Clay, hard	St/C-2	N= 20	150
(8) Silty Sand, dense	S3	N= 60	200

* fsi: unit friction force along pile shaft.

Geotechnical Feature for Main Bridge

Substructure		P12	P13	P14	P15	P16	P17
Borehole Number		BRD12	BRD12	BRD12	BRD15	BRD15	BRD15
Existing Ground Level		+1.14	+1.26	+1.14	-13.81	-12.12	-9.55
Pilecap bottom level		-2.62	-2.28	-2.36	+0.50	+0.50	+0.50
Design Ground Level		-2.62	-2.28	-2.36	-23.81	-22.12	-19.55
Layer Condition	No	Approx. Height & Thickness (m)	Approx. Height & Thickness (m)	Approx. Height & Thickness (m)	Approx. Height & Thickness (m)	Approx. Height & Thickness (m)	Approx. Height & Thickness (m)
	(1)				-23.81~-28.50 (4.69m)	-22.12~-28.50 (6.38m)	-19.55~-28.50 (8.95m)
	(2)	-2.62 ~ -34.30 (31.68m)	-2.28 ~ -34.30 (32.02m)	-2.36 ~ -34.30 (31.94m)	-28.50 ~ -31.50 (3.0m)	-28.50 ~ -31.50 (3.0m)	-28.50 ~ -31.50 (3.0m)
	(3)	-34.30 ~ -56.90 (22.60m)	-34.30 ~ -56.90 (22.60m)	-34.30 ~ -56.90 (22.60m)			
	(4)				-31.50 ~ -55.00 (23.5m)	-31.50 ~ -55.00 (23.5m)	-31.50 ~ -55.00 (23.5m)
	(5)	-56.90 ~ -68.90 (12.00m)	-56.90 ~ -68.90 (12.00m)	-56.90 ~ -68.90 (12.00m)	-55.00 ~ -62.00 (7.0m)	-55.00 ~ -62.00 (7.0m)	-55.00 ~ -62.00 (7.0m)
	(6)				-62.00 ~ -97.20 (35.2m)	-62.00 ~ -97.20 (35.2m)	-62.00 ~ -97.20 (35.2m)
	(7)				-97.2 ~ -123.0 (25.8m)	-97.2 ~ -123.0 (25.8m)	-97.2 ~ -123.0 (25.8m)
	(8)				-123.0 ~	-123.0 ~	-123.0 ~

(4) Loading and Load Combinations

1) Vessel Collision CV (AASHTO 3.14)

Design Impact Velocity:

Items	*P15*	*P16*	*P17*
Distance from pier to edge of channel (m)	255	325	395
Design Impact Velocity (m/s)	4.94	3.26	2.42

Tonnage of Design Vessel: 3000MG

Application of Vessel Collision Force

- *Amplitude:* 100% of the design impact force in a direction parallel to the alignment of the centerline of the navigable channel, or 50% of the design impact force in a direction normal to the alignment of the centerline of the channel (applied separately)
- *Location:* The design impact force is applied as a concentrated force on the pier at the mean high water level of the waterway.

2) Water Loads (AASHTO 3.7)

a) Buoyancy: $P_B = 1000*g*V$ (N).

Where: V=Volume of substructure components under water surface (m^3).

g=gravity acceleration (~9.81 m/s^2).

b) Longitudinal Stream Pressure:

$p = 5.14 \times 10^{-4} C_D V^2$ (MPa)

Where: V=design velocity of water (m/s)

C_D= drag coefficient for piersIf type of pier is semicircular-nosed then

C_D =0.7, if square-ended then C_D=1.4

3) Load Combinations

a) Combination of Loads (AASHTO LRFD, 3.4.1)

Load Combination Limit State	DC DD DW EH EV ES	LL IM CE BR PL LS EL	WA	WS	WL	FR	TU CR SH	TG	SE	Use one of these at a time			
										EQ	IC	CT	CV
STRENGTH-I	γ_p	1.75	1.00			1.00	0.50	γ_{tg}	γ_{ce}	–	–	–	–
STRENGTH-II	γ_p	1.35	1.00			1.00	0.50	γ_{tg}	γ_{ce}	–	–	–	–
STRENGTH-III	γ_p	-	1.00	1.40		1.00	0.50	γ_{tg}	γ_{ce}	–	–	–	–
STRENGTH-IV: EH, EV, ES, DW DC ONLY	 γ_p 1.50	-	1.00			1.00	0.50	–	–	–	–	–	–
STRENGTH-V	γ_p	1.35	1.00	0.40	1.00	1.00	0.50	γ_{tg}	γ_{ce}				
EXTREME EVENT-I	γ_p	γ_{eq}	1.00			1.00	-	-	-	1.00	–	–	–
EXTREME EVENT-II	γ_p	0.50	1.00			1.00	-	-	-	–	1.00	1.00	1.00
SERVICE-I	1.00	1.00	1.00	0.30	1.00	1.00	1.00	γ_{tg}	γ_{ce}	–	–	–	–
SERVICE-II	1.00	1.30	1.00			1.00	1.00	γ_{tg}	γ_{ce}	–	–	–	–
SERVICE-III	1.00	0.80	1.00			1.00	1.00	γ_{tg}	γ_{ce}	–	–	–	–
FATIGUE-LL,IM & CE ONLY	-	0.75	1.00			1.00	-	-	-	–	–	–	–

* Loading Denotations:

- Permanent Loads
  - DD = downdrag
  - DC = dead load of structural components and nonstructural attachments
  - DW = dead load of wearing surfaces and utilities
  - EH = horizontal earth pressure load
  - EL = accumulated locked-in effects resulting from the construction process
  - ES = earth surcharge load
  - EV = vertical pressure from dead load of earth fill
- Transient Loads
  - BR = vehicular braking force
  - CE = vehicular centrifugal force
  - CR = creep
  - CT = vehicular collision force
  - CV = vessel collision force
  - EQ = earthquake
  - FR = friction
  - IC = ice load
  - IM = vehicular dynamic load allowance
  - LL = vehicular live load
  - LS = live load surcharge

PL = pedestrian live load
SE = settlement
SH = shrinkage
TG = temperature gradient
TU = uniform temperature
WA = water load and stream pressure
WL = wind on live load
WS = wind load on structure

b) Application of Load Combinations:

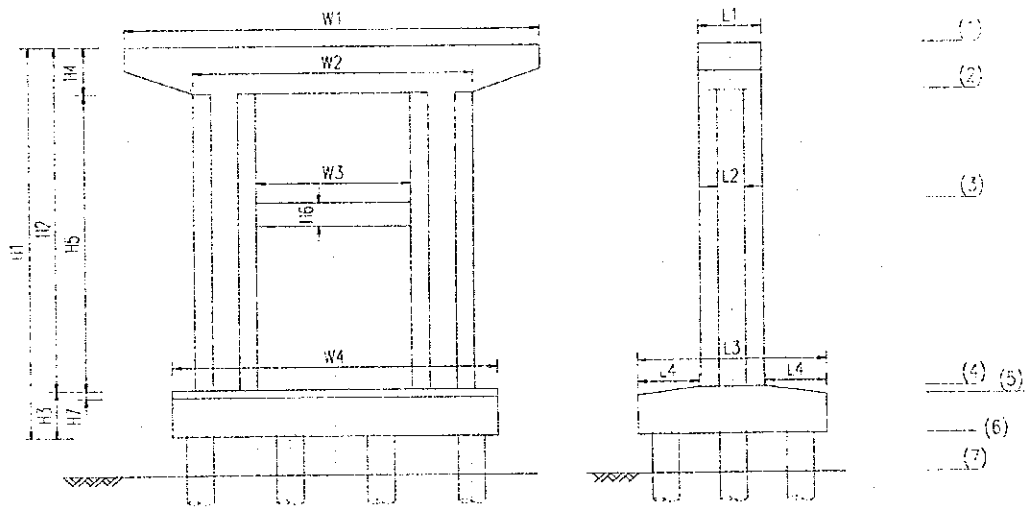
Load Items	Notation	Load Combinations										
		STRENGTH I-1	STRENGTH I-2	STRENGTH III	STRENGTH IV	STRENGTH V-1	STRENGTH V-2	EXTREME EVENT I-1	EXTREME EVENT I-2	EXTREME EVENT II	SERVICE I-1	SERVICE I-2
Deadload from superstructure	DC1	1.25	0.90	1.25	1.50	1.25	0.90	1.25	0.90	1.25	1.00	1.00
Deadload of pier	DC2	1.25	0.90	1.25	1.50	1.25	0.90	1.25	0.90	1.25	1.00	1.00
Superimposed Load of superstructure	DW	1.50	0.65	1.50	1.50	1.50	0.65	1.50	0.65	1.50	1.00	1.00
Live load max	LLmax	1.75				1.35		0.50		0.50	1.00	
Live load min	LLmin		1.75				1.35		0.50			1.00
Dynamic Allowance max	Immax	1.75				1.35		0.50		0.50	1.00	
Dynamic Allowance min	Immin		1.75				1.35		0.50			1.00
Braking max	BRmax	1.75				1.35		0.50		0.50	1.00	
Braking min	BRmin		1.75				1.35		0.50			1.00
Water pressure	WA	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Wind pressure on vehicles	WL					1.00	1.00				1.00	1.00
Wind pressure on Superstructure	WS1			1.40		0.40	0.40				0.30	0.30
Wind pressure on Substructure	WS2			1.40		0.40	0.40				0.30	0.30
Friction load	FR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Temperature uniform	TU	0.50	0.50	0.50	0.50	0.50	0.50				1.00	1.00
Temperature Gradient	TG										0.50	0.50
Creep	CR	0.50	0.50	0.50	0.50	0.50	0.50				1.00	1.00
Shrinkage	SH	0.50	0.50	0.50	0.50	0.50	0.50				1.00	1.00
Earthquake from Superstructure	EQ1							1.00	1.00			
Earthquake of Substructure	EQ2							1.00	1.00			
Vessel Collision	CV									1.00		

3.13.2 Design of P12 pier

(1) Stability Calculation

1) Dimension of Pier

Portion	Length (Figure)	Portion	Length (m)	Portion	Level (Level)	Portion	Level (m)
H1	25.00	W1	23.00	(1)	+22.38	(5)	-0.12
H2	22.00	W2	15.00	(2)	+19.38	(6)	-2.62
H3	3.00	W3	7.00	(3)	+12.38	(7)	+1.14
H4	3.00	L1	4.00	(4)	+0.38		
H5	19.00	W4	18.00				
H6	1.50	L2	2.00				
H7	0.50	L3	10.50				
		L4	3.15				



2) Summary of Load Combination Forces at the Botom of Pile Cap

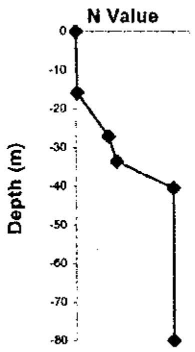
Load Combination		V (tf)	Longitudinal H (tf)	Longitudinal M (tf.m)	Transverse H (tf)	Transverse M (tf.m)
1	STRENGTH I-1	7349.5	104.9	2621.3	11.2	322.5
2	STRENGTH I-2	4149.3	-8.1	-202.7	11.2	322.5
3	STRENGTH III	6229.6	61.4	1221.5	49.9	1039.6
4	STRENGTH IV	7403.0	20.8	520.1	0.0	0.0
5	STRENGTH V-1	7093.5	97.2	2341.5	25.3	618.2
6	STRENGTH V-2	4209.9	10.1	162.9	25.3	618.2
7	EXTREME EVENT I-1	6378.8	1174.2	23376.2	1153.7	23057.1
8	EXTREME EVENT I-2	4167.7	1141.9	22569.3	1153.7	23057.1
9	SERVICE I-1	5652.4	98.3	2391.2	19.5	479.4
10	SERVICE I-2	4861.2	33.8	777.4	19.5	479.4

3) Pile Capacity

INPUT DATA

BoreHole			BRD12
Pile Diameter	D	=	1500 mm
Factor of Safety	FS	=	3
Pile length	L	=	81.00
Pile Embedded Length	Le	=	81.00 m
Pile Cross-Section Circumference	P	=	4.712 m
Pile Cross-Section Area	Ab	=	1.767 m2
Concrete Unit Weight	γc	=	2.5 t/m3
Ultmate Soil End Bearing Capacit	3qu	=	300 t/m2
Soil Type of Bearing Layer			1 (1/2 = Sand/Clay)

SKIN FRICTION CAPACITY Formula: Qs = S (fs * P * d) for N > 0



Layer Number	Thickness d (m)	Soil Type '1'=Sand; '2'=clay		γ'e (t/m3)	N	fs (t/m2)	Qs (t)
1	31.68	2	Clay	0.70	1.0	1.0	149
2	22.60	1	Sand	0.90	20.0	1.0	106
3	13.00	2	Clay	1.00	25.0	15.0	919
4	13.72	1	Sand	1.20	60.0	20.0	1293
Total L =	81	m				Total Qs =	2468

END BEARING CAPACITY Formula: Qt = qu* Ab

Type of Pile		Soil Type of B.P	End Bearing Capacity		
Cast-in-situ	Friction & Bearing	Sand		530 tonne	

ULTIMATE BEARING CAPACITY (Qult)

* Qult = Qt + Qs — 2998 tonne

REPLACED EFFECTIVE WEIGHT OF SOIL (Ws)

127 tonne

BUOYANT WEIGHT OF PILE (W)

215 tonne

Allowable Bearing Capacity for Service Load Combinations ($Qall_1$)

* $Qall_1$ = (Qult - Ws) / FS + Ws - W — 869 tonne

Allowable Bearing Capacity for Earthquake & Strength Load Combinations($Qall_2$)

* $Qall_2$ = (Qult - Ws) / FS + Ws - W — 1348 tonne

FS= 2

Design Uplift Capacity for Service Load Combinations (Qup_1)

* Qup_1 = Qs / FS + W — 626 tonne

FS = 6

Design Uplift Capacity for Earthquake & Strength Load Combinations(Qup_2)

* Qup_2 = Qs / FS + W — 1037 tonne

FS= 3

4) Reaction of Pile

a) Displacement

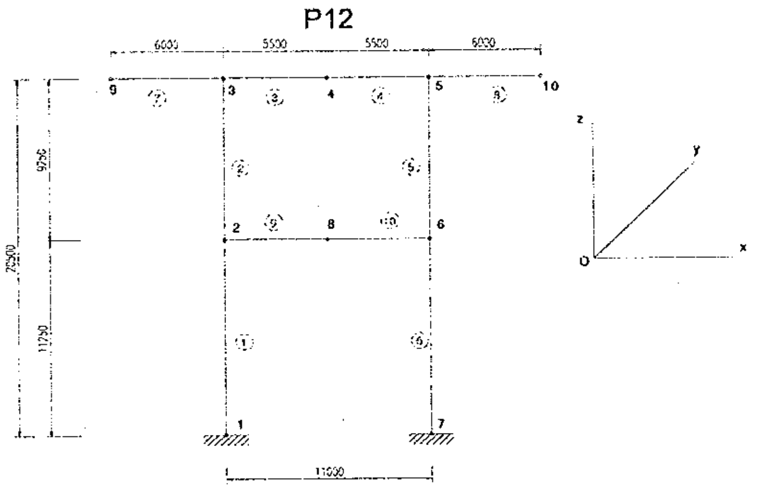
Load Combination		Longitudinal			Transverse			d xa(cm)	Remark
		d x(cm)	d y(cm)	a (rad)	d x(cm)	d y(cm)	a (rad)		
1	STRENGTH I-1	0.20	0.74	0.000284	0.01	0.74	0.000011	3.00	OK
2	STRENGTH I-2	-0.02	0.42	-0.000022	0.01	0.42	0.000011	3.00	OK
3	STRENGTH III	0.11	0.62	0.000136	0.06	0.62	0.000037	3.00	OK
4	STRENGTH IV	0.04	0.74	0.000056	0.00	0.74	0.000000	3.00	OK
5	STRENGTH V-1	0.18	0.71	0.000254	0.03	0.71	0.000022	3.00	OK
6	STRENGTH V-2	0.02	0.42	0.000019	0.03	0.42	0.000022	3.00	OK
7	EXTREME EVENT I-1	2.01	0.64	0.002603	1.40	0.64	0.000832	2.00	OK
8	EXTREME EVENT I-2	1.95	0.42	0.002516	1.40	0.42	0.000832	2.00	OK
9	SERVICE I-1	0.27	0.57	0.000270	0.04	0.57	0.000017	1.50	OK
10	SERVICE I-2	0.09	0.49	0.000089	0.04	0.49	0.000017	1.50	OK

b) Bearing and Uplift forces of piles:

Load Combination		Longitudinal		Transverse		Allowable Capacities		Checking	
		PNmax(tf)	PNmin(tf)	PNmax(tf)	PNmin(tf)	Bearing (tf)	Uplift (tf)	Bearing	Uplift
1	STRENGTH I-1	700.81	524.11	619.40	605.52	1382.0	-1064.0	OK	OK
2	STRENGTH I-2	352.61	338.94	352.72	338.83	1382.0	-1064.0	OK	OK
3	STRENGTH III	561.54	476.73	542.40	495.87	1382.0	-1064.0	OK	OK
4	STRENGTH IV	634.45	599.39	616.92	616.92	1382.0	-1064.0	OK	OK
5	STRENGTH V-1	670.39	511.86	604.68	577.57	1382.0	-1064.0	OK	OK
6	STRENGTH V-2	356.67	344.98	364.38	337.27	1382.0	-1064.0	OK	OK
7	EXTREME EVENT I-1	1343.04	-279.91	1050.50	12.63	1382.0	-1064.0	OK	OK
8	EXTREME EVENT I-2	1131.58	-436.97	866.24	-171.63	1382.0	-1064.0	OK	OK
9	SERVICE I-1	555.16	386.91	481.83	460.23	892.0	-640.0	OK	OK
10	SERVICE I-2	432.67	377.53	415.90	394.30	892.0	-640.0	OK	OK

(2) Design of Pier Sections

1) Calculation model



2) Loads from superstructure at pier top

Load	V (tf)	Longitudinal H (tf)	Longitudinal M (tf.m)	Transverse H (tf)	Transverse M (tf.m)	Remarks
DC1	1334.5	0.0	0.0	0.0	0.0	
DW1	203.1	0.0	0.0	0.0	0.0	
LLmax	567.4	14.0	0.0	0.0	0.0	
LLmin	-143.8	-16.5	0.0	0.0	0.0	
IMmax	72.6	0.0	0.0	0.0	0.0	
IMmin	-7.6	0.0	0.0	0.0	0.0	
BRmax	0.0	34.1	0.0	6.4	23.7	
BRmin	0.0	0.0	0.0	6.4	23.7	
TUmax	33.5	41.6	0.0	0.0	0.0	
TUmin	-7.9	-46.5	0.0	0.0	0.0	
CR	82.2	0.0	0.0	0.0	0.0	
WL	0.0	0.0	0.0	2.3	13.8	
WS1	0.0	0.0	0.0	18.6	39.9	
EQ1-L	-112.9	747.0	0.0	224.1	181.5	
EQ1-T	-112.9	224.1	0.0	747.0	181.5	

Loads acting on pier:

- Dead Load DC2: 2.5t/m3
- Wind Pressure on Structure WS2: 0.194t/m2
- Earthquake in longitudinal direction (EQ2-L):
  - +12% of self-weight in longitudinal direction.
  - +3.6% of self-weight in transverse direction.
- Earthquake in transverse direction (EQ2-T):
  - +12% of self-weight in transverse direction.
  - +3.6% of self-weight in longitudinal direction.

3) Envelope of Member End Actions

MEMBER	JOINT	TYPE	Nx (tf)	Sy (tf)	Sz (tf)	Mx (tf.m)	My (tf.m)	Mz (tf.m)
1	1	MAX	-721.77	160.044	493.54	4.2467	4774.41	2996.45
		CASE	12A	12B	12A	13	10B	12B
		MIN	-3351.65	-510.411	-510.06	-3.2966	-4679.06	-9513.83
		CASE	10B	11	10B	10B	12A	11
1	2	MAX	2859.46	463.161	462.81	3.2966	698	4037.49
		CASE	10B	11	10B	10B	10B	11
		MIN	367.4	-145.869	-446.29	-4.2467	-607.46	-1275.69
		CASE	12A	12B	12A	13	12A	12B
2	2	MAX	-569.65	144.459	499.07	1.97	679.98	1276.49
		CASE	12A	12B	10A	4A	10B	12B
		MIN	-2592.14	-458.411	-412.01	-4.5627	-571.33	-4040.28
		CASE	10B	11	12B	11	12A	11
2	3	MAX	2253.08	425.861	379.46	4.5627	2417.43	613.73
		CASE	10B	11	12B	11	12B	11
		MIN	325.53	-134.694	-466.52	-1.97	-3200.74	-194.78
		CASE	12A	12B	10A	4A	10A	12B
3	3	MAX	198.53	155.349	190.27	25.0649	5059.26	193.26
		CASE	10A	11	12A	11	10B	11
		MIN	-113.61	-48.853	-1364.12	-7.2606	-2450.63	-58.53
		CASE	12B	12B	10B	12B	12A	12B
3	4	MAX	71.54	36.013	890.97	7.2606	1120.09	513.82
		CASE	12B	12B	10B	12B	1	11
		MIN	-155.04	-111.729	-496.36	-25.0649	419.59	-166.92
		CASE	10A	11	12A	11	2	12B
4	4	MAX	167.96	37.558	807.6	25.0649	-421.1	166.92
		CASE	10B	12B	10A	11	12B	12B
		MIN	-85.16	-117.062	-542.69	-7.2606	-1124.69	-513.82
		CASE	12A	11	12B	12B	1	11
4	5	MAX	128.65	160.682	236.6	7.2606	2707.67	67.03
		CASE	12A	11	12B	12B	12B	12B
		MIN	-210.03	-50.398	-1280.76	-25.0649	-4589.81	-222.59
		CASE	10B	12B	10A	11	10A	11
5	5	MAX	2036.26	419.284	464.75	83.1285	3036.93	653.99
		CASE	10A	11	10B	11	10B	11
		MIN	200.4	-132.788	-384.8	-26.0706	-2543.34	-206.45
		CASE	12B	12B	12A	12B	12A	12B
5	6	MAX	-444.53	142.553	417.35	26.0706	690.99	1273.39
		CASE	12B	12B	12A	12B	10B	12B
		MIN	-2375.33	-451.834	-497.3	-83.1285	-564.94	-4029.57
		CASE	10A	11	10B	11	12A	11
6	6	MAX	2636.38	453.834	442.73	76.2933	537.66	4032.37
		CASE	10A	11	12B	11	12B	11
		MIN	239.35	-143.168	-466.35	-23.7967	-812.32	-1274.2
		CASE	12B	12B	10A	12B	10A	12B
6	7	MAX	-593.72	157.343	513.61	23.7967	4724.68	2964.57
		CASE	12B	12B	10A	12B	10B	12B
		MIN	-3128.57	-501.084	-489.98	-76.2933	-4715.77	-9403.78
		CASE	10A	11	12B	11	12A	11

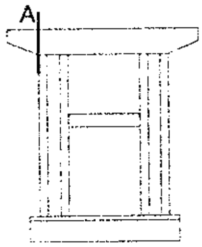
(Continued)

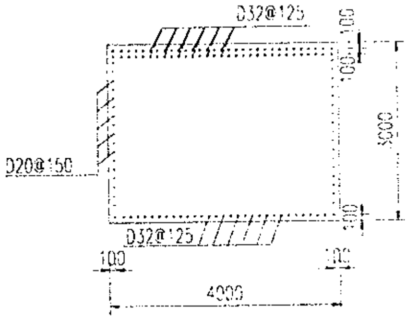
MEMBER	JOINT	TYPE	Nx (tf)	Sy (tf)	Sz (tf)	Mx (tf.m)	My (tf.m)	Mz (tf.m)
7	3	MAX	53.44	53.632	-370.65	0	-1291.77	57.86
		CASE	10A	11	12A	12B	12A	12B
		MIN	-51.31	-15.721	-668.12	0	-2463.52	-197.82
		CASE	10B	12B	5	11	5	11
7	9	MAX	0	0	0	0	0	0
		CASE	4B	11	12A	12B	10B	12B
		MIN	0	0	0	0	0	0
		CASE	10A	12B	10B	13	12A	11
8	5	MAX	41.6	41.722	-291.85	0	1737.76	139.46
		CASE	10A	11	12A	13	5	11
		MIN	-40.18	-12.271	-520.01	0	932.42	-40.96
		CASE	10B	12B	5	12B	12B	12B
8	10	MAX	0	0	0	0	0	0
		CASE	4B	11	12B	11	12B	10B
		MIN	0	0	0	0	0	0
		CASE	10B	12B	10A	10B	10A	11
9	2	MAX	-38.98	4.75	202.26	2.7911	910.16	1.2
		CASE	12A	11	12A	11	10B	3
		MIN	-67.62	-1.411	-267.32	-0.8085	-824.84	-0.38
		CASE	5	12B	10B	12B	12A	4A
9	8	MAX	67.62	0.399	232.17	0.8085	31.38	11.51
		CASE	5	12B	10B	12B	5	11
		MIN	41.67	-1.375	-227.57	-2.7911	18.93	-3.76
		CASE	8B	11	12A	11	12A	12B
10	6	MAX	67.62	2.049	205.18	0.8085	835.88	10.34
		CASE	5	13	12B	12B	12B	11
		MIN	40.77	-0.663	-261.06	-2.7911	-886.72	-3.35
		CASE	12B	10B	10A	11	10A	12B
10	8	MAX	-41.67	1.375	227.57	2.7911	-18.93	3.76
		CASE	8B	11	12A	11	12A	12B
		MIN	-67.62	-0.399	-232.17	-0.8085	-31.38	-11.51
		CASE	5	12B	10B	12B	5	11

(3) Design of Section

1) Flexural Resistance and Bar Arrangement

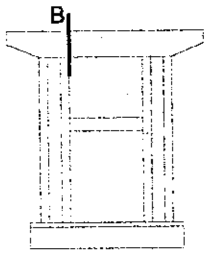
a) Section A

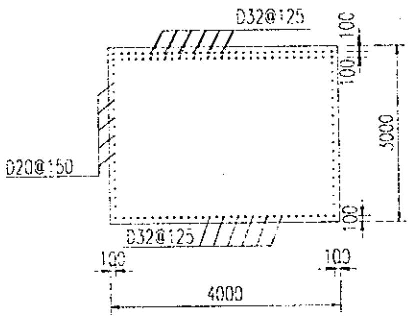




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	2463.5	-1291.8	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			5	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number of tensile bars	n	(nos.)	64	32	
Resistance					
Flexural Resistance	Mr	(tf.m)	5344.44	3035.95	
Axial Compressive Resistance	Nr	(tf.m)	-	-	
Compressive Depth	c	(mm)	220.84	163.83	
Resistance Factor	φ		0.90	0.90	
Checking Resistance			**OK**	**OK**	
Checking Reinforcement Ratio			OK	OK	

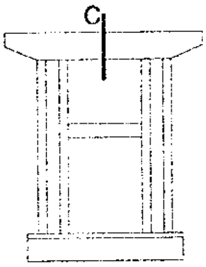
b) Section B

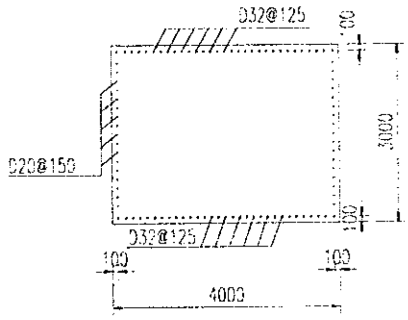




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	5059.3	2450.6	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number of tensile bars	n	(nos.)	64	32	
Resistance					
Flexural Resistance	Mr	(tf.m)	5344.44	3035.95	
Axial Compressive Resistance	Nr	(tf.m)	-	-	
Compressive Depth	c	(mm)	220.84	163.83	
Resistance Factor	φ		0.90	0.90	
Checking Resistance			**OK**	**OK**	
Checking Reinforcement Ratio			OK	OK	

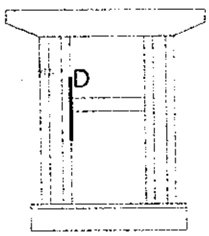
c) Section C

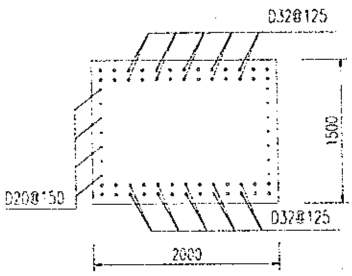




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	-421.1	1124.7	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			12B	1	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number of tensile bars	n	(nos.)	64	32	
Total Area of tensile reinforcement	Ast	(mm2)	51472	25736	
Bar spacing	@	(mm)	125.0	125	
Concrete Cover	cv	(mm)	100	100	
Resistance					
Flexural Resistance	Mr	(tf.m)	3010.64	3010.64	
Axial Compressive Resistance	Nr	(tf.m)	-	-	
Compressive Depth	c	(mm)	139.35	139.35	
Resistance Factor	φ		0.90	0.90	
Checking Resistance			**OK**	**OK**	
Checking Reinforcement Ratio			OK	OK	

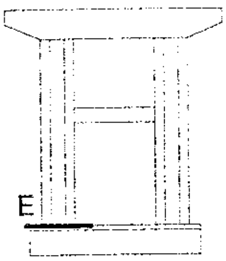
d) Section D

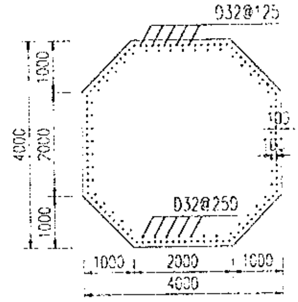




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	910.2	824.8	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	2	
Number of tensile bars	n	(nos.)	26	26	
Resistance					
Flexural Resistance	Mr	(tf.m)	1071.2	1071.2	
Axial Compressive Resistance	Nr	(tf.m)	-	-	
Compressive Depth	c	(mm)	199.84	199.84	
Resistance Factor	φ		0.90	0.90	
Checking Resistance			OK	OK	
Checking Reinforcement Ratio			OK	OK	

e) Section E

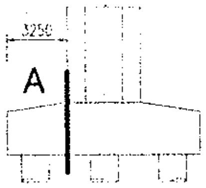


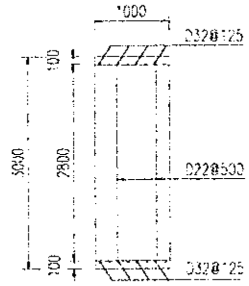


Item	Notation	Unit	Tensile Side			Remark
			Left	Right	Front	
Factored Loads						
Maximum Moment	M	(tf.m)	4774.4	4679.1	9513.8	
Factored Axial Force	N	(tf)	3,351.7	721.8	2,229.4	
Load case of Max. Moment			10B	12A	11	
Bar Arrangement						
Dia. of main reinforcement	Dm	(mm)		32		
Number of reinf. layers	nlay	(nos.)		2		
Number of bars	n	(nos.)				
In layer 1				106		
In layer 2				48		
Resistance						
Flexural Resistance	Mr	(tf.m)	14061.02	9402.67	9865.51	
Axial Compressive Resistance	Nr	(tf.m)	9871.04	1450.40	2311.74	
Compressive Depth	c	(mm)	2112.67	790.24	939.18	
Resistance Factor	φ		0.753	0.868	0.802	
Checking Resistance			OK	OK	OK	
Checking Reinforcement Ratio			OK	OK	OK	

(4) Design of Pile Cap

1) Section Analysis of Section A





Total width of section 18000 mm
Calculation width 1000 mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3000	
Material Properties				
Concrete strength	fc	MPa	24	
Yield Strength of Rebars	fy	MPa	390	
Elastic modulus of Concrete	Ec	MPa	26332	
Elastic modulus of Steel	Es	MPa	200000	
Allowable Comp. Stress of Concrete	fca	MPa	10.8	
Allowable Stress of Steel	fsa	MPa	-234	

b) Envelope of Sectional Forces

Item	Notation	Unit	Value	Load Case
Maximum Flexural Moment				
for Calculating Top Reinforcement	Mu_{top}	kN.mm	-2181007	EXTREME EVENT I-2
for Calculating Bottom Reinforcement	$Mu_{bot.}$	kN.mm	4471426	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	2527	EXTREME EVENT I-1
Coincidental moment	$Mu_{coin.}$	kN.mm	4471426	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	32	
Area of 1 bar	A1s	mm2	804.2	
Numbers of Rebar	ns	nos	8	
Bottom Reinforcement				
Diameter	ϕbot.	mm	32	
Area of 1 bar	A1's	mm2	804.2	
Numbers of Rebar	n's	nos	8	
Total Area of Bottom Reinf.	A's	mm2	6434.0	
Concrete Cover	C's	mm	100.0	
Shear Reinforcement				
Diameter	ϕv.	mm	22	
Area of 1 bar	A1v	mm2	380.1	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	760.3	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	2181007	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{top}	kN.mm	6415080	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.214	
$\rho min=0.03fc/fy$		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	4471426	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{bot}	kN.mm	6415080	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.214	
$\rho min=0.03fc/fy$		%	0.185	OK

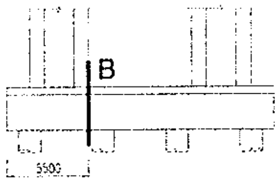
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

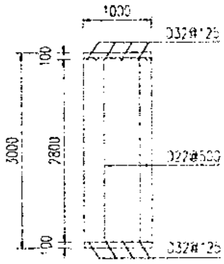
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	2526507	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2160	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		1.7	
Area of shear reinf. within a distance s	A_v	mm^2	760	
Strain in the tensile reinforcement	ε_x		0.002000	
Inclination angle of diagonal comp. stres	θ	degrees	42.83	
Shear stress on the concrete	v	MPa	1.300	
Area of Conc. on flexural tensile side	Act	mm^2	1500000	
Nominal Resistance of Concrete	V_c	N	1493091	
Nominal Resistance of Reinforcement	V_s	N	1381789	
Nominal Resistance	Vn	N	2,874,880	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,587,392	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			1563813	Tensile at bottom
SERVICE I-2			1096676	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.95	
SERVICE I-2			0.67	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-6.75	
SERVICE I-2			-4.73	
Checking Stress of Steel			OK	

2) Section Analysis of Section B





Total width of section	10500	mm
Calculation width	1000	mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3000	
Material Properties				
Concrete strength	fc	MPa	24	
Yield Strength of Rebars	fy	MPa	390	
Elastic modulus of Concrete	Ec	MPa	26332	
Elastic modulus of Steel	Es	MPa	200000	
Allowable Comp. Stress of Concrete	fca	MPa	10.8	
Allowable Stress of Steel	fsa	MPa	-234	

b) Envelope of Sectional Forces

Item	Notation	Unit	Value	Load Case
Maximum Flexural Moment				
for Calculating Top Reinforcemen	Mutop	kN.mm	-1255602	EXTREME EVENT I-2
for Calculating Bottom Reinforcen	Mubot.	kN.mm	1638279	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	1960	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	1638279	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	32	
Area of 1 bar	A1s	mm2	804.2	
Numbers of Rebar	ns	nos	8	
Total Area of Top Reinf.	As	mm2	6434.0	
Concrete Cover	Cs	mm	100.0	
Bottom Reinforcement				
Diameter	ϕbot.	mm	32	
Area of 1 bar	A1's	mm2	804.2	
Numbers of Rebar	n's	nos	8	
Total Area of Bottom Reinf.	A's	mm2	6434.0	
Concrete Cover	C's	mm	100.0	
Shear Reinforcement				
Diameter	ϕv.	mm	22	
Area of 1 bar	A1v	mm2	380.1	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	760.3	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1255602	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{top}	kN.mm	6415080	
Checking Resistance			**OK**	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	**0.214**	
$\rho min = 0.03fc/fy$		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	1638279	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{bot}	kN.mm	6415080	
Checking Resistance			**OK**	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	**0.214**	
$\rho min = 0.03fc/fy$		%	**0.185**	OK

Notes: Reinforcement selection is controlled by the Minimum Reinforcement Ratio Requirement.

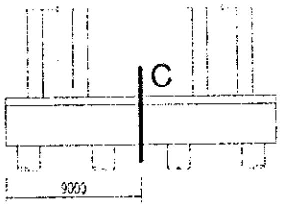
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

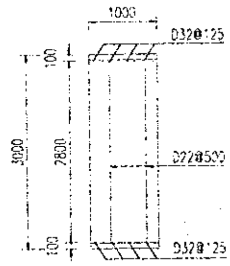
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	1960430	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2160	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		2.0	
Area of shear reinf. within a distance s	A_v	mm^2	760	
Strain in the tensile reinforcement	ε_x		0.001474	
Inclination angle of diagonal comp. stres	θ	degrees	40.74	
Shear stress on the concrete	v	MPa	1.008	
Area of Conc. on flexural tensile side	Act	mm^2	1500000	
Nominal Resistance of Concrete	V_c	N	1730129	
Nominal Resistance of Reinforcement	V_s	N	1487163	
Nominal Resistance	Vn	N	3,217,292	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,895,563	
Checking			**OK**	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			204823	Tensile at bottom
SERVICE I-2			204823	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.12	
SERVICE I-2			0.12	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-0.88	
SERVICE I-2			-0.88	
Checking Stress of Steel			OK	

3) Section Analysis of Section C





Total width of section 10500 mm
Calculation width 1000 mm

i) Section Dimensions & Material Properties:

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3000	
Material Properties				
Concrete strength	fc	MPa	24	
Yield Strength of Rebars	fy	MPa	390	
Elastic modulus of Concrete	Ec	MPa	26332	
Elastic modulus of Steel	Es	MPa	200000	
Allowable Comp. Stress of Concrete	fca	MPa	10.8	
Allowable Stress of Steel	fsa	MPa	-234	

ii) Envelope of Sectional Forces:

Item	Notation	Unit	Value	Load Case
Maximum Flexural Moment				
for Calculating Top Reinforcemen	Mutop	kN.mm	-1001230	STRENGTH I-1
for Calculating Bottom Reinforcen	Mubot.	kN.mm	-485690	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	-264	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	-1001230	

iii) Bar Arrangement:

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	32	
Area of 1 bar	A1s	mm2	804.2	
Numbers of Rebar	ns	nos	8	
Total Area of Top Reinf.	As	mm2	6434.0	
Concrete Cover	Cs	mm	100.0	
Bottom Reinforcement				
Diameter	ϕbot.	mm	32	The same to section B
Area of 1 bar	A1's	mm2	804.2	
Numbers of Rebar	n's	nos	8	
Total Area of Bottom Reinf.	A's	mm2	6434.0	
Concrete Cover	C's	mm	100.0	
Shear Reinforcement				
Diameter	ϕv.	mm	22	
Area of 1 bar	A1v	mm2	380.1	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	760.3	

iv) Checking for Flexural Resistance (AASHTO 5.7.3.2):

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1001230	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{top}	kN.mm	6415080	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.214	
$\rho min = 0.03fc/fy$		%	0.185	OK

Notes: Reinforcement selection is controlled by the Minimum Reinforcement Ratio Requirement.

V) Checking for Shear Resistance (AASHTO 5.8.3.3):

The shear force at this section is relatively small, so the calculation will be omitted

vi) Checking for Flexural Stress:

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			-770446	Tensile at top
SERVICE I-2			-585717	Tensile at top
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.47	
SERVICE I-2			0.36	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-3.32	
SERVICE I-2			-2.53	
Checking Stress of Steel			OK	

(5) Section Calculation of Pile
Dia : 1500 mm
Length : 81.0 m
Number : 12 nos.

1) Sectional Forces (Extracted from the Results of Pile Group Analysis)

Load Case	Longitudinal			Transverse		
	Sectional Force		Depth	Sectional Force		Depth
	Mmax (tf.m)	Nmin (tf)	Z(m)	Mmax (tf.m)	Nmin (tf)	Z(m)
STRENGTH I-1	17.15	524.11	5.502	0.94	605.52	8.226
STRENGTH I-2	1.33	338.94	5.50	0.94	338.83	8.23
STRENGTH III	8.40	476.73	6.15	3.79	495.87	8.77
STRENGTH IV	3.40	599.39	5.50	0.00	616.92	0.00
STRENGTH V-1	15.42	511.86	5.61	2.01	577.57	8.54
STRENGTH V-2	1.02	344.98	6.69	2.01	337.27	8.54
EXTREME EVENT I-1	160.74	-279.91	6.15	86.73	12.63	8.83
EXTREME EVENT I-2	155.51	-436.97	6.16	86.73	-171.63	8.83
SERVICE I-1	14.34	386.91	7.81	1.69	460.23	10.75
SERVICE I-2	4.78	377.53	7.98	1.69	394.30	10.75

2) Section Calculation

a) General Conditions

Item	Notation	Unit	Value	Remark
Number of Reinf. layers	n_{layer}	nos	1	
Concrete cover	cv	m	150	
Diameter of Rebars	d	mm	32	
Number of Rebars	n_{st}	nos	30	
Total Area of Reinforcement	A_{st}	mm2	24127	

b) Checking Resistance (AASHTO 5.7.2)

Load Case		Type of force	Unit	Longitudinal		Transverse		Remark
				Actual	Allowable	Actual	Allowable	
STRENGTH I-1		PNmin	tf	524.11	3914.9	605.52	4154.7	OK
at Z=	5.50m	M	tf.m	17.15	128.1	0.94	6.3	OK
STRENGTH I-2		PNmin	tf	338.94	4135.6	338.83	4145.1	OK
at Z=	5.50m	M	tf.m	1.33	16.1	0.94	11.3	OK
STRENGTH III		PNmin	tf	476.73	4007.2	495.87	4103.2	OK
at Z=	6.15m	M	tf.m	8.40	70.5	3.79	31.2	OK
STRENGTH IV		PNmin	tf	599.39	4120.1	616.92	4166.0	OK
at Z=	5.50m	M	tf.m	3.40	23.4	0.00	0.0	OK
STRENGTH V-1		PNmin	tf	511.86	3930.6	577.57	4138.6	OK
at Z=	5.61m	M	tf.m	15.42	118.4	2.01	14.6	OK
STRENGTH V-2		PNmin	tf	344.98	4143.3	337.27	4118.0	OK
at Z=	6.69m	M	tf.m	1.02	12.2	2.01	24.4	OK
EXTREME EVENT I-1		PNmin	tf	-279.91	-371.6	12.63	62.7	OK
at Z=	6.15m	M	tf.m	160.74	213.4	86.73	430.3	OK
EXTREME EVENT I-2		PNmin	tf	-436.97	-459.2	-171.63	-395.4	OK
at Z=	6.16m	M	tf.m	155.51	163.4	86.73	199.8	OK

c) Checking Stress

Load Case		Force		Tensile Steel (tf/m2)		Comp. Concrete (tf/m2)		Remark
		PN (tf)	M(tf.m)	Actual	Allowable	Actual	Allowable	
SERVICE I-1	Horizontal	386.91	14.34	1164.94	23861	242.23	1377	OK
at Z=7.81m	Transverse	460.23	1.69	1,614.65	23861	246.02	1377	
SERVICE I-2	Horizontal	377.53	4.78	1273.95	23861	211.11	1377	OK
at Z=7.98m	Transverse	394.30	1.69	1,379.74	23861	211.44	1377	

d) Checking Minimum Steel Ratio

Item	Notation	Unit	Value	Remark
Total Area of Reinforcement	A_{st}	mm2	24127	
Gross Area of Section	Ag	mm2	1767145.9	
Reinforcement Ratio	ρst	%	1.37	
Minimum Reinforcement ratio	ρmin	%	0.40	OK

(6) Calculation of Footing Concrete stress that pile connected

1)Vertical bearing stress of footing concrete

$\sigma_{cv}=P/(\pi D^2/4) <= \sigma_{ca}$

Maximum Reaction force of pile	P=	1343040 kg	Load Combination: 7
Diameter of Pile	D=	150 cm	
Vertical bearing stress	σ_{cv}	76.00 kg/cm^2	
Allowable bearing stress	$\sigma_{ca}=0.5xf_c$ =	150.00 kg/cm^2	

σ_{cv} <= σ_{ca} --> OK

2) Vertical Punching Shear Stress

$\tau_c=P/\{\pi h(D+h)\} <= \tau_a$

Maximum Reaction force of pile	P=	1343040 kg	Load Combination: 7
Diameter of Pile	D=	150 cm	
Depth from pile head to upper surface of pile cap	h=	290 cm	
Punching shear stress	τ_c=	3.35 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

τ_c <= τ_a --> OK

3) Horizontal Bearing stress

$\sigma_{ch}=H/(Dl) <= \sigma_{ca}$

Max. Horizontal force at pile head	H=	97850 kg	Load Combination: 7
Diameter of Pile	D=	150 cm	
Embedded Length of Pile	l=	10 cm	
Horizontal bearing stress	σ_{ch}	65.23 kg/cm^2	
Allowable bearing stress	$\sigma_{ca}=0.3xf_c$ =	90.00 kg/cm^2	

σ_{ch} <= σ_{ca} --> OK

4)Horizontal Punching Shear Stress:

$\tau_c=H/\{h' \times (2l+D+2h')\} <= \tau_a$

Max. Horizontal force at pile head	H=	97850 kg	Load Combination: 7
Diameter of Pile	D=	150 cm	
Distance from side of pile to the nearest edge of pile cap	h'=	75 cm	
Embedded Length of Pile	l=	10 cm	
Punching shear stress	τ_c=	4.08 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

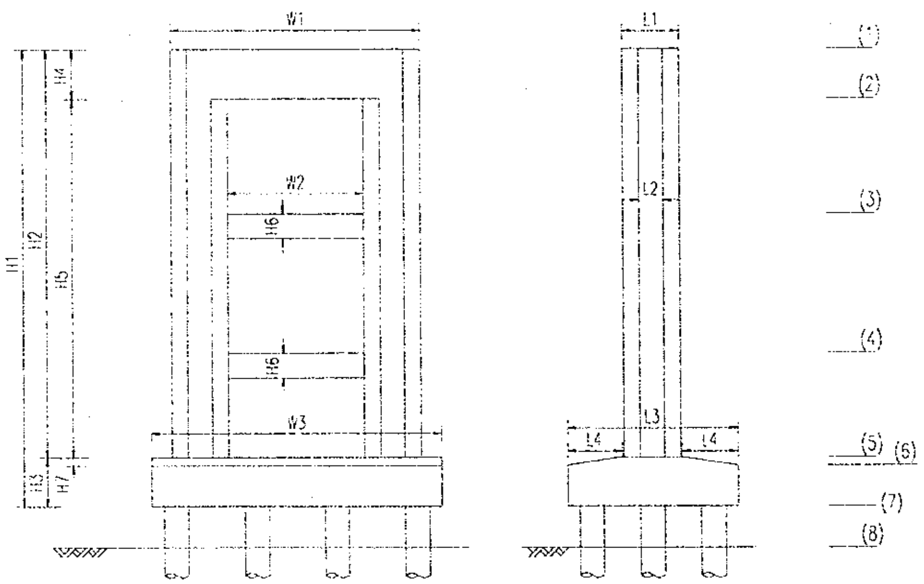
τ_c <= τ_a --> OK

3.13.3 Design of P13 pier

(1) Stability Calculation

1)Dimension of Pier

Portion	Length	Portion	Length	Portion	Level	Portion	Level
(Figure)		(m)		(Level)		(m)	
H1	27.60	W1	15.00	(1)	+25.32	(6)	+0.22
H2	24.60	W2	7.00	(2)	+22.32	(7)	-2.28
H3	3.00	L1	4.00	(3)	+15.32	(8)	+1.26
H4	3.00	W3	18.00	(4)	+6.82		
H5	21.60	L2	2.00	(5)	+0.72		
H6	1.50	L3	10.50				
H7	0.50	L4	3.15				



2) Summary of Load Combination forces at the Bottom of Pile Cap

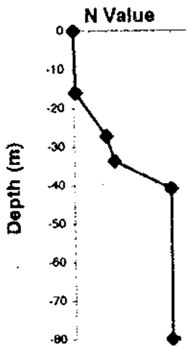
Load Combination		V (tf)	Longitudinal H (tf)	Longitudinal M (tf.m)	Transverse H (tf)	Transverse M (tf.m)
1	STRENGTH I-1	8269.3	42.6	1177.1	0.0	0.0
2	STRENGTH I-2	4429.1	-10.9	-300.4	0.0	0.0
3	STRENGTH III	7108.6	59.5	1216.1	26.7	408.4
4	STRENGTH IV	8528.5	18.2	502.4	0.0	0.0
5	STRENGTH V-1	8004.0	48.9	1226.8	7.6	116.7
6	STRENGTH V-2	4587.2	7.6	87.0	7.6	116.7
7	EXTREME EVENT I-1	7167.5	1060.4	22263.4	1053.4	22070.6
8	EXTREME EVENT I-2	4650.4	1045.1	21841.2	1053.4	22070.6
9	SERVICE I-1	6361.1	59.2	1543.3	5.7	87.5
10	SERVICE I-2	5302.7	28.6	698.9	5.7	87.5

3) Piel Capacity

INPUT DATA

BoreHole			BRD12
Pile Diameter	D	=	1500 mm
Factor of Safety	FS	=	3
Pile length	L	=	82.00
Pile Embedded Length	Le	=	82.00 m
Pile Cross-Section Circumference	P	=	4.712 m
Pile Cross-Section Area	Ab	=	1.767 m2
Concrete Unit Weight	γc	=	2.5 t/m3
Ultmate Soil End Bearing Capacit	3qu	=	300 t/m2
Soil Type of Bearing Layer			1 (1/2 = Sand/Clay)

SKIN FRICTION CAPACITY Formula: Qs = S (fs * P * d) for N > 0



Layer Number	Thickness d (m)	Soil Type '1'=Sand; '2'=clay		γ'e (t/m3)	N	fs (t/m2)	Qs (t)
1	32.02	2	Clay	0.70	1.0	1.0	151
2	22.60	1	Sand	0.90	20.0	1.0	106
3	13.00	2	Clay	1.00	25.0	15.0	919
4	14.38	1	Sand	1.20	60.0	20.0	1355
Total L =	82	m				Total Qs =	2532

END BEARING CAPACITY Formula: Qt = qu* Ab

Type of Pile		Soil Type of B.P	End Bearing Capacity		
Cast-in-situ	Friction & Bearing	Sand		530 tonne	

ULTIMATE BEARING CAPACITY (Qult)

* Qult = Qt + Qs 3062 tonne

REPLACED EFFECTIVE WEIGHT OF SOIL (Ws)

129 tonne

BUOYANT WEIGHT OF PILE (W)

217 tonne

Allowable Bearing Capacity for Service Load Combinations ($Qall_1$)

* $Qall_1$ = (Qult - Ws) / FS + Ws - W 889 tonne

Allowable Bearing Capacity for Earthquake & Strength Load Combinations($Qall_2$)

* $Qall_2$ = (Qult - Ws) / FS + Ws - W 1378 tonne

FS= 2

Design Uplift Capacity for Service Load Combinations (Qup_1)

* Qup_1 = Qs / FS + W 639 tonne

FS = 6

Design Uplift Capacity for Earthquake & Strength Load Combinations(Qup_2)

* Qup_2 = Qs / FS + W 1061 tonne

FS= 3

4) Reaction of Piel

a) Displacement

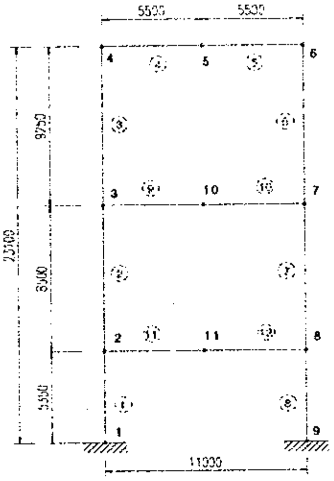
Load Combination		Longitudinal			Transverse			δ xa(cm)	Remark
		δ x(cm)	δ y(cm)	α (rad)	δ x(cm)	δ y(cm)	α (rad)		
1	STRENGTH I-1	0.08	0.83	0.000126	0.00	0.83	0.000000	3.00	OK
2	STRENGTH I-2	-0.02	0.44	-0.000032	0.00	0.44	0.000000	3.00	OK
3	STRENGTH III	0.10	0.71	0.000135	0.03	0.71	0.000015	3.00	OK
4	STRENGTH IV	0.04	0.85	0.000054	0.00	0.85	0.000000	3.00	OK
5	STRENGTH V-1	0.09	0.80	0.000133	0.01	0.80	0.000004	3.00	OK
6	STRENGTH V-2	0.01	0.46	0.000011	0.01	0.46	0.000004	3.00	OK
7	EXTREME EVENT I-	1.85	0.72	0.002458	1.29	0.72	0.000791	2.00	OK
8	EXTREME EVENT I-	1.82	0.47	0.002413	1.29	0.47	0.000791	2.00	OK
9	SERVICE I-1	0.17	0.64	0.000172	0.01	0.64	0.000003	1.50	OK
10	SERVICE I-2	0.08	0.53	0.000079	0.01	0.53	0.000003	1.50	OK

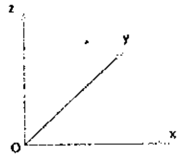
b) Bearing and Uplift forces of piles

Load Combination		Longitudinal		Transverse		Allowable Capacities		Checking	
		PNmax(tf)	PNmin(tf)	PNmax(tf)	PNmin(tf)	Bearing (tf)	Uplift (tf)	Bearing	Uplift
1	STRENGTH I-1	728.34	649.87	689.11	689.11	1378.0	-1061.0	OK	OK
2	STRENGTH I-2	379.11	359.08	369.09	369.09	1378.0	-1061.0	OK	OK
3	STRENGTH III	634.45	550.32	601.98	582.79	1378.0	-1061.0	OK	OK
4	STRENGTH IV	727.46	693.96	710.71	710.71	1378.0	-1061.0	OK	OK
5	STRENGTH V-1	708.34	625.66	669.74	664.26	1378.0	-1061.0	OK	OK
6	STRENGTH V-2	385.61	378.93	385.01	379.53	1378.0	-1061.0	OK	OK
7	EXTREME EVENT I-	1364.52	-169.94	1090.80	103.78	1378.0	-1061.0	OK	OK
8	EXTREME EVENT I-	1140.69	-365.62	881.04	-105.98	1378.0	-1061.0	OK	OK
9	SERVICE I-1	583.89	476.30	532.23	527.96	889.0	-639.0	OK	OK
10	SERVICE I-2	466.47	417.32	444.03	439.76	889.0	-639.0	OK	OK

(2) Design of Pier Sections

1) Calculation model





2) Loads from superstructure at pier top

Load	V	Longitudinal		Transverse		Remarks
	(tf)	H (tf)	M (tf.m)	H (tf)	M (tf.m)	
DC1	2265.9	0.0	0.0	0.0	0.0	
DW1	0.0	0.0	0.0	0.0	0.0	
LLmax	663.2	14.0	0.0	0.0	0.0	
LLmin	-395.2	-16.6	0.0	0.0	0.0	
TUmax	18.4	36.4	0.0	0.0	0.0	
TUmin	-56.2	-40.5	0.0	0.0	0.0	
EQ1-L	-263.6	643.8	0.0	193.1	0.0	
EQ1-T	-263.6	193.1	0.0	643.8	0.0	

Loads acting on pier
- Dead Load DC2: 2.5t/m3
- Wind Pressure on Structure WS2: 0.194t/m2
- Earthquake in longitudinal direction (EQ2-L):
  +12% of self-weight in longitudinal direction.
  +3.6% of self-weight in transverse direction.
- Earthquake in transverse direction (EQ2-T):
  +12% of self-weight in transverse direction.
  +3.6% of self-weight in longitudinal direction.