3) Envelope of Member End Actions

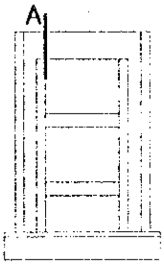
MEMBER	JOINT	TYPE	Nx (tf)	Sy (tf)	Sz (tf)	Mx (tf.m)	My (tf.m)	Mz (tf.m)
1	1	MAX	-721.57	442.245	439.66	55.9713	3745.79	9014.96
		CASE	12A	11	12B	11	10A	11
		MIN	-3874.36	-135.741	-437.34	-17.1713	-3741.95	-2775.35
		CASE	10B	12B	10A	12B	12B	12B
1	2	MAX	3640.3	129	414.87	17.1713	1453.02	2067.17
		CASE	10B	12B	10A	12B	10B	12B
		MIN	553.04	-419.775	-417.19	-55.9713	-1469.25	-6709.05
		CASE	12A	11	12B	11	12A	11
2	2	MAX	-706.69	416.625	411.42	52.6953	2369.74	6709.05
		CASE	12A	11	12B	11	12A	11
		MIN	-3430.21	-128.055	-415.34	-16.2339	-2531.68	-2067.17
		CASE	10B	12B	10A	12B	10B	12B
2	3	MAX	3058.34	117.345	379.64	16.2339	1041.1	1024.22
		CASE	10B	12B	10A	12B	10A	12B
		MIN	438.94	-380.925	-375.72	-52.6953	-845.84	-3319.47
		CASE	12A	11	12B	11	12B	11
3	3	MAX	-659.6	377.775	576.66	59.4399	278.09	3319.47
		CASE	12A	11	10B	11	12A	11
		MIN	-2781.24	-116.4	-269.76	-18.3837	-667.08	-1024.22
		CASE	10B	12B	12A	12B	10B	12B
3	4	MAX	2442.18	106.635	237.21	18.3837	1686.4	159.96
		CASE	10B	12B	12A	12B	12A	12B
		MIN	415.48	-345.225	-544.11	-59.4399	-3675.9	-517.84
		CASE	12A	11	10B	11	10B	11
4	4	MAX	22.61	128.275	110.55	0	4492.07	59.44
		CASE	12A	11	12A	10B	10B	11
		MIN	-329.51	-39.505	-1299.6	0	-2042.21	-18.39
		CASE	10B	12B	10B	11	12A	12B
4	5	MAX	309.71	33.565	1093.35	0	2397.11	591.63
		CASE	10B	12B	10B	11	1	11
		MIN	-2.81	-108.475	-259.05	0	907.11	-182.56
		CASE	12A	11	12A	10B	2	12B
5	5	MAX	-21.64	33.565	1005.45	0	-907.11	182.56
		CASE	12B	12B	10A	10B	2	12B
		MIN	-285.27	-108.475	-171.15	0	-2397.11	-591.63
		CASE	10A	11	12B	11	1	11
5	6	MAX	305.07	128.275	22.65	0	1842	18.39
		CASE	10A	11	12B	11	12B	12B
		MIN	1.84	-39.505	-1211.7	0	-4291.86	-59.44
		CASE	12B	12B	10A	10B	10A	11
6	6	MAX	2207.4	106.635	519.67	59.4399	3512.36	159.96
		CASE	1	12B	10A	11	10A	12B
		MIN	679.18	-345.225	-212.77	-18.3837	-1522.85	-517.84
		CASE	12B	11	12B	12B	12B	11
6	7	MAX	-923.3	377.775	245.32	18.3837	641.21	3319.47
		CASE	12B	11	12B	12B	10A	11
		MIN	-2546.47	-116.4	-552.22	-59.4399	-252.21	-1024.22
		CASE	1	12B	10A	11	12B	12B

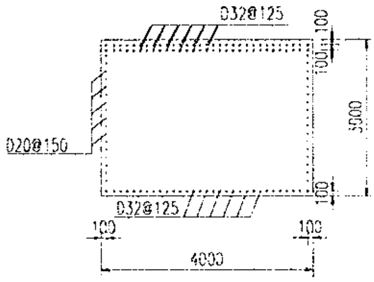
(Continued)

7	7	MAX	2794.64	117.345	377.89	52.6953	870.32	1024.22
		CASE	10A	12B	12A	11	12A	12B
		MIN	702.64	-380.925	-381.81	-16.2339	-1065.58	-3319.47
		CASE	12B	11	10B	12B	10B	11
7	8	MAX	-970.39	416.625	417.51	16.2339	2525.63	6709.05
		CASE	12B	11	10B	12B	10A	11
		MIN	-3166.51	-128.055	-413.59	-52.6953	-2363.69	-2067.17
		CASE	10A	12B	12A	11	12B	12B
8	8	MAX	3376.6	129	419	55.9713	1463.26	2067.17
		CASE	10A	12B	12A	11	12B	12B
		MIN	816.74	-419.775	-416.68	-17.1713	-1447.04	-6709.05
		CASE	12B	11	10B	12B	10A	11
8	9	MAX	-985.27	442.245	439.15	17.1713	3745.64	9014.96
		CASE	12B	11	10B	12B	12A	11
		MIN	-3610.66	-135.741	-441.47	-55.9713	-3749.47	-2775.35
		CASE	10A	12B	12A	11	10B	12B
9	3	MAX	235.81	3.15	220.66	0	903.39	4.04
		CASE	1	11	12A	13	10B	12B
		MIN	92.86	-0.945	-277.1	0	-822.52	-13.05
		CASE	2	10B	10B	12B	12A	11
9	10	MAX	-92.86	0	244.29	0	12.72	18.56
		CASE	2	11	10B	12B	5	11
		MIN	-235.81	0	-244.29	0	7.47	-5.7
		CASE	1	13	10A	13	12B	12B
10	7	MAX	-92.86	3.15	220.66	0	821.13	13.05
		CASE	2	11	12B	10B	12B	11
		MIN	-235.81	-0.945	-277.1	0	-901.99	-4.04
		CASE	1	10B	10A	11	10A	12B
10	10	MAX	235.81	0	244.29	0	-7.47	5.7
		CASE	1	11	10A	11	12B	12B
		MIN	92.86	0	-244.29	0	-12.72	-18.56
		CASE	2	13	10B	10B	5	11
11	2	MAX	0.9	3.15	153.65	0	658.49	0.96
		CASE	12A	11	12A	11	10B	12B
		MIN	-7.13	-0.945	-210.09	0	-593.19	-3.03
		CASE	10B	10B	10B	10B	12A	11
11	11	MAX	6.17	0	177.28	0	23.37	8.54
		CASE	4A	11	10B	10B	5	11
		MIN	2.11	0	-177.28	0	14.01	-2.61
		CASE	2	10A	10A	11	12B	12B
12	8	MAX	6.77	3.15	153.65	0	593.13	3.03
		CASE	10A	11	12B	10B	12B	11
		MIN	-0.54	-0.945	-210.09	0	-658.42	-0.96
		CASE	12B	10B	10A	11	10A	12B
12	11	MAX	-2.11	0	177.28	0	-14.01	2.61
		CASE	2	13	10A	11	12B	12B
		MIN	-6.17	0	-177.28	0	-23.37	-8.54
		CASE	4A	11	10B	10B	5	11

4) Design of Sections

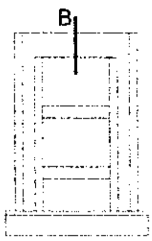
a) Section A

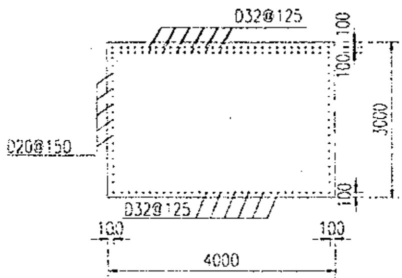




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	4492.1	2042.2	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number 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	

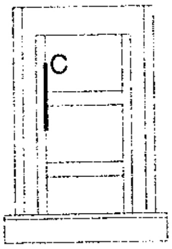
b) Section B

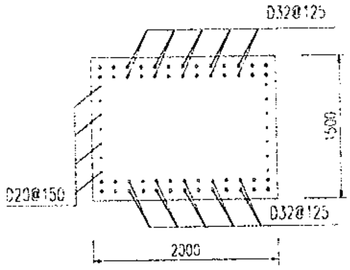




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	-907.1	2397.1	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			2	1	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number of tensile bars	n	(nos.)	64	32	
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	

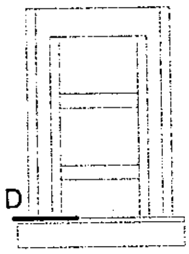
c) Section C

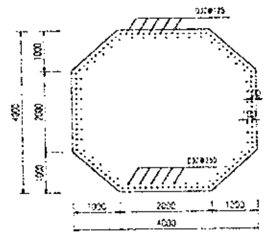




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	903.4	822.5	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	2	
Number 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**	

d) Section D

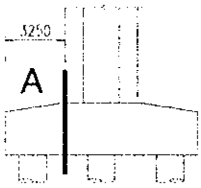


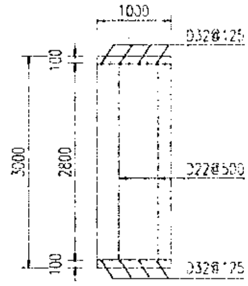


Item	Notation	Unit	Tensile Side			Remark
			Left	Right	Front	
Factored Loads						
Maximum Moment	M	(tf.m)	3745.8	3742.0	9015.0	
Factored Axial Force	N	(tf)	1,723.4	2,872.5	2,384.0	
Load case of Max. Moment			10A	12B	11	
Bar Arrangement						
Dia. of main reinforcement	Dm	(mm)		32		
Number of reinf. layers	nlay	(nos.)		2		
Number of bars	n	(nos.)				
In layer 1				106		
In layer 2				48		
Resistance						
Flexural Resistance	Mr	(tf.m)	13705.35	14457.63	10252.25	
Axial Compressive Resistance	Mr	(tf.m)	6305.62	11098.00	2711.18	
Compressive Depth	c	(mm)	1488.14	2251.28	1002.11	
Resistance Factor	φ		0.825	0.774	0.796	
Checking Resistance			**OK**	**OK**	**OK**	
Checking Reinforcement Ratio			**OK**	**OK**	**OK**	

(3) Design of Pile Cap

1) Section Analysis of "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	-1908902	EXTREME EVENT I-2
for Calculating Bottom Reinforcement	$Mu_{bot.}$	kN.mm	4553343	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	2573	EXTREME EVENT I-1
Coincidental moment	$Mu_{coin.}$	kN.mm	4553343	

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	

e) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1908902	
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	4553343	
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

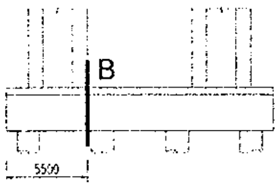
f) Checking for Shear Resistance (AASHTO 5.8.3.3)

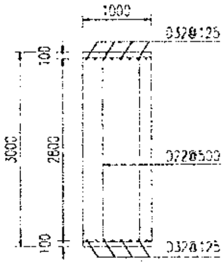
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	2573317	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2160	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit 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. stress	θ	degrees	42.79	
Shear stress on the concrete	v	MPa	1.324	
Area of Conc. on flexural tensile side	Act	mm^2	1500000	
	Fe		1	
Nominal Resistance of Concrete	V_c	N	1493091	
Nominal Resistance of Reinforcement	V_s	N	1383725	
Nominal Resistance	Vn	N	2,876,817	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,589,135	
Checking			**OK**	

g) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			1673380	Tensile at bottom
SERVICE I-2			1225578	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			1.02	
SERVICE I-2			0.75	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-7.22	
SERVICE I-2			-5.29	
Checking Stress of Steel			OK	

2) Section Analysis of "B"





Total width of section [illegible] 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	-1186523	EXTREME EVENT I-2
for Calculating Bottom Reinforcem	Mubot.	kN.mm	1569200	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	2108	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	1569200	

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	1186523	
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	1569200	
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.

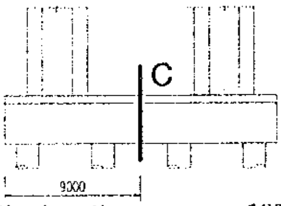
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

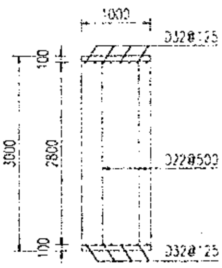
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	2107886	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2160	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		1.9	
Area of shear reinf. within a distance s	A_v	mm^2	760	
Strain in the tensile reinforcement	ε_x		0.001506	
Inclination angle of diagonal comp. stress	θ	degrees	41.02	
Shear stress on the concrete	v	MPa	1.084	
Area of Conc. on flexural tensile side	Act	mm^2	1500000	
Nominal Resistance of Concrete	V_c	N	1668749	
Nominal Resistance of Reinforcement	V_s	N	1472463	
Nominal Resistance	Vn	N	3,141,212	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,827,091	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			181280	Tensile at bottom
SERVICE I-2			181280	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.11	
SERVICE I-2			0.11	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-0.78	
SERVICE I-2			-0.78	
Checking Stress of Steel			OK	

3) Section Analysis of "C"





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	-1215995	STRENGTH I-1
for Calculating Bottom Reinforcen	Mubot.	kN.mm	-551016	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	-251	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	-1215995	

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	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	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1215995	
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	-551016	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{bot}	kN.mm	8609150	
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)

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

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			-935939	Tensile at top
SERVICE I-2			-688813	Tensile at top
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.57	
SERVICE I-2			0.42	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-4.04	
SERVICE I-2			-2.97	
Checking Stress of Steel			OK	

(4) Section Calculation of Pile
Dia : 1500 mm
Length : 82.0 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	7.59	649.87	5.209	0.00	689.11	0
STRENGTH I-2	1.94	359.08	5.22	0.00	369.09	0.00
STRENGTH III	8.30	550.32	6.08	1.90	582.79	9.41
STRENGTH IV	3.24	693.96	5.21	0.00	710.71	0.00
STRENGTH V-1	8.02	625.66	5.49	0.54	664.26	9.13
STRENGTH V-2	0.76	378.93	7.47	0.54	379.53	9.13
EXTREME EVENT I-1	150.81	-169.94	6.00	80.12	103.78	8.77
EXTREME EVENT I-2	148.12	-365.62	6.01	80.12	-105.98	8.77
SERVICE I-1	9.08	476.30	7.59	0.46	527.96	11.25
SERVICE I-2	4.20	417.32	7.80	0.46	439.76	11.25

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	28	
Total Area of Reinforcement	A_{st}	mm2	22519	

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	649.87	3855.1	689.11	3891.7	OK
at Z= 5.21m	M	tf.m	7.59	44.9	0.00	0.0	OK
STRENGTH I-2	PNmin	tf	359.08	4349.1	369.09	4379.3	OK
at Z= 5.22m	M	tf.m	1.94	23.3	0.00	0.0	OK
STRENGTH III	PNmin	tf	550.32	3969.6	582.79	4029.0	OK
at Z= 6.08m	M	tf.m	8.30	59.8	1.90	13.2	OK
STRENGTH IV	PNmin	tf	693.96	3850.0	710.71	3858.8	OK
at Z= 5.21m	M	tf.m	3.24	17.9	0.00	0.0	OK
STRENGTH V-1	PNmin	tf	625.66	3879.9	664.26	3924.2	OK
at Z= 5.49m	M	tf.m	8.02	49.9	0.54	3.1	OK
STRENGTH V-2	PNmin	tf	378.93	4348.8	379.53	4352.0	OK
at Z= 7.47m	M	tf.m	0.76	8.6	0.54	6.4	OK
EXTREME EVENT I-1	PNmin	tf	-169.94	-327.0	103.78	1012.0	OK
at Z= 6.00m	M	tf.m	150.81	290.1	80.12	781.3	OK
EXTREME EVENT I-2	PNmin	tf	**-365.62**	**-489.9**	-105.98	-359.6	**OK**
at Z= 6.01m	M	tf.m	**148.12**	**198.5**	80.12	271.9	**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	476.30	9.08	1569.31	23861	276.08	1377	OK
at Z=7.59m	Transverse	527.96	0.46	1,431.28	23861	231.54	1377	
SERVICE I-2	Horizontal	417.32	4.20	1883.50	23861	279.54	1377	OK
at Z=7.80m	Transverse	439.76	0.46	1,567.69	23861	233.05	1377	

d) Checking Minimum Steel Ratio

Item	Notation	Unit	Value	Remark
Total Area of Reinforcement	A_{st}	mm2	22519	
Gross Area of Section	Ag	mm2	1767145.9	
Reinforcement Ratio	ρst	%	1.27	
Minimum Reinforcement ratio	ρmin	%	0.40	OK

(5) Calculation of Footing Concret Stress that Pile connected

1) Vertical bearing stress of footing concrete

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

Reaction force of pile	P=	1364520 kg	Load Combination: 7
Diameter of Pile	D=	150 cm	
Vertical bearing stress	σ_{cv}	77.22 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

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

Reaction force of pile	P=	1364520 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=	3.40 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

τ_c <= τ_a --> OK

3) Horizontal Bearing stress

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

Horizontal force at pile head	H=	88370 kg	Load Combination: 7
Diameter of Pile	D=	150 cm	
Embedded Length of Pile	l=	10 cm	
Horizontal bearing stress	σ_{ch}	58.91 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

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

Horizontal force at pile head	H=	88370 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=	3.68 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

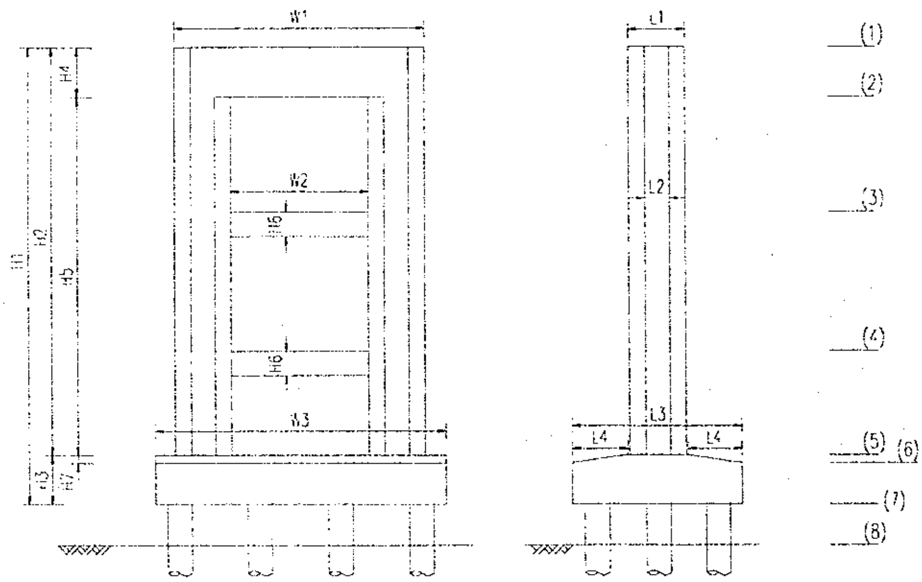
τ_c <= τ_a --> OK

3.13.4 Design of P14 pier

(1) Stability Calculation

1) Dimension of Pier

(Figure)		(m)		(Level)		(m)	
Portion	Length	Portion	Length	Portion	Level	Portion	Level
H1	30.48	W1	15.00	(1)	+28.12	(6)	+0.14
H2	27.48	W2	7.00	(2)	+25.12	(7)	-2.36
H3	3.00	L1	4.00	(3)	+18.12	(8)	+1.14
H4	3.00	W3	18.00	(4)	+9.62		
H5	24.48	L2	2.00	(5)	+0.64		
H6	1.50	L3	10.50				
H7	0.50	L4	3.15				



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

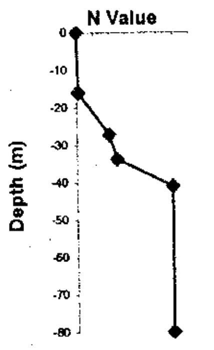
Load Combination		V	Longitudinal		Transverse	
		(tf)	H (tf)	M (tf.m)	H (tf)	M (tf.m)
1	STRENGTH I-1	5964.7	48.4	1328.8	0.0	0.0
2	STRENGTH I-2	1624.8	-24.0	-660.5	0.0	0.0
3	STRENGTH III	4349.1	60.1	1142.0	29.8	409.7
4	STRENGTH IV	5213.7	15.6	428.7	0.0	0.0
5	STRENGTH V-1	5595.4	53.6	1326.9	8.5	117.0
6	STRENGTH V-2	1970.8	-2.3	-207.7	8.5	117.0
7	EXTREME EVENT I-1	4052.4	1086.9	23072.3	1077.6	22815.1
8	EXTREME EVENT I-2	1947.8	1066.3	22503.9	1077.6	22815.1
9	SERVICE I-1	4433.5	59.4	1524.6	6.4	87.8
10	SERVICE I-2	2645.3	18.1	387.9	6.4	87.8

3) Pile 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	31.94	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	14.46	1	Sand	1.20	60.0	20.0	1363
Total L =	82	m				Total Qs =	2539

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 — 3069 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 — 892 tonne

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

* $Qall_2$ = (Qult - Ws) / FS + Ws - W — 1382 tonne

FS= 2

Design Uplift Capacity for Service Load Combinations (Qup_1)

* Qup_1 = Qs / FS + W — 640 tonne

FS = 6

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

* Qup_2 = Qs / FS + W — 1064 tonne

FS= 3

4) Reaction of Pile

a) Displacement

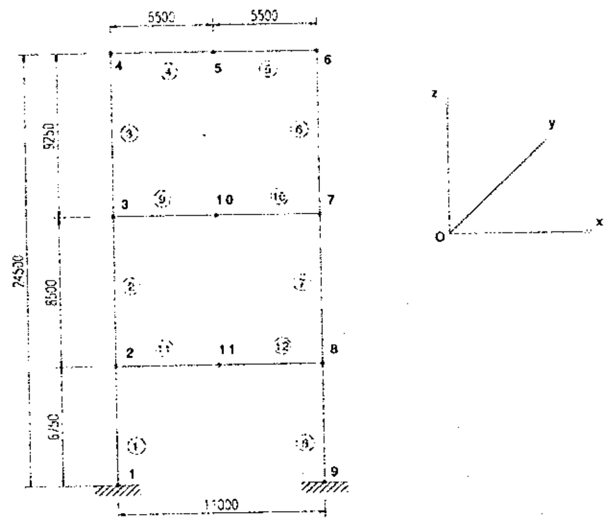
Load Combination		Longitudinal			Transverse			δ xa(cm)	Remark
		δ x(cm)	δ y(cm)	α (rad)	δ x(cm)	δ y(cm)	α (rad)		
1	STRENGTH I-1	0.08	0.80	0.000130	0.00	0.84	0.000000	3.00	OK
2	STRENGTH I-2	-0.03	0.37	-0.000046	0.00	0.33	0.000000	3.00	OK
3	STRENGTH III	0.11	0.67	0.000145	0.04	0.67	0.000019	3.00	OK
4	STRENGTH IV	0.03	0.81	0.000050	0.00	0.81	0.000000	3.00	OK
5	STRENGTH V-1	0.09	0.77	0.000139	0.01	0.80	0.000005	3.00	OK
6	STRENGTH V-2	0.01	0.40	0.000003	0.01	0.37	0.000005	3.00	OK
7	EXTREME EVENT I-	1.96	0.63	0.002723	1.33	0.64	0.000816	2.00	OK
8	EXTREME EVENT I-	1.62	0.38	0.001720	1.33	0.37	0.000816	2.00	OK
9	SERVICE I-1	0.16	0.61	0.000172	0.01	0.63	0.000004	1.50	OK
10	SERVICE I-2	0.07	0.48	0.000069	0.01	0.46	0.000004	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	702.19	621.28	695.14	695.14	1382.0	-1064.0	OK	OK
2	STRENGTH I-2	323.61	295.04	278.02	278.02	1382.0	-1064.0	OK	OK
3	STRENGTH III	605.79	515.23	572.05	548.97	1382.0	-1064.0	OK	OK
4	STRENGTH IV	687.87	656.49	672.18	672.18	1382.0	-1064.0	OK	OK
5	STRENGTH V-1	681.85	595.35	667.66	661.07	1382.0	-1064.0	OK	OK
6	STRENGTH V-2	332.02	329.98	310.16	303.56	1382.0	-1064.0	OK	OK
7	EXTREME EVENT I-	1376.13	-323.65	1045.21	26.35	1382.0	-1064.0	OK	OK
8	EXTREME EVENT I-	850.54	-222.77	814.36	-204.50	1382.0	-1064.0	OK	OK
9	SERVICE I-1	562.66	455.02	530.50	525.37	892.0	-640.0	OK	OK
10	SERVICE I-2	418.20	375.40	381.48	376.35	892.0	-640.0	OK	OK

(3) Design of Pier Sections

1) Calculation of 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	1744.9	0.0	0.0	0.0	0.0	
DW1	0.0	0.0	0.0	0.0	0.0	
LLmax	694.1	14.1	0.0	0.0	0.0	
LLmin	-650.4	-17.0	0.0	0.0	0.0	
TUmax	51.8	31.2	0.0	0.0	0.0	
TUmin	-50.0	-34.4	0.0	0.0	0.0	
EQ1-L	-732.4	643.8	0.0	193.1	0.0	
EQ1-T	-732.4	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.

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	-895.07	448.125	445.96	51.9746	3977.72	9638.22
		CASE	12A	11	12B	11	10A	11
		MIN	-3922.23	-137.685	-444.13	-15.9658	-3976.47	-2971.03
		CASE	10B	12B	10A	12B	12B	12B
1	2	MAX	3626.91	129.18	415.78	15.9658	1064.57	2070.36
		CASE	10B	12B	10A	12B	10B	12B
		MIN	682.44	-419.775	-417.61	-51.9746	-1078.18	-6709.05
		CASE	12A	11	12B	11	12A	11
2	2	MAX	-873.38	416.625	411.95	49.8482	2183.7	6709.05
		CASE	12A	11	12B	11	12A	11
		MIN	-3379.54	-128.235	-416.81	-15.3843	-2348.29	-2070.36
		CASE	10B	12B	10A	12B	10B	12B
2	3	MAX	3007.66	117.525	381.11	15.3843	1239.16	1025.88
		CASE	10B	12B	10A	12B	10A	12B
		MIN	605.63	-380.925	-376.25	-49.8482	-1033.23	-3319.47
		CASE	12A	11	12B	11	12B	11
3	3	MAX	-621.66	377.775	568.9	57.2009	160.58	3319.47
		CASE	2	11	10B	11	12A	11
		MIN	-2715.38	-116.58	-251.25	-17.7282	-560.87	-1025.88
		CASE	10B	12B	12A	12B	10B	12B
3	4	MAX	2376.31	106.815	218.7	17.7282	1660.46	160.23
		CASE	10B	12B	12A	12B	12A	12B
		MIN	377.54	-345.225	-536.35	-57.2009	-3721.93	-517.84
		CASE	2	11	10B	11	10B	11
4	4	MAX	4.1	128.275	61.79	0	4526.45	57.2
		CASE	12A	11	12A	11	10B	11
		MIN	-321.75	-39.565	-1289.51	0	-1988.51	-17.73
		CASE	10B	12B	10B	12B	12A	12B
4	5	MAX	301.95	33.625	1083.26	0	2085.36	593.87
		CASE	10B	12B	10B	12B	1	11
		MIN	15.71	-108.475	-210.29	0	424.29	-183.55
		CASE	12A	11	12A	11	2	12B
5	5	MAX	-15.71	33.625	1083.26	0	-424.29	183.55
		CASE	12B	12B	10A	11	2	12B
		MIN	-301.95	-108.475	-210.29	0	-2085.36	-593.87
		CASE	10A	11	12B	12B	1	11
5	6	MAX	321.75	128.275	61.79	0	1988.51	17.73
		CASE	10A	11	12B	12B	12B	12B
		MIN	-4.1	-39.565	-1289.51	0	-4526.45	-57.2
		CASE	12B	12B	10A	11	10A	11
6	6	MAX	2376.31	106.815	536.35	57.2009	3721.93	160.23
		CASE	10A	12B	10A	11	10A	12B
		MIN	377.54	-345.225	-218.7	-17.7282	-1660.46	-517.84
		CASE	2	11	12B	12B	12B	11
6	7	MAX	-621.66	377.775	251.25	17.7282	560.87	3319.47
		CASE	2	11	12B	12B	10A	11
		MIN	-2715.38	-116.58	-568.9	-57.2009	-160.58	-1025.88
		CASE	10A	12B	10A	11	12B	12B

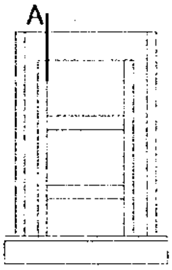
(Continued)

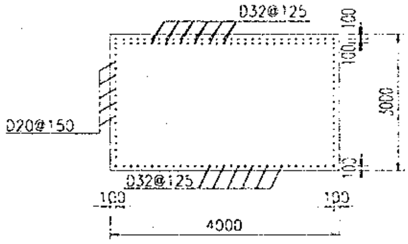
7	7	MAX	3007.66	117.525	376.25	49.8482	1033.23	1025.88
		CASE	10A	12B	12A	11	12A	12B
		MIN	605.63	-380.925	-381.11	-15.3843	-1239.16	-3319.47
		CASE	12B	11	10B	12B	10B	11
7	8	MAX	-873.38	416.625	416.81	15.3843	2348.29	6709.05
		CASE	12B	11	10B	12B	10A	11
		MIN	-3379.54	-128.235	-411.95	-49.8482	-2183.7	-2070.36
		CASE	10A	12B	12A	11	12B	12B
8	8	MAX	3626.91	129.18	417.61	51.9746	1078.18	2070.36
		CASE	10A	12B	12A	11	12B	12B
		MIN	682.44	-419.775	-415.78	-15.9658	-1064.57	-6709.05
		CASE	12B	11	10B	12B	10A	11
8	9	MAX	-895.07	448.125	444.13	15.9658	3976.47	9638.22
		CASE	12B	11	10B	12B	12A	11
		MIN	-3922.23	-137.685	-445.96	-51.9746	-3977.72	-2971.03
		CASE	10A	12B	12A	11	10B	12B
9	3	MAX	206.49	3.15	235.85	0	956.11	4.24
		CASE	1	11	12A	13	10B	12B
		MIN	47.56	-0.945	-292.29	0	-874.63	-13.66
		CASE	2	10B	10B	12B	12A	11
9	10	MAX	-47.56	0	259.48	0	14.74	19.17
		CASE	2	11	10B	12B	5	11
		MIN	-206.49	0	-259.48	0	7.81	-5.89
		CASE	1	12B	10A	13	12A	12B
10	7	MAX	-47.56	3.15	235.85	0	874.63	13.66
		CASE	2	11	12B	12B	12B	11
		MIN	-206.49	-0.945	-292.29	0	-956.11	-4.24
		CASE	1	10B	10A	11	10A	12B
10	10	MAX	206.49	0	259.48	0	-7.81	5.89
		CASE	1	11	10A	11	12A	12B
		MIN	47.56	0	-259.48	0	-14.74	-19.17
		CASE	2	13	10B	12B	5	11
11	2	MAX	0.64	3.15	190.94	0	788.98	1.31
		CASE	12A	11	12A	13	10B	12B
		MIN	-7.34	-0.945	-247.38	0	-723.65	-4.18
		CASE	10B	10B	10B	12B	12A	11
11	11	MAX	5.95	0	214.57	0	23.47	9.69
		CASE	4A	10B	10B	12B	5	11
		MIN	-0.43	0	-214.57	0	14.03	-2.97
		CASE	4B	11	10A	13	12A	12B
12	8	MAX	7.34	3.15	190.94	0	723.65	4.18
		CASE	10A	11	12B	12B	12B	11
		MIN	-0.64	-0.945	-247.38	0	-788.98	-1.31
		CASE	12B	10B	10A	13	10A	12B
12	11	MAX	0.43	0	214.57	0	-14.03	2.97
		CASE	4B	11	10A	13	12A	12B
		MIN	-5.95	0	-214.57	0	-23.47	-9.69
		CASE	4A	12B	10B	12B	5	11

4) Design of Section

1) Flexural Resistance and Bar Arrangement

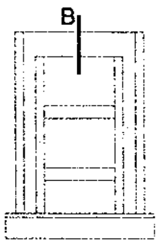
a) Section A

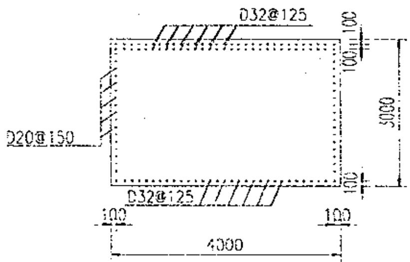




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	4526.5	1988.5	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number 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	

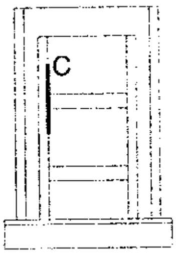
b) Section B

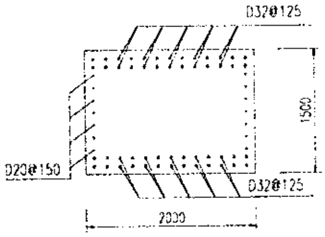




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	-424.3	2085.4	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			2	1	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number of tensile bars	n	(nos.)	64	32	
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	

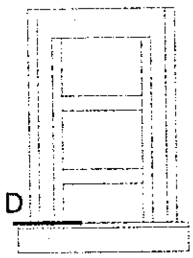
c) Section C

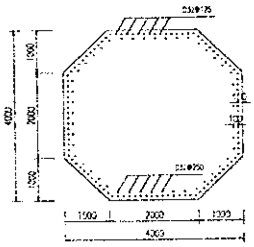




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	956.1	874.6	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	2	
Number 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	

d) Section D

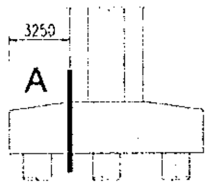


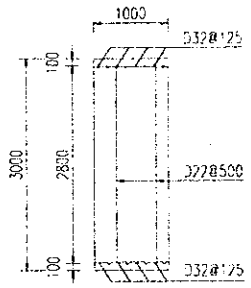


Item	Notation	Unit	Tensile Side			Remark
			Left	Right	Front	
Factored Loads						
Maximum Moment	M	(tf.m)	3977.7	3976.5	9638.2	
Factored Axial Force	N	(tf)	1,894.4	1,922.9	2,604.1	
Load case of Max. Moment			10A	12B	11	
Bar Arrangement						
Dia. of main reinforcement	Dm	(mm)	32			
Number of reinf. layers	nlay	(nos.)	2			
Number of bars	n	(nos.)				
In layer 1			106			
In layer 2			48			
Resistance						
Flexural Resistance	Mr	(tf.m)	13784.5	13582.96	10218.56	
Axial Compressive Resistance	Nr	(tf.m)	6564.90	6698.75	2760.92	
Compressive Depth	c	(mm)	1532.47	1552.83	1014.71	
Resistance Factor	φ		0.817	0.816	0.786	
Checking Resistance			OK	OK	OK	
Checking Reinforcement Ratio			OK	OK	OK	

(3) Desing of Pile Cap

1) Section Analysis of "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	-1884793	EXTREME EVENT I-2
for Calculating Bottom Reinforcement	$Mu_{bot.}$	kN.mm	4597620	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	2599	EXTREME EVENT I-1
Coincidental moment	$Mu_{coin.}$	kN.mm	4597620	

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	
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	25	
Area of 1 bar	A1v	mm2	490.9	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	981.7	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1884793	
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	4597620	
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

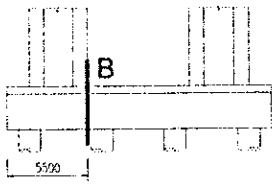
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

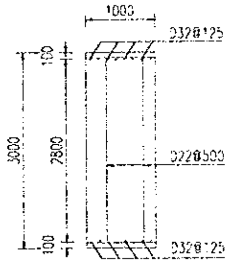
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	2598618	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2160	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		1.7	
Area of shear reinf. within a distance s	A_v	mm^2	982	
Strain in the tensile reinforcement	ε_x		0.002000	
Inclination angle of diagonal comp. stress	θ	degrees	42.77	
Shear stress on the concrete	v	MPa	1.337	
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	1788087	
Nominal Resistance	Vn	N	3,281,178	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,953,061	
Checking			**OK**	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			1592416	Tensile at bottom
SERVICE I-2			1041492	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.97	
SERVICE I-2			0.63	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-6.87	
SERVICE I-2			-4.49	
Checking Stress of Steel			OK	

2) 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	-1229777	EXTREME EVENT I-2
for Calculating Bottom Reinforcen	Mubot.	kN.mm	1612454	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	1959	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	1612454	

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	
Shear Reinforcement				
Diameter	ϕv.	mm	25	
Area of 1 bar	A1v	mm2	490.9	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	981.7	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1229777	
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	1612454	
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.

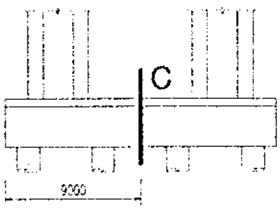
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

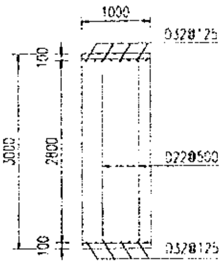
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	1958521	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2160	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		2.0	
Area of shear reinf. within a distance s	A_v	mm^2	982	
Strain in the tensile reinforcement	ε_x		0.001466	
Inclination angle of diagonal comp. stress	θ	degrees	40.66	
Shear stress on the concrete	v	MPa	1.007	
Area of Conc. on flexural tensile side	Act	mm^2	1500000	
Nominal Resistance of Concrete	V_c	N	1756578	
Nominal Resistance of Reinforcement	V_s	N	1925727	
Nominal Resistance	Vn	N	3,682,305	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	3,314,074	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			182448	Tensile at bottom
SERVICE I-2			182448	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.11	
SERVICE I-2			0.11	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-0.79	
SERVICE I-2			-0.79	
Checking Stress of Steel			OK	

3) Section C





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	-1232890	STRENGTH I-1
for Calculating Bottom Reinforcem	Mubot.	kN.mm	-295848	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	-260	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	-1232890	

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	The same to section B
Area of 1 bar	A1's	mm2	804.2	
Numbers of Rebar	n's	nos	8	
Shear Reinforcement				
Diameter	ϕv.	mm	25	
Area of 1 bar	A1v	mm2	490.9	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	981.7	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1232890	
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	-295848.3	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{bot}	kN.mm	8609150	
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)

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

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			-929887	Tensile at top
SERVICE I-2			-512350	Tensile at top
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.57	
SERVICE I-2			0.31	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-4.01	
SERVICE I-2			-2.21	
Checking Stress of Steel			OK	

(4) Section Calculation of Pile
Dia : 1500 mm
Length : 82.0 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	7.85	621.28	4.914	0.00	695.14	0.00
STRENGTH I-2	2.77	295.04	4.91	0.00	278.02	0.00
STRENGTH III	8.86	515.23	5.87	2.51	548.97	9.05
STRENGTH IV	3.04	656.49	4.91	2.51	672.18	0.00
STRENGTH V-1	8.37	595.35	5.23	0.61	661.07	9.03
STRENGTH V-2	0.38	329.98	9.06	0.61	303.56	9.03
EXTREME EVENT I-1	165.61	-323.65	5.74	82.19	26.35	8.75
EXTREME EVENT I-2	115.24	-222.77	7.11	82.19	-204.50	8.75
SERVICE I-1	8.95	455.02	7.30	0.52	525.37	11.19
SERVICE I-2	3.62	375.40	7.61	0.52	376.35	11.19

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	28	
Total Area of Reinforcement	A_{st}	mm2	22519	

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	621.28	3888.9	695.14	3882.5	OK
at Z= 4.91m	M	tf.m	7.85	48.9	0.00	0.0	OK
STRENGTH I-2	PNmin	tf	295.04	4406.2	278.02	4518.0	OK
at Z= 4.91m	M	tf.m	2.77	41.3	0.00	0.0	OK
STRENGTH III	PNmin	tf	515.23	4002.4	548.97	4069.5	OK
at Z= 5.87m	M	tf.m	8.86	68.8	2.51	18.6	OK
STRENGTH IV	PNmin	tf	656.49	3906.6	672.18	3889.9	OK
at Z= 4.91m	M	tf.m	3.04	18.1	2.51	14.6	OK
STRENGTH V-1	PNmin	tf	595.35	3913.5	661.07	3928.2	OK
at Z= 5.23m	M	tf.m	8.37	55.0	0.61	3.6	OK
STRENGTH V-2	PNmin	tf	329.98	4429.8	303.56	4463.2	OK
at Z= 9.06m	M	tf.m	0.38	5.1	0.61	8.8	OK
EXTREME EVENT I-1	PNmin	tf	-323.65	-441.3	26.35	168.9	OK
at Z= 5.74m	M	tf.m	165.61	225.8	82.19	526.8	OK
EXTREME EVENT I-2	PNmin	tf	-222.77	-439.0	-204.50	-491.5	OK
at Z= 7.11m	M	tf.m	115.24	227.1	82.19	197.5	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	455.02	8.95	1495.06	23861	264.51	1377	OK
at Z=7.30m	Transverse	525.37	0.52	1,289.88	23861	207.84	1377	
SERVICE I-2	Horizontal	375.40	3.62	1873.32	23861	278.34	1377	OK
at Z=7.61m	Transverse	376.35	0.52	1,339.75	23861	199.79	1377	

d) Checking Minimum Steel Ratio

Item	Notation	Unit	Value	Remark
Total Area of Reinforcement	A_{st}	mm2	22519	
Gross Area of Section	Ag	mm2	1767145.9	
Reinforcement Ratio	ρst	%	1.27	
Minimum Reinforcement ratio	ρmin	%	0.40	OK

5) Checking Footing Concret Stress that Pile connected

1) Vertical bearing stress of footing concrete

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

Reaction force of pile	P=	1376130 kg	Load Combination: 7
Diameter of Pile	D=	150 cm	
Vertical bearing stress	σ_{cv}	77.87 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

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

Reaction force of pile	P=	1376130 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=	3.43 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

τ_c <= τ_a --> OK

3) Horizontal Bearing stress

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

Horizontal force at pile head	H=	90380 kg	Load Combination: 7
Diameter of Pile	D=	150 cm	
Embedded Length of Pile	l=	10 cm	
Horizontal bearing stress	σ_{ch}	60.25 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

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

Horizontal force at pile head	H=	90380 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=	3.77 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

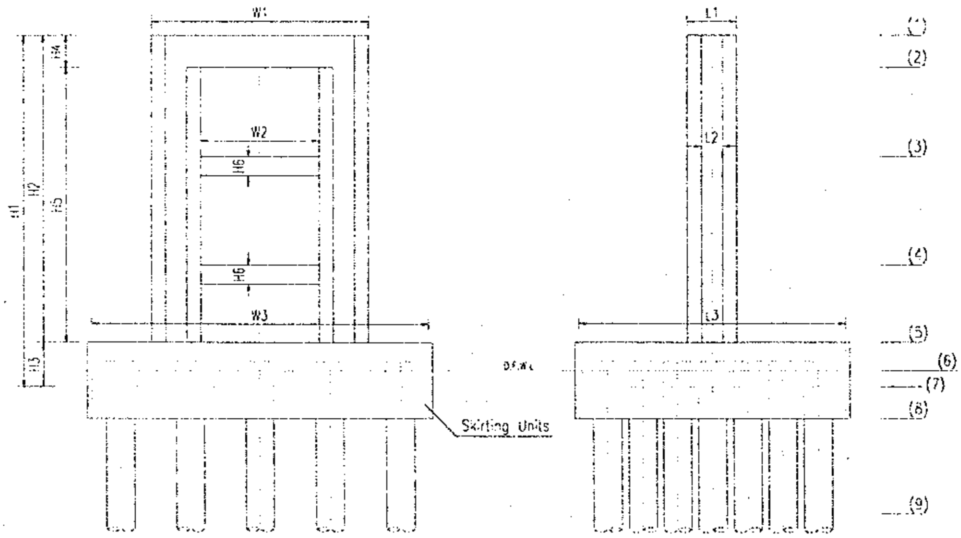
τ_c <= τ_a --> OK

3.13.5 Design of P15 pier

(1) Stability Calculation

1) Dimension of Pier

(Figure)		(m)			(Level)		(m)
Portion	Length	Portion	Length	Portion	Level	Portion	Level
H1	27.62	W1	15.00	(1)	+28.12	(6)	+1.78
H2	24.12	W2	7.00	(2)	+25.12	(7)	+0.50
H3	3.50	L1	4.00	(3)	+18.12	(8)	-2.00
H4	3.00	W3	24.00	(4)	+9.62	(9)	-23.81
H5	21.12	L2	2.00	(5)	+4.00		
H6	1.50	L3	19.00				
W4	0.00	L4	0.00				



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

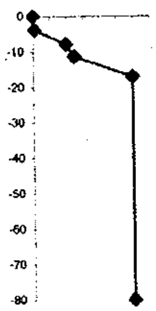
Load Combination		V	Longitudinal		Transverse	
		(tf)	H (tf)	M (tf.m)	H (tf)	M (tf.m)
1	STRENGTH I-1	10704.13	47.46803	1311.067	39.28608	-24.0431
2	STRENGTH I-2	5496.167	-7.3165	-202.082	39.28608	-24.0431
3	STRENGTH III	9488.7	73.14528	1231.353	77.27961	411.3941
4	STRENGTH IV	11527.03	17.48822	483.0247	39.28608	-24.0431
5	STRENGTH V-1	10426.32	56.51752	1335.608	50.14138	100.3675
6	STRENGTH V-2	5756.481	14.25517	168.3222	50.14138	100.3675
7	EXTREME EVENT I-1	9225.408	1422.787	22975.73	1453.508	22715.1
8	EXTREME EVENT I-2	5699.091	1407.135	22543.4	1453.508	22715.1
9	EXTREME EVENT II	9859.624	901.1343	1375.501	1824.423	2253.792
10	SERVICE I-1	8121.248	64.03428	1599.573	47.42755	69.26489
11	SERVICE I-2	6775.93	32.72883	734.9161	47.42755	69.26489

3) Pile Capacity

INPUT DATA

BoreHole			BRD15
Pile Diameter	D1	=	2200 mm
	D2	=	2000 mm
Factor of Safety	FS	=	3
Pile length	L	=	74.00 m
	L0	=	24.31 m
	L1	=	15.69 m
	L2	=	34.00 m
Pile Embedded Length	Le	=	49.69 m
Pile Cross-Section Circumference	P1	=	6.912 m
	P2	=	6.283 m
Pile Cross-Section Area	Ab1	=	3.801 m2
	Ab2	=	3.142 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 = Σ (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	7.69	2	Clay	0.70	1.0	1.0	53
2-1	8.00	2	Clay	1.00	12.0	2.0	111
2-2	15.50	2	Clay	1.00	12.0	2.0	195
3	7.00	2	Clay	1.05	25.0	15.0	660
4	11.50	1	Sand	1.20	60.0	20.0	1445
Total L =	49.69	m				Total Qs =	2463

END BEARING CAPACITY Formula: Qt = qu* Ab

Type of Pile		Soil Type of B.P	End Bearing Capacity		
Cast-in-situ	Friction & Bearing	Sand		942 tonne	

ULTIMATE BEARING CAPACITY (Qult)
* Qult = Qt + Qs — **3405.9** tonne

REPLACED EFFECTIVE WEIGHT OF SOIL (Ws) — **166.0** tonne

BUOYANT WEIGHT OF PILE (W) — **480.7** tonne

Allowable Bearing Capacity for Service Load Combinations ($Qall_1$)
* $Qall_1$ = (Qult - Ws) / FS + Ws - W — **765.2** tonne

Allowable Bearing Capacity for Earthquake & Strength Load Combinations($Qall_2$)
* $Qall_2$ = (Qult - Ws) / FS + Ws - W — **1305.2** tonne
FS= 2

Design Uplift Capacity for Service Load Combinations (Qup_1)
* Qup_1 = Qs / FS + W — **891.3** tonne
FS = 6

Design Uplift Capacity for Earthquake & Strength Load Combinations(Qup_2)
* Qup_2 = Qs / FS + W — **1301.8** tonne
FS= 3

4) Reaction of Pile

a) Displacement

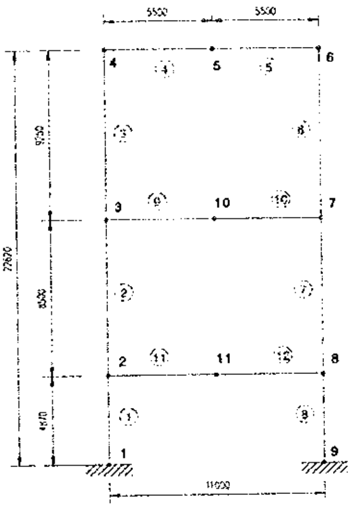
Load Combination		Longitudinal			Transverse			δ xa(cm)	Remark
		δ x(cm)	δ y(cm)	α (rad)	δ x(cm)	δ y(cm)	α (rad)		
1	STRENGTH I-1	0.07	0.76	0.000054	0.05	0.76	0.000009	3.00	OK
2	STRENGTH I-2	-0.01	0.39	-0.000008	0.05	0.39	0.000009	3.00	OK
3	STRENGTH III	0.10	0.67	0.000063	0.10	0.67	0.000023	3.00	OK
4	STRENGTH IV	0.02	0.82	0.000020	0.05	0.82	0.000009	3.00	OK
5	STRENGTH V-1	0.08	0.74	0.000059	0.06	0.74	0.000013	3.00	OK
6	STRENGTH V-2	0.02	0.41	0.000011	0.06	0.41	0.000013	3.00	OK
7	EXTREME EVENT I-1	1.91	0.65	0.001207	1.85	0.65	0.000625	2.00	OK
8	EXTREME EVENT I-2	1.89	0.40	0.001190	1.85	0.40	0.000625	2.00	OK
9	EXTREME EVENT II	1.15	0.70	0.000431	2.27	0.70	0.000442	3.00	OK
10	SERVICE I-1	0.13	0.58	0.000071	0.08	0.58	0.000012	1.50	OK
11	SERVICE I-2	0.06	0.48	0.000034	0.08	0.48	0.000012	1.50	OK

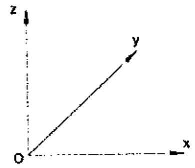
b) Bearing and Uplift forces of piles

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	626.47	562.87	601.39	587.96	1305.2	-1301.8	OK	OK
2	STRENGTH I-2	310.24	300.45	312.06	298.63	1305.2	-1301.8	OK	OK
3	STRENGTH III	564.37	489.93	545.05	509.25	1305.2	-1301.8	OK	OK
4	STRENGTH IV	652.10	628.67	647.10	633.67	1305.2	-1301.8	OK	OK
5	STRENGTH V-1	613.73	544.75	589.14	569.34	1305.2	-1301.8	OK	OK
6	STRENGTH V-2	326.01	313.61	329.71	309.91	1305.2	-1301.8	OK	OK
7	EXTREME EVENT I-1	1222.23	-197.19	1002.15	22.90	1305.2	-1301.8	OK	OK
8	EXTREME EVENT I-2	1015.83	-382.60	806.24	-173.01	1305.2	-1301.8	OK	OK
9	EXTREME EVENT II	800.92	294.60	893.93	201.58	1305.2	-1301.8	OK	OK
10	SERVICE I-1	492.62	409.74	460.78	441.57	765.2	-891.3	OK	OK
11	SERVICE I-2	396.38	356.50	386.04	366.84	765.2	-891.3	OK	OK

(2) Design of Pier Sections

1) Calculation model





2) Loads from superstructure at pier top

Load	V (tf)	Longitudinal		Transverse		Remarks
		H (tf)	M (tf.m)	H (tf)	M (tf.m)	
DC1	1742.9	0.0	0.0	0.0	0.0	
DW1	0.0	0.0	0.0	0.0	0.0	
LLmax	694.5	17.1	0.0	0.0	0.0	
LLmin	-650.8	-14.2	0.0	0.0	0.0	
TUmax	-47.3	35.0	0.0	0.0	0.0	
TUmin	49.4	-31.5	0.0	0.0	0.0	
EQ1-L	-634.2	645.0	0.0	193.5	0.0	
EQ1-T	-634.2	193.5	0.0	645.0	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.

3) Envelope of Member End Actions

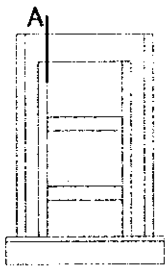
MEMBER	JOINT	TYPE	Nx (tf)	Sy (tf)	Sz (tf)	Mx (tf.m)	My (tf.m)	Mz (tf.m)
1	1	MAX	-931.12	440.229	438.04	57.4869	3676.78	8803.16
		CASE	12A	11	12B	11	10A	11
		MIN	-3744.7	-135.317	-436.76	-17.6591	-3669.35	-2714.41
		CASE	10B	12B	10A	12B	12B	12B
1	2	MAX	3531.64	129.18	416.31	17.6591	1588.57	2070.36
		CASE	10B	12B	10A	12B	10B	12B
		MIN	777.72	-419.775	-417.58	-57.4869	-1602.22	-6709.05
		CASE	12A	11	12B	11	12A	11
2	2	MAX	-913.04	416.625	411.95	53.775	2429.71	6709.05
		CASE	2	11	12B	11	12A	11
		MIN	-3334.81	-128.235	-416.84	-16.5906	-2594.26	-2070.36
		CASE	10B	12B	10A	12B	10B	12B
2	3	MAX	2962.94	117.525	381.14	16.5906	993.33	1025.88
		CASE	10B	12B	10A	12B	10A	12B
		MIN	645.29	-380.925	-376.25	-53.775	-787.23	-3319.47
		CASE	2	11	12B	11	12B	11
3	3	MAX	-621.66	377.775	568.92	60.289	293.3	3319.47
		CASE	2	11	10B	11	12A	11
		MIN	-2691.24	-116.58	-251.25	-18.6769	-693.76	-1025.88
		CASE	10B	12B	12A	12B	10B	12B
3	4	MAX	2352.18	106.815	218.7	18.6769	1527.73	160.23
		CASE	10B	12B	12A	12B	12A	12B
		MIN	377.54	-345.225	-536.37	-60.289	-3589.18	-517.84
		CASE	2	11	10B	11	10B	11
4	4	MAX	4.1	128.275	37.66	0	4393.73	60.29
		CASE	12A	11	12A	11	10B	11
		MIN	-321.77	-39.565	-1265.38	0	-1855.78	-18.68
		CASE	10B	12B	10B	10B	12A	12B
4	5	MAX	301.97	33.625	1059.13	0	2085.35	590.78
		CASE	10B	12B	10B	10B	1	11
		MIN	15.71	-108.475	-186.16	0	424.32	-182.6
		CASE	12A	11	12A	11	2	12B
5	5	MAX	-15.71	33.625	1059.13	0	-424.32	182.6
		CASE	12B	12B	10A	11	2	12B
		MIN	-301.97	-108.475	-186.16	0	-2085.35	-590.78
		CASE	10A	11	12B	12B	1	11
5	6	MAX	321.77	128.275	37.66	0	1855.78	18.68
		CASE	10A	11	12B	12B	12B	12B
		MIN	-4.1	-39.565	-1265.38	0	-4393.73	-60.29
		CASE	12B	12B	10A	11	10A	11
6	6	MAX	2352.18	106.815	536.37	60.289	3589.18	160.23
		CASE	10A	12B	10A	11	10A	12B
		MIN	377.54	-345.225	-218.7	-18.6769	-1527.73	-517.84
		CASE	2	11	12B	12B	12B	11
6	7	MAX	-621.66	377.775	251.25	18.6769	693.76	3319.47
		CASE	2	11	12B	12B	10A	11
		MIN	-2691.24	-116.58	-568.92	-60.289	-293.3	-1025.88
		CASE	10A	12B	10A	11	12B	12B

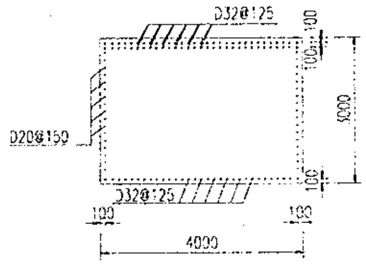
(Continued)

7	7	MAX	2962.94	117.525	376.25	53.775	787.23	1025.88
		CASE	10A	12B	12A	11	12A	12B
		MIN	645.29	-380.925	-381.14	-16.5906	-993.33	-3319.47
		CASE	2	11	10B	12B	10B	11
7	8	MAX	-913.04	416.625	416.84	16.5906	2594.26	6709.05
		CASE	2	11	10B	12B	10A	11
		MIN	-3334.81	-128.235	-411.95	-53.775	-2429.71	-2070.36
		CASE	10A	12B	12A	11	12B	12B
8	8	MAX	3531.64	129.18	417.58	57.4869	1602.22	2070.36
		CASE	10A	12B	12A	11	12B	12B
		MIN	777.72	-419.775	-416.31	-17.6591	-1588.57	-6709.05
		CASE	12B	11	10B	12B	10A	11
8	9	MAX	-931.12	440.229	436.76	17.6591	3669.35	8803.16
		CASE	12B	11	10B	12B	12A	11
		MIN	-3744.7	-135.317	-438.04	-57.4869	-3676.78	-2714.41
		CASE	10A	12B	12A	11	10B	12B
9	3	MAX	206.55	3.15	215.26	0	884.03	3.98
		CASE	1	11	12A	11	10B	12B
		MIN	47.47	-0.945	-271.7	0	-802.55	-12.82
		CASE	2	10B	10B	12B	12A	11
9	10	MAX	-47.47	0	238.89	0	14.74	18.33
		CASE	2	10B	10B	12B	5	11
		MIN	-206.55	0	-238.89	0	7.81	-5.63
		CASE	1	13	10A	11	12A	12B
10	7	MAX	-47.47	3.15	215.26	0	802.55	12.82
		CASE	2	11	12B	12B	12B	11
		MIN	-206.55	-0.945	-271.7	0	-884.03	-3.98
		CASE	1	10B	10A	13	10A	12B
10	10	MAX	206.55	0	238.89	0	-7.81	5.63
		CASE	1	11	10A	13	12A	12B
		MIN	47.47	0	-238.89	0	-14.74	-18.33
		CASE	2	10B	10B	12B	5	11
11	2	MAX	0.67	3.15	140.39	0	612.04	0.89
		CASE	12A	11	12A	13	10B	3
		MIN	-6.83	-0.945	-196.83	0	-546.72	-2.59
		CASE	10B	10B	10B	12B	12A	11
11	11	MAX	5.58	0	164.01	0	23.46	8.1
		CASE	4A	12B	10B	12B	5	11
		MIN	0.86	0	-164.01	0	14.03	-2.48
		CASE	4B	13	10A	13	12A	12B
12	8	MAX	6.83	3.15	140.39	0	546.72	2.59
		CASE	10A	11	12B	12B	12B	11
		MIN	-0.67	-0.945	-196.83	0	-612.04	-0.89
		CASE	12B	10B	10A	13	10A	3
12	11	MAX	-0.86	0	164.01	0	-14.03	2.48
		CASE	4B	11	10A	13	12A	12B
		MIN	-5.58	0	-164.01	0	-23.46	-8.1
		CASE	4A	10B	10B	12B	5	11

4) Flexural Resistance and Bar Arrangement

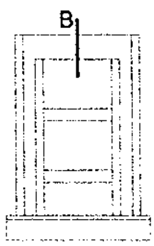
a) Section A

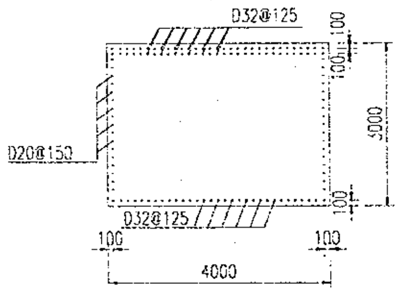




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	4393.7	1855.8	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number 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	

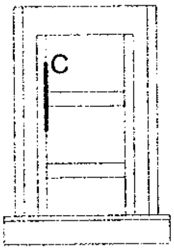
b) Section B

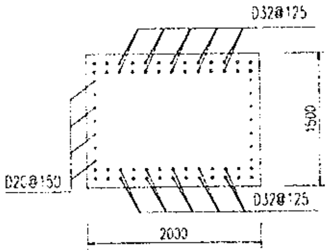




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	-424.3	2085.4	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			2	1	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number of tensile bars	n	(nos.)	64	32	
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	

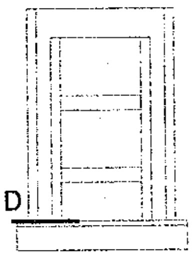
c) Section C

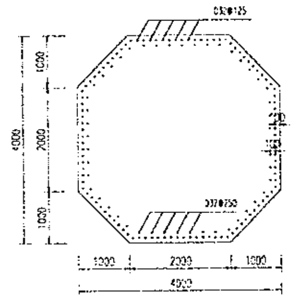




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	884.0	802.6	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	2	
Number 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	

d) Section D

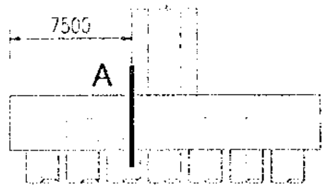


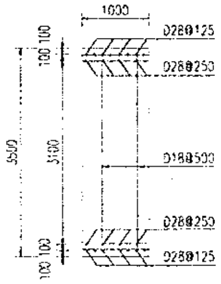


Item	Notation	Unit	Tensile Side			Remark
			Left	Right	Front	
Factored Loads						
Maximum Moment	M	(tf.m)	3676.8	3669.4	8803.2	
Factored Axial Force	N	(tf)	1,907.5	2,768.4	2,550.4	
Load case of Max. Moment			10A	12B	11	
Bar Arrangement						
Dia. of main reinforcement	Dm	(mm)		32		
Number of reinf. layers	nlay	(nos.)		2		
Number of bars	n	(nos.)				
In layer 1				106		
In layer 2				48		
Resistance						
Flexural Resistance	Mr	(tf.m)	14251.13	14551.89	10556.12	
Axial Compressive Resistance	Nr	(tf.m)	7393.55	10979.06	3058.20	
Compressive Depth	c	(mm)	1649.54	2224.69	1057.81	
Resistance Factor	φ		0.816	0.779	0.788	
Checking Resistance			OK	OK	OK	
Checking Reinforcement Ratio			OK	OK	OK	

(3) Design of Pile Cap

1) Section Analysis of "A"





Total width of section 24000 mm
Calculation width 1000 mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3500	
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	-5945355	EXTREME EVENT I-2
for Calculating Bottom Reinforcement	$Mu_{bot.}$	kN.mm	7220805	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	2183	EXTREME EVENT I-1
Coincidental moment	$Mu_{coin.}$	kN.mm	7220805	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	28	
Area of 1 bar	A1s	mm2	615.8	
Numbers of Rebar	ns	nos	12	
Bottom Reinforcement				
Diameter	ϕbot.	mm	28	
Area of 1 bar	A1's	mm2	615.8	
Numbers of Rebar	n's	nos	12	
Shear Reinforcement				
Diameter	ϕv.	mm	18	
Area of 1 bar	A1v	mm2	254.5	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	508.9	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	5945355	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{top}	kN.mm	8609150	
Checking Resistance			**OK**	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	7220805	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{bot}	kN.mm	8609150	
Checking Resistance			**OK**	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	0.185	OK

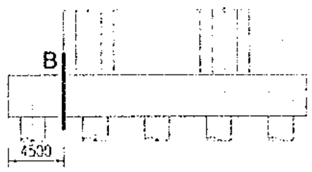
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

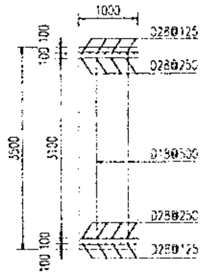
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	2183288	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2520	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		1.7	
Area of shear reinf. within a distance s	A_v	mm^2	509	
Strain in the tensile reinforcement	ε_x		0.002000	
Inclination angle of diagonal comp. stress	θ	degrees	43.00	
Shear stress on the concrete	v	MPa	0.963	
Area of Conc. on flexural tensile side	Act	mm^2	1750000	
Nominal Resistance of Concrete	V_c	N	1741940	
Nominal Resistance of Reinforcement	V_s	N	1072764	
Nominal Resistance	Vn	N	2,814,704	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,533,233	
Checking			**OK**	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			1488329	Tensile at bottom
SERVICE I-2			570897	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.82	
SERVICE I-2			0.41	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-5.89	
SERVICE I-2			-2.94	
Checking Stress of Steel			OK	

2) Section Analysis of "B"





Total width of section 19000 mm
Calculation width 1000 mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3500	
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	-1548195	EXTREME EVENT I-2
for Calculating Bottom Reinforcen	Mubot.	kN.mm	4213157	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	1643	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	4213157	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	28	
Area of 1 bar	A1s	mm2	615.8	
Numbers of Rebar	ns	nos	12	
Bottom Reinforcement				
Diameter	ϕbot.	mm	28	
Area of 1 bar	A1's	mm2	615.8	
Numbers of Rebar	n's	nos	12	
Shear Reinforcement				
Diameter	ϕv.	mm	18	
Area of 1 bar	A1v	mm2	254.5	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	508.9	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1548195	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{top}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	4213157	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{bot}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	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	1642627	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2520	
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		1.8	
Area of shear reinf. within a distance s	A_v	mm^2	509	
Strain in the tensile reinforcement	ε_x		0.001749	
Inclination angle of diagonal comp. stress	θ	degrees	41.99	
Shear stress on the concrete	v	MPa	0.724	
Area of Conc. on flexural tensile side	Act	mm^2	1750000	
Nominal Resistance of Concrete	V_c	N	1844407	
Nominal Resistance of Reinforcement	V_s	N	1111412	
Nominal Resistance	Vn	N	2,955,819	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,660,237	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			1636148	Tensile at bottom
SERVICE I-2			1250388	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.75	
SERVICE I-2			0.57	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-5.31	
SERVICE I-2			-4.05	
Checking Stress of Steel			OK	

(4) Section Calculation of Pile

Dia : D1 =	2200 mm	L1 =	40.0 m
D2 =	2000 mm	L2 =	34.0 m
Length :	74.0 m		
Number :	18 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	39.05	562.87	0.00	36.78	587.96	0.00
STRENGTH I-2	-6.00	300.45	0.00	36.78	298.63	0.00
STRENGTH III	62.56	489.93	0.00	71.60	509.25	0.00
STRENGTH IV	14.39	628.67	0.00	36.78	633.67	0.00
STRENGTH V-1	47.15	544.75	0.00	46.67	569.34	0.00
STRENGTH V-2	12.46	313.61	0.00	46.67	309.91	0.00
EXTREME EVENT I-1	1220.70	-197.19	0.00	1322.18	22.90	0.00
EXTREME EVENT I-2	1207.79	-382.60	0.00	1322.18	-173.01	0.00
EXTREME EVENT II	814.33	294.60	0.00	1701.84	201.58	0.00
SERVICE I-1	56.94	409.74	0.00	46.83	441.57	0.00
SERVICE I-2	29.34	356.50	0.00	46.83	366.84	0.00

2) Section Calculation

a) Distribution of Axial Force and Bending Moment in Composite Section

Diameter of Pile 2.20 m

Thickness of Casing 0.014 m (2mm corrosion assumed)

Es= 20000000

Ec= 2500000

n=Es/Ec= 8.00

As0= 0.096761 m2

Ac= 3.801327 m2

Atrans= 4.575416 m2

Is0= 0.059668 m4

Ic0= 1.149901 m4

Itrans= 1.627242 m4

* Casing: - Axial 16.92%

- Bending 29.33%

* RC: - Axial 83.08%

- Bending 70.67%

b) General Conditions

Item	Notation	Unit	Value	Remark
Diameter of pile	D	mm	2200	
Steel Casing			Yes	
Number of Reinf. layers	n_{layer}	nos	1	
Concrete cover	cv	m	250	
Diameter of Rebars	d	mm	32	
Number of Rebars	n_{st}	nos	46	
Total Area of Reinforcement	A_{st}	mm2	36995	

c) Checking Resistance (AASHTO 5.7.2)

i) In longitudinal Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	562.87	467.64	8880.48	95.23	1856.9	OK
	M (tf.m)	39.05	27.59	523.96	11.46	223.36	OK
STRENGTH I-2	PN (tf)	300.45	249.62	-1257.10	50.83	2352.5	OK
	M (tf.m)	-6.00	-4.24	21.32	-1.76	-81.46	OK
STRENGTH III	PN (tf)	489.93	407.04	8475.94	82.89	1632.4	OK
	M (tf.m)	62.56	44.21	921.01	18.35	361.42	OK
STRENGTH IV	PN (tf)	628.67	522.31	9176.38	106.36	2085.5	OK
	M (tf.m)	14.39	10.17	178.76	4.22	82.77	OK
STRENGTH V-1	PN (tf)	544.75	452.59	8759.82	92.16	1784.6	OK
	M (tf.m)	47.15	33.32	644.91	13.83	267.82	OK
STRENGTH V-2	PN (tf)	313.61	260.55	9409.71	53.06	1996.4	OK
	M (tf.m)	12.46	8.80	318.23	3.66	137.53	OK
EXTREME EVENT I-1	PN (tf)	-197.19	-163.83	-186.56	-33.36	-120.3	OK
	M (tf.m)	1,220.70	862.62	982.29	358.08	1291.44	OK
EXTREME EVENT I-2	PN (tf)	-382.60	**-317.87**	**-326.36**	-64.73	-224.3	**OK**
	M (tf.m)	1,207.79	**853.49**	**876.28**	354.30	1227.51	**OK**
EXTREME EVENT II	PN (tf)	294.60	244.76	640.34	49.84	252.5	OK
	M (tf.m)	814.33	575.45	1,505.48	238.88	1210.1	OK

ii) In Transverse Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	587.96	488.49	8907.71	99.47	1887.2	OK
	M (tf.m)	36.78	25.99	473.61	10.79	204.69	OK
STRENGTH I-2	PN (tf)	298.63	248.11	8720.85	50.52	1647.9	OK
	M (tf.m)	36.78	25.99	913.35	10.79	351.90	OK
STRENGTH III	PN (tf)	509.25	423.09	8346.94	86.16	1589.9	OK
	M (tf.m)	71.60	50.60	998.24	21.00	387.58	OK
STRENGTH IV	PN (tf)	633.67	526.46	8892.00	107.21	1907.9	OK
	M (tf.m)	36.78	25.99	438.54	10.79	192.01	OK
STRENGTH V-1	PN (tf)	569.34	473.02	8770.18	96.32	1803.3	OK
	M (tf.m)	46.67	32.98	611.35	13.69	256.30	OK
STRENGTH V-2	PN (tf)	309.91	257.48	8471.12	52.43	1558.4	OK
	M (tf.m)	46.67	32.98	1,085.23	13.69	406.92	OK
EXTREME EVENT I-1	PN (tf)	22.90	19.03	23.08	3.87	13.6	OK
	M (tf.m)	1,322.18	934.33	1,133.29	387.85	1357.10	OK
EXTREME EVENT I-2	PN (tf)	-173.01	-143.74	-154.80	-29.27	-98.5	OK
	M (tf.m)	1,322.18	934.33	1,006.20	387.85	1304.87	OK
EXTREME EVENT II	PN (tf)	201.58	**167.48**	**168.86**	34.10	89.5	**OK**
	M (tf.m)	1,701.84	**1,202.62**	**1,212.53**	499.22	1310.4	**OK**

c) Checking Stress in RC portion

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	340.42	40.24	565.34	-23861	213.32	1101	OK
	Transverse	366.86	33.09	702.65	-23861	210.42	1101	
SERVICE I-2	Horizontal	296.19	20.73	621.70	-23861	158.54	1101	OK
	Transverse	304.78	33.09	532.85	-23861	185.42	1101	

d) Checking Minimum Steel Ratio

Item	Notation	Unit	Value	Remark
Total Area of Reinforcement	A_{st}	mm2	36995	
Gross Area of Section	Ag	mm2	3801327	
Reinforcement Ratio	ρst	%	0.97	
Minimum Reinforcement ratio	ρmin	%	0.40	OK

(5) Calculation of Footing Concrete Stress that Pile connected

1) Vertical bearing stress of footing concrete

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

Reaction force of pile	P=	1222230 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Vertical bearing stress	σ_{cv}	32.15 kg/cm^2	
Allowable bearing stress	$\sigma_{ca}=0.5xf_c$ =	120.00 kg/cm^2	

σ_{cv} <= σ_{ca} --> OK

2) Vertical Punching Shear Stress

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

Reaction force of pile	P=	1222230 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Depth from pile head to upper surface of pile cap	h=	150 cm	
Punching shear stress	τ_c=	7.01 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

τ_c <= τ_a --> OK

3) Horizontal Bearing stress

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

Horizontal force at pile head	H=	101360 kg	Load Combination: 9
Diameter of Pile	D=	220 cm	
Embedded Length of Pile	l=	200 cm	
Horizontal bearing stress	σ_{ch}	2.30 kg/cm^2	
Allowable bearing stress	$\sigma_{ca}=0.3xf_c$ =	72.00 kg/cm^2	

σ_{ch} <= σ_{ca} --> OK

4) Horizontal Punching Shear Stress

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

Horizontal force at pile head	H=	101360 kg	Load Combination: 9
Diameter of Pile	D=	220 cm	
Distance from side of pile to the nearest edge of pile cap	h'=	90 cm	
Embedded Length of Pile	l=	200 cm	
Punching shear stress	τ_c=	1.41 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

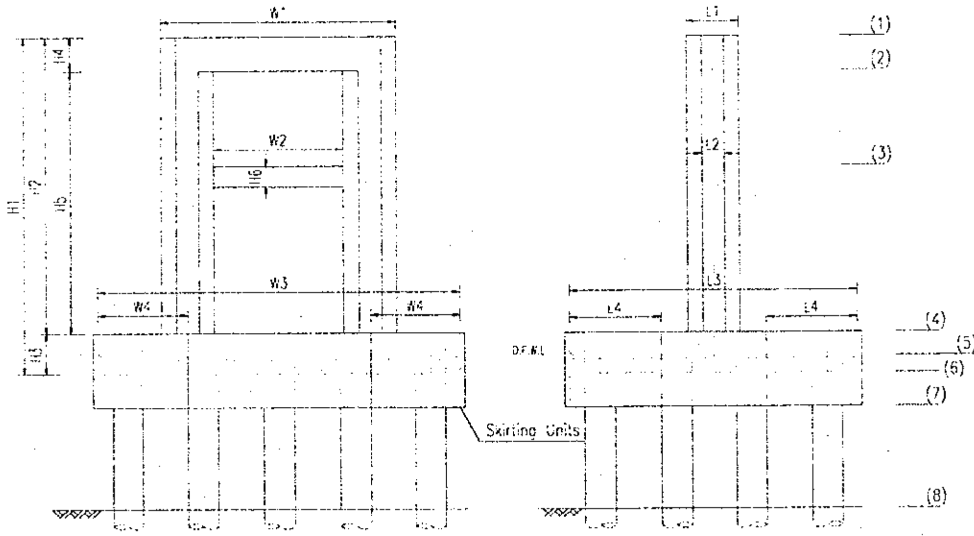
τ_c <= τ_a --> OK

3.13.6 Design of P16 pier

(1) Stability Calculation

1) Dimension of Pier

(Figure)		(m)		(Level)		(m)	
Portion	Length	Portion	Length	Portion	Level	Portion	Level
H1	24.82	W1	15.00	(1)	+25.32	(5)	+1.78
H2	21.32	W2	7.00	(2)	+22.32	(6)	+0.50
H3	3.50	L1	4.00	(3)	+15.32	(7)	-2.00
H4	3.00	W3	24.00	(4)	+4.00	(8)	-22.12
H5	18.32	L2	2.00				
H6	1.50	L3	19.00				
		W4	6.00				
		L4	6.00				



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

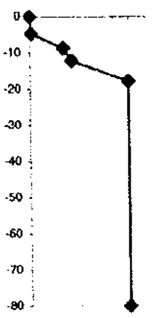
Load Combination		V	Longitudinal		Transverse	
		(tf)	H (tf)	M (tf.m)	H (tf)	M (tf.m)
1	STRENGTH I-1	10251.2	49.8	1236.4	22.3	-13.7
2	STRENGTH I-2	5690.8	-4.1	-101.2	22.3	-13.7
3	STRENGTH III	9090.5	70.3	1121.8	57.3	342.1
4	STRENGTH IV	11024.9	20.5	510.0	22.3	-13.7
5	STRENGTH V-1	9985.9	57.3	1245.1	32.3	88.0
6	STRENGTH V-2	5848.9	15.8	213.3	32.3	88.0
7	EXTREME EVENT I-1	9183.3	1309.5	20234.4	1323.4	20013.2
8	EXTREME EVENT I-2	5946.0	1294.1	19852.3	1323.4	20013.2
9	EXTREME EVENT II	9431.9	681.4	1066.3	1368.4	1703.9
10	SERVICE I-1	7809.7	68.5	1566.1	29.8	62.6
11	SERVICE I-2	6751.2	37.7	801.8	29.8	62.6

3) Capacity of Pile

INPUT DATA

BoreHole			BRD15
Pile Diameter	D1	=	2200 mm
	D2	=	2000 mm
Factor of Safety	FS	=	3
Pile length	L	=	74.00 m
	L0	=	22.62 m
	L1	=	17.38 m
	L2	=	34.00 m
Pile Embedded Length	Le	=	51.38 m
Pile Cross-Section Circumference	P1	=	6.912 m
	P2	=	6.283 m
Pile Cross-Section Area	Ab1	=	3.801 m2
	Ab2	=	3.142 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 = Σ (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	9.38	2	Clay	0.70	1.0	1.0	65
2-1	8.00	2	Clay	1.00	12.0	2.0	111
2-2	15.50	2	Clay	1.00	12.0	2.0	195
3	7.00	2	Clay	1.05	25.0	15.0	660
4	11.50	1	Sand	1.20	60.0	20.0	1445
Total L =	51.38	m				Total Qs =	2475

<u>END BEARING CAPACITY</u> Formula: Qt = qu* Ab

Type of Pile		Soil Type of B.P	End Bearing Capacity		
Cast-in-situ	Friction & Bearing	Sand		942 tonne	

<u>ULTIMATE BEARING CAPACITY (Qult)</u>

* Qult = Qt + Qs **3417.5** tonne

<u>REPLACED EFFECTIVE WEIGHT OF SOIL (Ws)</u>

170.5 tonne

<u>BUOYANT WEIGHT OF PILE (W)</u>

474.3 tonne

<u>Allowable Bearing Capacity for Service Load Combinations ($Qall_1$)</u>

* $Qall_1$ = (Qult - Ws) / FS + Ws - W **778.6** tonne

<u>Allowable Bearing Capacity for Earthquake & Strength Load Combinations($Qall_2$)</u>

* $Qall_2$ = (Qult - Ws) / FS + Ws - W **1319.7** tonne

FS= 2

<u>Design Uplift Capacity for Service Load Combinations (Qup_1)</u>

* Qup_1 = Qs / FS + W **886.8** tonne

FS = 6

<u>Design Uplift Capacity for Earthquake & Strength Load Combinations(Qup_2)</u>

* Qup_2 = Qs / FS + W **1299.3** tonne

FS= 3

4) Reaction of Pile

a) Displacement

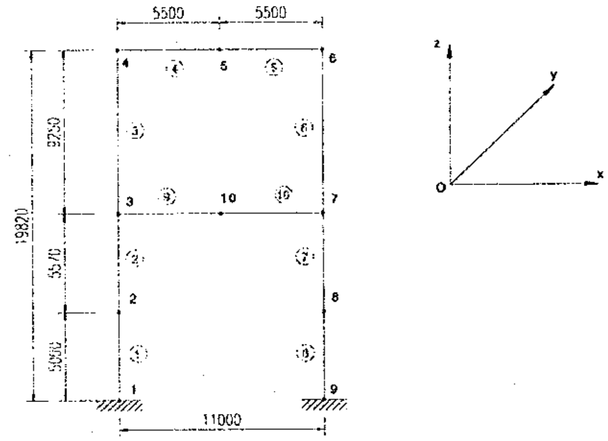
Load Combination		Longitudinal			Transverse			δ xa(cm)	Remark
		δ x(cm)	δ y(cm)	α (rad)	δ x(cm)	δ y(cm)	α (rad)		
1	STRENGTH I-1	0.08	0.80	0.000060	0.03	0.80	0.000007	3.00	OK
2	STRENGTH I-2	-0.01	0.44	-0.000005	0.03	0.44	0.000007	3.00	OK
3	STRENGTH III	0.11	0.71	0.000067	0.08	0.71	0.000026	3.00	OK
4	STRENGTH IV	0.03	0.86	0.000025	0.03	0.86	0.000007	3.00	OK
5	STRENGTH V-1	0.09	0.78	0.000064	0.05	0.78	0.000012	3.00	OK
6	STRENGTH V-2	0.02	0.46	0.000014	0.05	0.46	0.000012	3.00	OK
7	EXTREME EVENT I-1	1.97	0.72	0.001229	1.92	0.72	0.000837	2.00	OK
8	EXTREME EVENT I-2	1.94	0.46	0.001211	1.92	0.46	0.000837	2.00	OK
9	EXTREME EVENT II	0.98	0.74	0.000362	1.92	0.74	0.000486	3.00	OK
10	SERVICE I-1	0.15	0.61	0.000082	0.06	0.61	0.000012	1.50	OK
11	SERVICE I-2	0.08	0.53	0.000043	0.06	0.53	0.000012	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	676.97	604.43	646.37	635.03	1319.7	-1299.3	OK	OK
2	STRENGTH I-2	358.65	352.70	361.35	350.00	1319.7	-1299.3	OK	OK
3	STRENGTH III	608.37	527.94	588.75	547.56	1319.7	-1299.3	OK	OK
4	STRENGTH IV	704.00	674.11	694.73	683.39	1319.7	-1299.3	OK	OK
5	STRENGTH V-1	662.72	585.52	634.05	614.18	1319.7	-1299.3	OK	OK
6	STRENGTH V-2	373.91	357.20	375.49	355.62	1319.7	-1299.3	OK	OK
7	EXTREME EVENT I-1	1311.39	-163.48	1243.17	-95.26	1319.7	-1299.3	OK	OK
8	EXTREME EVENT I-2	1097.85	-354.60	1040.84	-297.59	1319.7	-1299.3	OK	OK
9	EXTREME EVENT II	806.60	372.39	978.08	200.91	1319.7	-1299.3	OK	OK
10	SERVICE I-1	537.03	439.18	497.49	478.72	778.6	-886.8	OK	OK
11	SERVICE I-2	447.82	396.08	431.33	412.57	778.6	-886.8	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	2268.8	0.0	0.0	0.0	0.0	
DW1	0.0	0.0	0.0	0.0	0.0	
LLmax	663.2	16.7	0.0	0.0	0.0	
LLmin	-395.2	-14.1	0.0	0.0	0.0	
TUmax	-19.5	41.1	0.0	0.0	0.0	
TUmin	-18.4	-36.8	0.0	0.0	0.0	
EQ1-L	-248.6	644.9	0.0	193.5	0.0	
EQ1-T	-248.6	193.5	0.0	644.9	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.

3) Envelope of Member End Actions

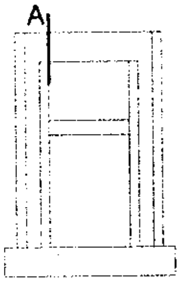
MEMBER	JOINT	TYPE	Nx (tf)	Sy (tf)	Sz (tf)	Mx (tf.m)	My (tf.m)	Mz (tf.m)
1	1	MAX	-827.45	439.095	428.68	53.4444	4446.96	8998.11
		CASE	12A	11	12B	11	10A	11
		MIN	-3712.03	-134.796	-445.06	-16.4483	-4433.29	-2770.29
		CASE	10B	12B	10A	12B	12B	12B
1	2	MAX	3477.97	128.055	422.59	16.4483	2218.37	2067.17
		CASE	10B	12B	10A	12B	10B	12B
		MIN	658.93	-416.625	-406.21	-53.4444	-2144.4	-6709.05
		CASE	12A	11	12B	11	12A	11
2	2	MAX	-658.93	416.625	406.21	53.4444	2144.4	6709.05
		CASE	12A	11	12B	11	12A	11
		MIN	-3477.97	-128.055	-422.59	-16.4483	-2218.37	-2067.17
		CASE	10B	12B	10A	12B	10B	12B
2	3	MAX	3106.1	117.345	386.89	16.4483	1314.21	1024.22
		CASE	10B	12B	10A	12B	10A	12B
		MIN	391.18	-380.925	-370.51	-53.4444	-1101.02	-3319.47
		CASE	12A	11	12B	11	12B	11
3	3	MAX	-633.83	377.775	577.69	60.029	129.03	3319.47
		CASE	12A	11	10B	11	12A	11
		MIN	-2807.01	-116.4	-268.99	-18.5522	-535.12	-1024.22
		CASE	10B	12B	12A	12B	10B	12B
3	4	MAX	2467.95	106.635	236.44	18.5522	1829.48	159.96
		CASE	10B	12B	12A	12B	12A	12B
		MIN	389.7	-345.225	-545.14	-60.029	-3815.84	-517.84
		CASE	12A	11	10B	11	10B	11
4	4	MAX	21.84	128.275	136.32	0	4633.54	60.03
		CASE	12A	11	12A	11	10B	11
		MIN	-330.54	-39.505	-1325.37	0	-2184.13	-18.56
		CASE	10B	12B	10B	12B	12A	12B
4	5	MAX	310.74	33.565	1119.12	0	2397.38	591.04
		CASE	10B	12B	10B	12B	1	11
		MIN	-2.04	-108.475	-284.82	0	907.29	-182.39
		CASE	12A	11	12A	11	2	12B
5	5	MAX	-22.39	33.565	1031.22	0	-907.29	182.39
		CASE	12B	12B	10A	13	2	12B
		MIN	-286.32	-108.475	-196.92	0	-2397.38	-591.04
		CASE	10A	11	12B	12B	1	11
5	6	MAX	306.12	128.275	48.42	0	1983.93	18.56
		CASE	10A	11	12B	12B	12B	12B
		MIN	2.59	-39.505	-1237.47	0	-4433.34	-60.03
		CASE	12B	12B	10A	13	10A	11
6	6	MAX	2207.4	106.635	520.72	60.029	3652.27	159.96
		CASE	1	12B	10A	11	10A	12B
		MIN	653.4	-345.225	-212.02	-18.5522	-1665.91	-517.84
		CASE	12B	11	12B	12B	12B	11
6	7	MAX	-897.53	377.775	244.57	18.5522	509.41	3319.47
		CASE	12B	11	12B	12B	10A	11
		MIN	-2546.47	-116.4	-553.27	-60.029	-103.32	-1024.22
		CASE	1	12B	10A	11	12B	12B

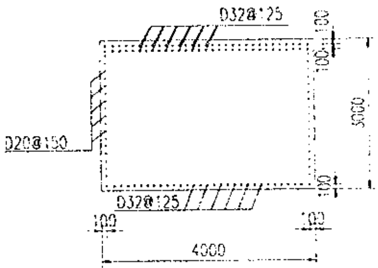
(Continued)

7	7	MAX	2842.4	117.345	372.59	53.4444	1125.33	1024.22
		CASE	10A	12B	12A	11	12A	12B
		MIN	654.88	-380.925	-388.97	-16.4483	-1338.52	-3319.47
		CASE	12B	11	10B	12B	10B	11
7	8	MAX	-922.63	416.625	424.67	16.4483	2211.79	6709.05
		CASE	12B	11	10B	12B	10A	11
		MIN	-3214.27	-128.055	-408.29	-53.4444	-2137.82	-2067.17
		CASE	10A	12B	12A	11	12B	12B
8	8	MAX	3214.27	128.055	408.29	53.4444	2137.82	2067.17
		CASE	10A	12B	12A	11	12B	12B
		MIN	922.63	-416.625	-424.67	-16.4483	-2211.79	-6709.05
		CASE	12B	11	10B	12B	10A	11
8	9	MAX	-1091.15	439.095	447.14	16.4483	4437.87	8998.11
		CASE	12B	11	10B	12B	12A	11
		MIN	-3448.33	-134.796	-430.76	-53.4444	-4451.54	-2770.29
		CASE	10A	12B	12A	11	10B	12B
9	3	MAX	243.89	3.15	242.65	0	979.86	4
		CASE	1	11	12A	11	10B	12B
		MIN	98.97	-0.945	-299.09	0	-899.85	-12.89
		CASE	2	10B	10B	10B	12A	11
9	10	MAX	-98.97	0	266.28	0	13.31	18.4
		CASE	2	12B	10B	10B	5	11
		MIN	-243.89	0	-266.28	0	7.83	-5.65
		CASE	1	13	10A	11	12B	12B
10	7	MAX	-98.97	3.15	242.65	0	898.45	12.89
		CASE	2	11	12B	12B	12B	11
		MIN	-243.89	-0.945	-299.09	0	-978.46	-4
		CASE	1	10B	10A	11	10A	12B
10	10	MAX	243.89	0	266.28	0	-7.83	5.65
		CASE	1	13	10A	11	12B	12B
		MIN	98.97	0	-266.28	0	-13.31	-18.4
		CASE	2	10B	10B	12B	5	11

(4) Flexural Resistance and Bar Arrangement

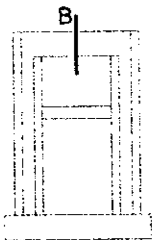
a) Section A

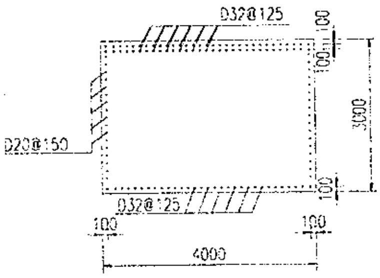




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	4633.5	2184.1	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number 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	

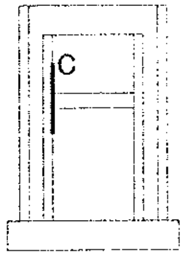
b) Section B

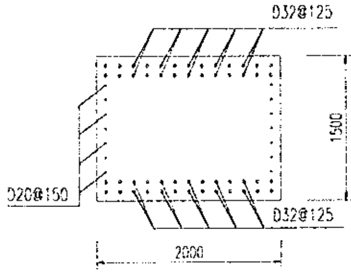




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	-907.3	2397.4	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			2	1	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number of tensile bars	n	(nos.)	64	32	
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	

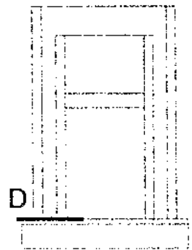
c) Section C

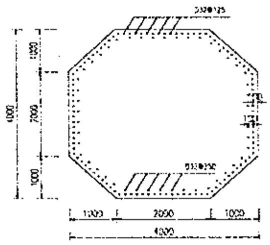




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	979.9	899.9	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	2	
Number of tensile bars	n	(nos.)	26	26	
Total Area of tensile reinforcement	Ast	(mm2)	20910	20910	
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**	
$\rho st = As_{tensile}/Ag$		%	**0.697**	**0.697**	

d) Section D

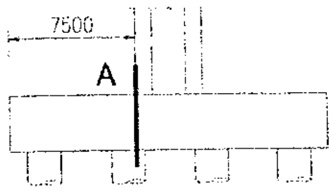


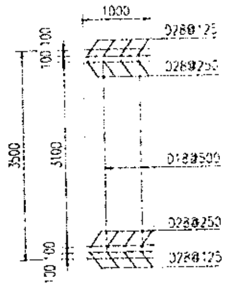


Item	Notation	Unit	Tensile Side			Remark
			Left	Right	Front	
Factored Loads						
Maximum Moment	M	(tf.m)	4447.0	4433.3	8998.1	
Factored Axial Force	N	(tf)	1,820.1	2,719.4	2,390.0	
Load case of Max. Moment			10A	12B	11	
Bar Arrangement						
Dia. of main reinforcement	Dm	(mm)		32		
Number of reinf. layers	nlay	(nos.)		2		
Number of bars	n	(nos.)				
In layer 1				106		
In layer 2				48		
In layer 3				-		
Flexural Resistance	Mr	(tf.m)	12917.1	14322.74	10267.39	
Axial Compressive Resistance	Nr	(tf.m)	5286.71	8785.72	2727.13	
Compressive Depth	c	(mm)	1350.81	1901.79	1004.65	
Resistance Factor	φ		0.820	0.781	0.795	
Checking Resistance			**OK**	**OK**	**OK**	
Checking Reinforcement Ratio			**OK**	**OK**	**OK**	
$\rho = As/Ag$		(%)	0.885	0.885	0.885	

(3) Design of Pile Cap

1) Sectional Analysis of "A"





Total width of section 24000 mm

Calculation width 1000 mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3500	
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	-5308854	EXTREME EVENT I-2
for Calculating Bottom Reinforcement	$Mu_{bot.}$	kN.mm	5783714	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	2244	EXTREME EVENT I-1
Coincidental moment	$Mu_{coin.}$	kN.mm	5783714	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	φtop	mm	28	
Area of 1 bar	A1s	mm2	615.8	
Numbers of Rebar	ns	nos	12	
Bottom Reinforcement				
Diameter	φbot.	mm	28	
Area of 1 bar	A1's	mm2	615.8	
Numbers of Rebar	n's	nos	12	
Shear Reinforcement				
Diameter	φv.	mm	18	
Area of 1 bar	A1v	mm2	254.5	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	508.9	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark	
Top Reinforcement					
Bending Moment	Mu_{top}	kN.mm	5308854		
Depth of Compressive Area	c	mm	145.236		
Flexural Resistance	Mr_{top}	kN.mm	8609150		
Checking Resistance			**OK**		
Checking Reinforcement Ratio					
$\rho st = As_{tensile}/(H.W)$		%	0.211		
$\rho min=0.03fc/fy$		%	0.185	OK	
Bottom Reinforcement					
Bending Moment	Mu_{bot}	kN.mm	5783714		
Depth of Compressive Area	c	mm	145.236		
Flexural Resistance	Mr_{bot}	kN.mm	8609150		
Checking Resistance			**OK**		
Checking Reinforcement Ratio					
$\rho st = As_{tensile}/(H.W)$		%	0.211		
$\rho min=0.03fc/fy$		%	0.185	OK	

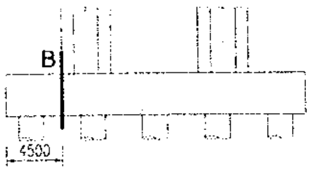
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

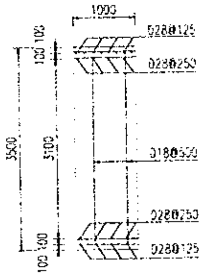
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	2243649	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2520	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		1.7	
Area of shear reinf. within a distance s	A_v	mm^2	509	
Strain in the tensile reinforcement	ε_x		0.002000	
Inclination angle of diagonal comp. stres	θ	degrees	43.00	
Shear stress on the concrete	v	MPa	0.989	
Area of Conc. on flexural tensile side	Act	mm^2	1750000	
Nominal Resistance of Concrete	V_c	N	1741940	
Nominal Resistance of Reinforcement	V_s	N	1072764	
Nominal Resistance	Vn	N	2,814,704	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,533,233	
Checking			**OK**	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			844145	Tensile at bottom
SERVICE I-2			167259	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.38	
SERVICE I-2			0.07	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-2.71	
SERVICE I-2			-0.54	
Checking Stress of Steel			OK	

2) Section Analysiss of "B"





Total width of section 19000 mm
Calculation width 1000 mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3500	
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	-1423213	EXTREME EVENT I-2
for Calculating Bottom Reinforcen	Mubot.	kN.mm	2248921	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	857	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	2248921	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	28	
Area of 1 bar	A1s	mm2	615.8	
Numbers of Rebar	ns	nos	12	
Bottom Reinforcement				
Diameter	ϕbot.	mm	28	
Area of 1 bar	A1's	mm2	615.8	
Numbers of Rebar	n's	nos	12	
Shear Reinforcement				
Diameter	ϕv.	mm	18	
Area of 1 bar	A1v	mm2	254.5	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	508.9	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1423213	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{top}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	2248921	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{bot}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	0.185	OK

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

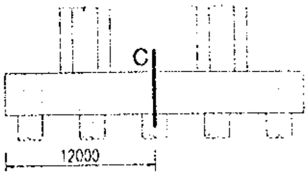
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

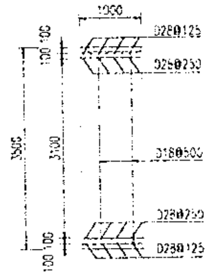
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	856933	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2520	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		2.3	
Area of shear reinf. within a distance s	A_v	mm^2	509	
Strain in the tensile reinforcement	ε_x		0.001003	
Inclination angle of diagonal comp. stres	θ	degrees	36.03	
Shear stress on the concrete	v	MPa	0.378	
Area of Conc. on flexural tensile side	Act	mm^2	1750000	
Nominal Resistance of Concrete	V_c	N	2356742	
Nominal Resistance of Reinforcement	V_s	N	1375374	
Nominal Resistance	Vn	N	3,732,116	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	3,358,905	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			541757	Tensile at bottom
SERVICE I-2			371019	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.24	
SERVICE I-2			0.17	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-1.74	
SERVICE I-2			-1.19	
Checking Stress of Steel			OK	

3) Section Analysis of "C"





Total width of section 19000 mm
Calculation width 1000 mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3500	
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	-2119787	EXTREME EVENT I-2
for Calculating Bottom Reinforcen	Mubot.	kN.mm	0	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	-1095	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	-2119787	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	28	
Area of 1 bar	A1s	mm2	615.8	
Numbers of Rebar	ns	nos	12	
Total Area of Top Reinf.	As	mm2	7389.0	
Concrete Cover	Cs	mm	100, 200	2 layers
Bottom Reinforcement				
Diameter	ϕbot.	mm	28	
Area of 1 bar	A1's	mm2	615.8	
Numbers of Rebar	n's	nos	12	
Total Area of Bottom Reinf.	A's	mm2	7389.0	
Concrete Cover	C's	mm	100, 200	2 layers
Shear Reinforcement				
Diameter	ϕv.	mm	18	
Area of 1 bar	A1v	mm2	254.5	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	508.9	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	2119787	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{top}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min = 0.03fc/fy$		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	0	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{bot}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min = 0.03fc/fy$		%	0.185	OK

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

f) Checking for Shear Resistance (AASHTO 5.8.3.3)

Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	1094888	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2520	
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		2.3	
Area of shear reinf. within a distance s	A_v	mm^2	509	
Strain in the tensile reinforcement	ε_x		0.001067	
Inclination angle of diagonal comp. stres	θ	degrees	36.67	
Shear stress on the concrete	v	MPa	0.483	
Area of Conc. on flexural tensile side	Act	mm^2	1750000	
Nominal Resistance of Concrete	V_c	N	2356742	
Nominal Resistance of Reinforcement	V_s	N	1343565	
Nominal Resistance	Vn	N	3,700,307	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	3,330,277	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			-1447483	Tensile at top
SERVICE I-2			-1310903	Tensile at top
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.65	
SERVICE I-2			0.59	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-4.65	
SERVICE I-2			-4.21	
Checking Stress of Steel			OK	

(4) Section Calculation of Pile

Dia : D1 =	2200 mm	L1 =	40.0 m
D2 =	2000 mm	L2 =	34.0 m
Length :	74.0 m		
Number :	16 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	43.61	604.43	0.00	22.12	635.03	0.00
STRENGTH I-2	-3.59	352.70	0.00	22.12	350.00	0.00
STRENGTH III	63.94	527.94	0.00	55.86	547.56	0.00
STRENGTH IV	17.95	674.11	0.00	22.12	683.39	0.00
STRENGTH V-1	50.85	585.52	0.00	31.76	614.18	0.00
STRENGTH V-2	14.52	357.20	0.00	31.76	355.62	0.00
EXTREME EVENT I-1	1193.48	-163.48	0.00	1258.73	-95.26	0.00
EXTREME EVENT I-2	1179.99	-354.60	0.00	1258.73	-297.59	0.00
EXTREME EVENT II	657.03	372.39	0.00	1350.70	200.91	0.00
SERVICE I-1	65.21	439.18	0.00	31.27	478.72	0.00
SERVICE I-2	36.10	396.08	0.00	31.27	412.57	0.00

2) Section Calculation

a) Distribution of Axial Force and Bending Moment in Composite Section

Diameter of Pile		2.20 m
Thickness of Casing		0.014 m (2mm corrosion assumed)
Es=	20000000	
Ec=	2500000	
n=Es/Ec=	8.00	
As0=	0.096761 m2	
Ac=	3.801327 m2	
Atrans=	4.575416 m2	
Is0=	0.059668 m4	
Ic0=	1.149901 m4	
Itrans=	1.627242 m4	
* Casing:	- Axial	16.92%
	- Bending	29.33%
* RC:	- Axial	83.08%
	- Bending	70.67%

b) General Conditions

Item	Notation	Unit	Value	Remark
Diameter of pile	D	mm	2200	
Steel Casing			Yes	
Number of Reinf. layers	n_{layer}	nos	1	
Concrete cover	cv	m	250	
Diameter of Rebars	d	mm	32	
Number of Rebars	n_{st}	nos	46	
Total Area of Reinforcement	A_{st}	mm2	36995	

c) Checking Resistance (AASHTO 5.7.2)

i) In longitudinal Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	604.43	502.17	8811.10	102.26	1844.8	OK
	M (tf.m)	43.61	30.82	540.42	12.79	230.79	OK
STRENGTH I-2	PN (tf)	352.70	293.03	-1258.50	59.67	2285.6	OK
	M (tf.m)	-3.59	-2.54	10.94	-1.05	-40.34	OK
STRENGTH III	PN (tf)	527.94	438.62	8491.16	89.32	1655.0	OK
	M (tf.m)	63.94	45.18	874.47	18.76	347.54	OK
STRENGTH IV	PN (tf)	674.11	560.06	9093.20	114.05	2065.0	OK
	M (tf.m)	17.95	12.68	205.91	5.27	95.34	OK
STRENGTH V-1	PN (tf)	585.52	486.46	8712.03	99.06	1783.4	OK
	M (tf.m)	50.85	35.93	643.48	14.92	268.55	OK
STRENGTH V-2	PN (tf)	357.20	296.77	9351.60	60.43	1991.8	OK
	M (tf.m)	14.52	10.26	323.42	4.26	140.38	OK
EXTREME EVENT I-1	PN (tf)	-163.48	-135.82	-161.26	-27.66	-102.9	OK
	M (tf.m)	1,193.48	843.38	1,001.34	350.10	1302.17	OK
EXTREME EVENT I-2	PN (tf)	-354.60	**-294.61**	**-313.18**	-59.99	-213.9	**OK**
	M (tf.m)	1,179.99	**833.85**	**886.41**	346.14	1233.91	**OK**
EXTREME EVENT II	PN (tf)	372.39	309.39	1203.72	63.00	371.6	OK
	M (tf.m)	657.03	464.29	1,806.37	192.74	1136.9	OK

ii) In Transverse Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	635.03	527.59	9074.67	107.44	2021.5	OK
	M (tf.m)	22.12	15.63	268.66	6.49	122.09	OK
STRENGTH I-2	PN (tf)	350.00	290.79	9173.38	59.21	1884.3	OK
	M (tf.m)	22.12	15.63	493.08	6.49	206.49	OK
STRENGTH III	PN (tf)	547.56	454.92	8628.97	92.64	1724.2	OK
	M (tf.m)	55.86	39.47	748.57	16.39	304.98	OK
STRENGTH IV	PN (tf)	683.39	567.77	9037.52	115.62	2034.4	OK
	M (tf.m)	22.12	15.63	248.53	6.49	114.18	OK
STRENGTH V-1	PN (tf)	614.18	510.27	8965.24	103.91	1937.6	OK
	M (tf.m)	31.76	22.44	393.84	9.32	173.73	OK
STRENGTH V-2	PN (tf)	355.62	295.45	8948.05	60.17	1773.5	OK
	M (tf.m)	31.76	22.44	679.24	9.32	274.63	OK
EXTREME EVENT I-1	PN (tf)	-95.26	-79.14	-93.62	-16.12	-58.0	OK
	M (tf.m)	1,258.73	889.49	1,052.25	369.24	1329.74	OK
EXTREME EVENT I-2	PN (tf)	-297.59	-247.24	-258.02	-50.35	-171.8	OK
	M (tf.m)	1,258.73	889.49	928.27	369.24	1259.79	OK
EXTREME EVENT II	PN (tf)	200.91	**166.92**	**218.01**	33.99	111.3	**OK**
	M (tf.m)	1,350.70	**954.48**	**1,246.65**	396.22	1297.0	**OK**

d) Checking Stress in RC portion

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	364.88	46.08	579.16	-23861	234.24	1101	OK
	Transverse	397.73	22.10	886.98	-23861	202.02	1101	
SERVICE I-2	Horizontal	329.07	25.51	668.19	-23861	180.84	1101	OK
	Transverse	342.77	22.10	736.65	-23861	179.89	1101	

e) Checking Minimum Steel Ratio

Item	Notation	Unit	Value	Remark
Total Area of Reinforcement	A_{st}	mm2	36995	
Gross Area of Section	Ag	mm2	3801327	
Reinforcement Ratio	ρst	%	**0.97**	
Minimum Reinforcement ratio	ρmin	%	**0.40**	**OK**

(5) Calculation of Footing Concrete Stress that Pile Connected

1) Vertical bearing stress of footing concrete

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

Reaction force of pile	P=	1311390 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Vertical bearing stress	σ_{cv}	34.50 kg/cm^2	
Allowable bearing stress	$\sigma_{ca}=0.5xf_c$ =	120.00 kg/cm^2	

σ_{cv} <= σ_{ca} --> OK

2) Vertical Punching Shear Stress

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

Reaction force of pile	P=	1311390 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Depth from pile head to upper surface of pile cap	h=	150 cm	
Punching shear stress	τ_c=	7.52 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

τ_c <= τ_a --> OK

3) Horizontal Bearing stress

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

Horizontal force at pile head	H=	85530 kg	Load Combination: 9
Diameter of Pile	D=	220 cm	
Embedded Length of Pile	l=	200 cm	
Horizontal bearing stress	σ_{ch}	1.94 kg/cm^2	
Allowable bearing stress	$\sigma_{ca}=0.3xf_c$ =	72.00 kg/cm^2	

σ_{ch} <= σ_{ca} --> OK

4) Horizontal Punching Shear Stress

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

Horizontal force at pile head	H=	85530 kg	Load Combination: 9
Diameter of Pile	D=	220 cm	
Distance from side of pile to the nearest edge of pile cap	h'=	90 cm	
Embedded Length of Pile	l=	200 cm	
Punching shear stress	τ_c=	1.19 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

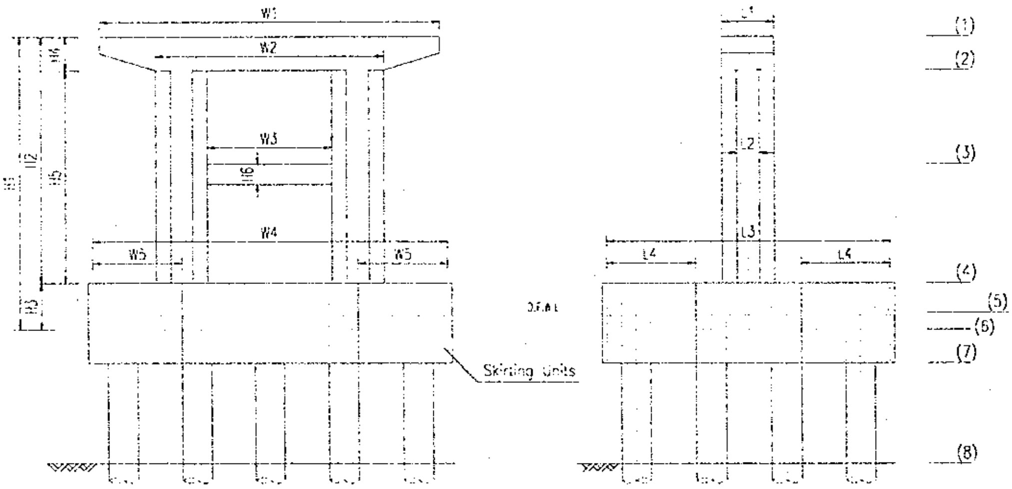
τ_c <= τ_a --> OK

3.13.7 Design of P17 pier

(1) Stabilty Calculation

1) Dimension of Piier

(Figure)	(m)			(Level)	(m)		
Portion	Length	Portion	Length	Portion	Level	Portion	Level
H1	21.88	W1	23.00	(1)	+22.38	(5)	+1.78
H2	18.38	W2	15.00	(2)	+19.38	(6)	+0.50
H3	3.50	W3	7.00	(3)	+12.38	(7)	-2.00
H4	3.00	L1	4.00	(4)	+4.00	(8)	-19.55
H5	15.38	W4	24.00				
H6	1.50	L2	1.50				
		L3	19.00				
		W5	6.00				
		L5	6.00				



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

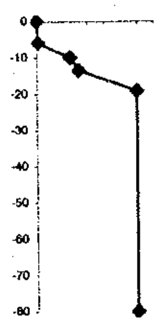
Load Combination		V	Longitudinal		Transverse	
		(tf)	H (tf)	M (tf.m)	H (tf)	M (tf.m)
1	STRENGTH I-1	9440.6	112.2	2455.9	32.5	274.3
2	STRENGTH I-2	5490.2	-1.1	-23.4	32.5	274.3
3	STRENGTH III	8320.9	75.1	1121.1	79.1	892.6
4	STRENGTH IV	10030.4	23.6	515.4	21.3	-13.0
5	STRENGTH V-1	9184.7	106.7	2185.5	48.8	532.5
6	STRENGTH V-2	5550.7	19.3	272.8	48.8	532.5
7	EXTREME EVENT I-1	8477.2	1433.8	20708.4	1433.2	20411.2
8	EXTREME EVENT I-2	5515.8	1401.4	20000.0	1433.2	20411.2
9	EXTREME EVENT II	8583.0	682.6	1393.1	1339.0	1746.4
10	SERVICE I-1	7207.6	108.8	2269.5	42.4	410.3
11	SERVICE I-2	6416.4	44.1	852.7	42.4	410.3

3) Pile Capacity

INPUT DATA

BoreHole			BRD15
Pile Diameter	D1	=	2200 mm
	D2	=	2000 mm
Factor of Safety	FS	=	3
Pile length	L	=	74.00 m
	L0	=	20.05 m
	L1	=	19.95 m
	L2	=	34.00 m
Pile Embedded Length	Le	=	53.95 m
Pile Cross-Section Circumference	P1	=	6.912 m
	P2	=	6.283 m
Pile Cross-Section Area	Ab1	=	3.801 m2
	Ab2	=	3.142 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 = Σ (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	11.95	2	Clay	0.70	1.0	1.0	83
2-1	8.00	2	Clay	1.00	12.0	2.0	111
2-2	15.50	2	Clay	1.00	12.0	2.0	195
3	7.00	2	Clay	1.05	25.0	15.0	660
4	11.50	1	Sand	1.20	60.0	20.0	1445
Total L =	53.95	m				Total Qs =	2493

END BEARING CAPACITY Formula: Qt = qu* Ab

Type of Pile		Soil Type of B.P	End Bearing Capacity		
Cast-in-situ	Friction & Bearing	Sand		942 tonne	

ULTIMATE BEARING CAPACITY (Qult)

* Qult = Qt + Qs 3435.3 tonne

REPLACED EFFECTIVE WEIGHT OF SOIL (Ws)

177.3 tonne

BUOYANT WEIGHT OF PILE (W)

464.5 tonne

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

* $Qall_1$ = (Qult - Ws) / FS + Ws - W 798.8 tonne

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

* $Qall_2$ = (Qult - Ws) / FS + Ws - W 1341.8 tonne

FS= 2

Design Uplift Capacity for Service Load Combinations (Qup_1)

* Qup_1 = Qs / FS + W 880.0 tonne

FS = 6

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

* Qup_2 = Qs / FS + W 1295.5 tonne

FS= 3

4) Reaction of Pile

a) Displacement

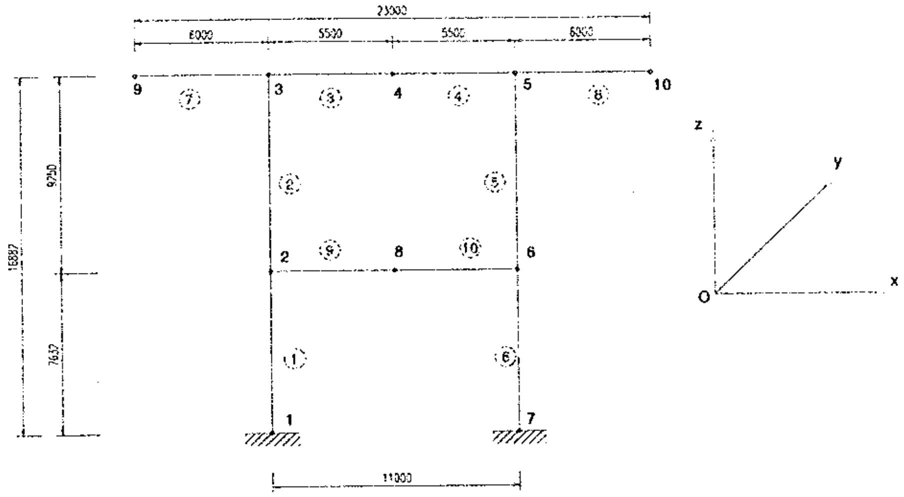
Load Combination		Longitudinal			Transverse			δ xa(cm)	Remark
		δ x(cm)	δ y(cm)	α (rad)	δ x(cm)	δ y(cm)	α (rad)		
1	STRENGTH I-1	0.16	0.72	0.000115	0.04	0.72	0.000014	3.00	OK
2	STRENGTH I-2	0.00	0.42	0.000000	0.04	0.42	0.000014	3.00	OK
3	STRENGTH III	0.10	0.63	0.000062	0.10	0.63	0.000039	3.00	OK
4	STRENGTH IV	0.03	0.76	0.000024	0.03	0.76	0.000006	3.00	OK
5	STRENGTH V-1	0.15	0.70	0.000105	0.06	0.70	0.000024	3.00	OK
6	STRENGTH V-2	0.03	0.42	0.000016	0.06	0.42	0.000024	3.00	OK
7	EXTREME EVENT I-1	1.97	0.64	0.001164	1.89	0.64	0.000788	2.00	OK
8	EXTREME EVENT I-2	1.92	0.42	0.001131	1.89	0.42	0.000788	2.00	OK
9	EXTREME EVENT II	0.89	0.65	0.000315	1.70	0.65	0.000403	3.00	OK
10	SERVICE I-1	0.23	0.55	0.000112	0.08	0.55	0.000021	1.50	OK
11	SERVICE I-2	0.09	0.49	0.000043	0.08	0.49	0.000021	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	661.01	519.07	601.78	578.29	1341.8	-1295.5	OK	OK
2	STRENGTH I-2	343.27	343.00	354.89	331.39	1341.8	-1295.5	OK	OK
3	STRENGTH III	558.42	481.69	552.22	487.89	1341.8	-1295.5	OK	OK
4	STRENGTH IV	641.81	611.99	631.53	622.27	1341.8	-1295.5	OK	OK
5	STRENGTH V-1	638.91	509.18	593.60	554.49	1341.8	-1295.5	OK	OK
6	STRENGTH V-2	356.51	337.33	366.48	327.36	1341.8	-1295.5	OK	OK
7	EXTREME EVENT I-1	1250.14	-190.49	1180.05	-120.40	1341.8	-1295.5	OK	OK
8	EXTREME EVENT I-2	1044.58	-355.10	994.96	-305.49	1341.8	-1295.5	OK	OK
9	EXTREME EVENT II	731.39	341.48	868.55	204.32	1341.8	-1295.5	OK	OK
10	SERVICE I-1	519.63	381.32	467.39	433.56	798.8	-880.0	OK	OK
11	SERVICE I-2	427.88	374.17	417.94	384.11	798.8	-880.0	OK	OK

(2) Design ofnPier 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

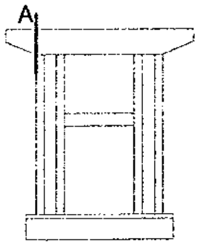
MEMBER	JOINT	TYPE	Nx (tf)	Sy (tf)	Sz (tf)	Mx (tf.m)	My (tf.m)	Mz (tf.m)
1	1	MAX	-772.29	496.167	496.26	17.4987	3818.75	7712.12
		CASE	12A	11	10B	13	12A	11
		MIN	-3027.85	-155.761	-477.22	-7.246	-3875.26	-2430.72
		CASE	10B	12B	12A	10B	10B	12B
1	2	MAX	2693.95	146.145	445.17	7.246	214.52	1278.64
		CASE	10B	12B	12A	10B	12B	12B
		MIN	531.88	-464.113	-464.21	-17.4987	-303.33	-4047.69
		CASE	12A	11	10B	13	10A	11
2	2	MAX	-666.77	459.304	411.85	7.3289	1107.11	4049.94
		CASE	12A	11	12B	13	12A	11
		MIN	-2494.42	-144.717	-499.31	-4.6161	-1215.34	-1279.29
		CASE	10B	12B	10A	10B	10B	12B
2	3	MAX	2155.36	134.952	466.76	4.6161	2668.14	195.58
		CASE	10B	12B	10A	10B	10A	12B
		MIN	422.64	-426.754	-379.3	-7.3289	-1882.17	-616.47
		CASE	12A	11	12B	13	12B	11
3	3	MAX	198.77	156.242	93.16	23.6656	4521.83	204.84
		CASE	10A	11	12A	11	10B	11
		MIN	-113.45	-49.112	-1266.4	-6.8553	-1916.46	-62.17
		CASE	12B	12B	10B	12B	12A	12B
3	4	MAX	71.38	36.272	793.24	6.8553	1120	507.15
		CASE	12B	12B	10B	12B	1	11
		MIN	-155.28	-112.622	-399.24	-23.6656	419.55	-164.71
		CASE	10A	11	12A	11	2	12B
4	4	MAX	168.18	37.299	710.84	23.6656	-421.06	164.71
		CASE	10B	12B	10A	11	12B	12B
		MIN	-84.99	-116.169	-445.32	-6.8553	-1124.6	-507.15
		CASE	12A	11	12B	12B	1	11
4	5	MAX	128.48	159.789	139.24	6.8553	2172.1	67.82
		CASE	12A	11	12B	12B	12B	12B
		MIN	-210.25	-50.139	-1184	-23.6656	-4057.69	-224.35
		CASE	10B	12B	10A	11	10A	11
5	5	MAX	1939.5	132.53	384.62	84.8837	2009.52	205.65
		CASE	10A	12B	12A	11	12A	12B
		MIN	297.77	-418.391	-464.97	-26.8618	-2499.07	-651.26
		CASE	12B	11	10B	12B	10B	11
5	6	MAX	-541.9	450.941	497.52	26.8618	1097.41	4019.91
		CASE	12B	11	10B	12B	12A	11
		MIN	-2278.57	-142.295	-417.17	-84.8837	-1230.58	-1270.59
		CASE	10A	12B	12A	11	10B	12B
6	6	MAX	2472.49	142.892	467.88	79.4162	427.72	1271.25
		CASE	10A	12B	10A	11	10B	12B
		MIN	404.27	-452.882	-441.74	-25.0557	-143.43	-4022.16
		CASE	12B	11	12B	12B	12A	11
6	7	MAX	-644.68	484.937	473.8	25.0557	3808.46	7600.87
		CASE	12B	11	12B	12B	12A	11
		MIN	-2806.39	-152.508	-499.94	-79.4162	-3893.24	-2398.49
		CASE	10A	12B	10A	11	10B	12B

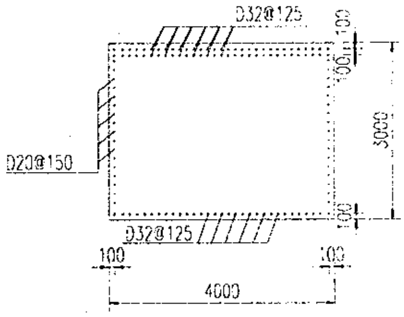
(Continued)

7	3	MAX	53.44	53.632	-370.65	0	-1291.77	57.86
		CASE	10A	11	12A	10B	12A	12B
		MIN	-51.31	-15.721	-668.12	0	-2463.52	-197.82
		CASE	10B	12B	5	13	5	11
7	9	MAX	0	0	0	0	0	0
		CASE	12B	11	12A	10B	10B	12B
		MIN	0	0	0	0	0	0
		CASE	12A	12B	10B	13	12A	11
8	5	MAX	41.6	41.722	-291.85	0	1737.76	139.46
		CASE	10A	11	12A	11	5	11
		MIN	-40.18	-12.271	-520.01	0	932.42	-40.96
		CASE	10B	12B	5	10B	12B	12B
8	10	MAX	0	0	0	0	0	0
		CASE	12B	13	12B	13	12B	12B
		MIN	0	0	0	0	0	0
		CASE	11	12B	10A	12B	10A	13
9	2	MAX	-40.28	4.809	134.89	2.2487	656.03	1.89
		CASE	12A	11	12A	11	10B	11
		MIN	-69.84	-1.428	-199.53	-0.6514	-572.12	-0.31
		CASE	5	12B	10B	12B	12A	4A
9	8	MAX	69.84	0.416	164.37	0.6514	31.25	9.82
		CASE	5	12B	10B	12B	5	11
		MIN	43.29	-1.434	-160.2	-2.2487	18.85	-3.2
		CASE	8B	11	12A	11	12A	12B
10	6	MAX	69.84	1.992	137.63	0.6514	582.5	8.87
		CASE	5	13	12B	12B	12B	11
		MIN	41.92	-0.648	-193.93	-2.2487	-635.1	-2.86
		CASE	12B	10B	10A	11	10A	12B
10	8	MAX	-43.29	1.434	160.2	2.2487	-18.85	3.2
		CASE	8B	11	12A	11	12A	12B
		MIN	-69.84	-0.416	-164.37	-0.6514	-31.25	-9.82
		CASE	5	12B	10B	12B	5	11

4) Flexural Resistance and Bar Arrangement

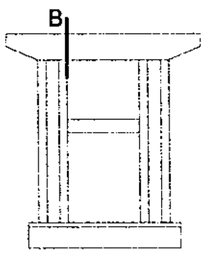
a) Section A

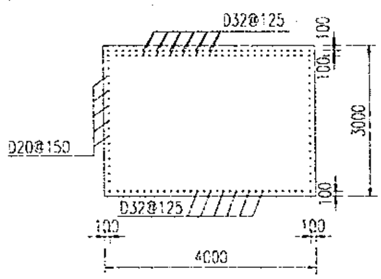




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	2463.5	-1291.8	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			5	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number 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	

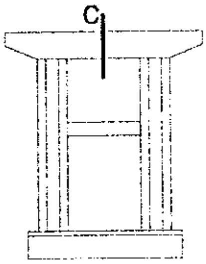
b) Section B

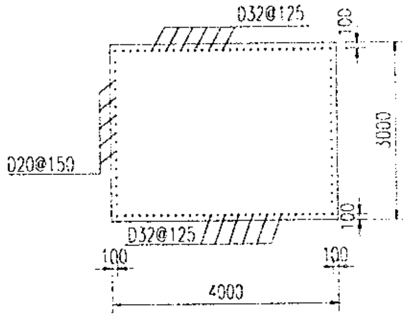




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	4521.8	1916.5	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number 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	

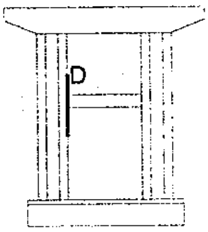
c) Section C

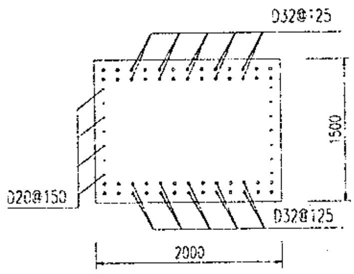




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	-421.1	1124.6	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			12B	1	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	1	
Number of tensile bars	n	(nos.)	64	32	
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	

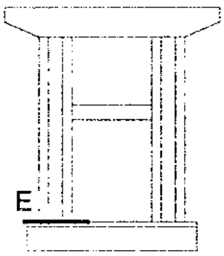
d) Section D

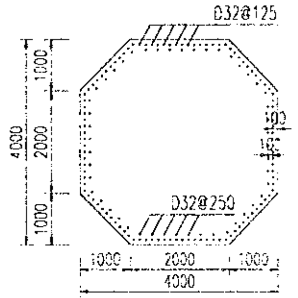




Item	Notation	Unit	Tensile Side		Remark
			Top	Bottom	
Factored Loads					
Maximum Moment	M	(tf.m)	656.0	572.1	
Factored Axial Force	N	(tf)	-	-	
Load case of Max. Moment			10B	12A	
Bar Arrangement					
Dia. of tensile reinforcement	Dm	(mm)	32	32	
Number of tensile reinf. layers	nlay	(nos.)	2	2	
Number 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

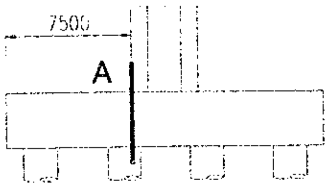


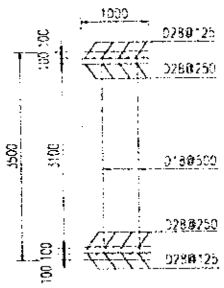


Item	Notation	Unit	Tensile Side			Remark
			Left	Right	Front	
Factored Loads						
Maximum Moment	M	(tf.m)	3818.8	3875.3	7712.1	
Factored Axial Force	N	(tf)	772.3	3,027.9	2,121.2	
Load case of Max. Moment			12A	10B	11	
Bar Arrangement						
Dia. of main reinforcement	Dm	(mm)		32		
Number of reinf. layers	nlay	(nos.)		2		
Number of bars	n	(nos.)				
In layer 1				106		
In layer 2				48		
Total Area of reinforcement	Ast	(mm2)		123854		
Bar spacing (inward)	@	(mm)		125,125		
Concrete Cover (inward)	cv	(mm)		100,200		
Resistance						
Flexural Resistance	Mr	(tf.m)	10122.1	14316.75	10572.12	
Axial Compressive Resistance	Nr	(tf.m)	2047.05	11186.32	2907.85	
Compressive Depth	c	(mm)	876.22	2278.55	1025.45	
Resistance Factor	φ		0.886	0.767	0.807	
Checking Resistance			**OK**	**OK**	**OK**	
Checking Reinforcement Ratio			**OK**	**OK**	**OK**	

(3) Design of Pile Cap

1) Section Analysis of "A"





Total width of section 24000 mm

Calculation width 1000 mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3500	
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	-5330704	EXTREME EVENT I-2
for Calculating Bottom Reinforcement	$Mu_{bot.}$	kN.mm	5319855	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	2067	EXTREME EVENT I-1
Coincidental moment	$Mu_{coin.}$	kN.mm	5319855	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	28	
Area of 1 bar	A1s	mm2	615.8	
Numbers of Rebar	ns	nos	12	
Bottom Reinforcement				
Diameter	ϕbot.	mm	28	
Area of 1 bar	A1's	mm2	615.8	
Numbers of Rebar	n's	nos	12	
Shear Reinforcement				
Diameter	ϕv.	mm	18	
Area of 1 bar	A1v	mm2	254.5	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	508.9	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	5330704	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{top}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min = 0.03fc/fy$		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	5319855	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{bot}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min = 0.03fc/fy$		%	0.185	OK

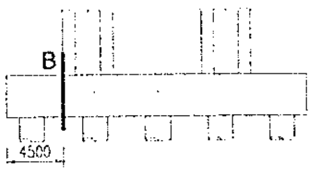
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

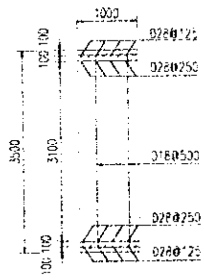
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	2066749	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2520	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		1.7	
Area of shear reinf. within a distance s	A_v	mm^2	509	
Strain in the tensile reinforcement	ε_x		0.002000	
Inclination angle of diagonal comp. stress	θ	degrees	43.00	
Shear stress on the concrete	v	MPa	0.911	
Area of Conc. on flexural tensile side	Act	mm^2	1750000	
Nominal Resistance of Concrete	V_c	N	1741940	
Nominal Resistance of Reinforcement	V_s	N	1072764	
Nominal Resistance	Vn	N	2,814,704	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,533,233	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			695282	Tensile at bottom
SERVICE I-2			11783	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.31	
SERVICE I-2			0.01	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-2.23	
SERVICE I-2			-0.04	
Checking Stress of Steel			OK	

2) Section Analysis of "B"





Total width of section	19000	mm
Calculation width	1000	mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3500	
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	-1443600	EXTREME EVENT I-2
for Calculating Bottom Reinforcem	Mubot.	kN.mm	2086028	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	792	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	2086028	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	28	
Area of 1 bar	A1s	mm2	615.8	
Numbers of Rebar	ns	nos	12	
Bottom Reinforcement				
Diameter	ϕbot.	mm	28	
Area of 1 bar	A1's	mm2	615.8	
Numbers of Rebar	n's	nos	12	
Total Area of Bottom Reinf.	A's	mm2	7389.0	
Concrete Cover	C's	mm	100, 200	2 layers
Shear Reinforcement				
Diameter	ϕv.	mm	18	
Area of 1 bar	A1v	mm2	254.5	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	508.9	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1443600	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{top}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	2086028	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{bot}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	0.185	OK

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

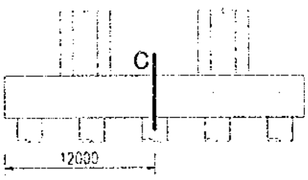
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

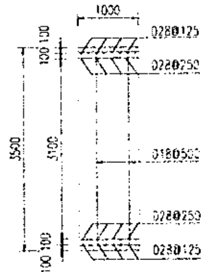
Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	791775	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2520	
Effective web width	b_v	mm	1000	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally cracked concrete to transmit tension	β		2.3	
Area of shear reinf. within a distance s	A_v	mm^2	509	
Strain in the tensile reinforcement	ε_x		0.000939	
Inclination angle of diagonal comp. stress	θ	degrees	35.27	
Shear stress on the concrete	v	MPa	0.349	
Area of Conc. on flexural tensile side	Act	mm^2	1750000	
Nominal Resistance of Concrete	V_c	N	2356742	
Nominal Resistance of Reinforcement	V_s	N	1414441	
Nominal Resistance	Vn	N	3,771,183	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	3,394,065	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			464079	Tensile at bottom
SERVICE I-2			336464	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.21	
SERVICE I-2			0.15	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-1.49	
SERVICE I-2			-1.08	
Checking Stress of Steel			OK	

3) Section Analysis of "C"





Total width of section	19000 mm
Calculation width	1000 mm

a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	1000	
Height	H	mm	3500	
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	-1991455	EXTREME EVENT I-2
for Calculating Bottom Reinforcem	Mubot.	kN.mm	0	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	-1035	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	-1991455	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	28	
Area of 1 bar	A1s	mm2	615.8	
Numbers of Rebar	ns	nos	12	
Bottom Reinforcement				
Diameter	ϕbot.	mm	28	
Area of 1 bar	A1's	mm2	615.8	
Numbers of Rebar	n's	nos	12	
Shear Reinforcement				
Diameter	ϕv.	mm	18	
Area of 1 bar	A1v	mm2	254.5	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	508.9	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1991455	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{top}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	0	
Depth of Compressive Area	c	mm	145.236	
Flexural Resistance	Mr_{bot}	kN.mm	8609150	
Checking Resistance			OK	
Checking Reinforcement Ratio				
$\rho st = As_{tensile}/(H.W)$		%	0.211	
$\rho min=0.03fc/fy$		%	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	1035077	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2520	
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		2.3	
Area of shear reinf. within a distance s	A_v	mm^2	509	
Strain in the tensile reinforcement	ε_x		0.001014	
Inclination angle of diagonal comp. stress	θ	degrees	36.14	
Shear stress on the concrete	v	MPa	0.456	
Area of Conc. on flexural tensile side	Act	mm^2	1750000	
Nominal Resistance of Concrete	V_c	N	2356742	
Nominal Resistance of Reinforcement	V_s	N	1369838	
Nominal Resistance	Vn	N	3,726,580	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	3,353,922	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			-1369794	Tensile at top
SERVICE I-2			-1267702	Tensile at top
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.61	
SERVICE I-2			0.57	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-4.40	
SERVICE I-2			-4.57	
Checking Stress of Steel			OK	

(4) Section Calculation of Pile

Dia : D1 = 2200 mm L1 = 40.0 m

D2 = 2000 mm L2 = 34.0 m

Length : 74.0 m

Number : 16 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	83.07	519.07	0.00	26.91	578.29	0.00
STRENGTH I-2	1.02	343.00	0.00	26.91	331.39	0.00
STRENGTH III	57.82	481.69	0.00	64.84	487.89	0.00
STRENGTH IV	17.48	611.99	0.00	18.19	622.27	0.00
STRENGTH V-1	79.63	509.18	0.00	40.06	554.49	0.00
STRENGTH V-2	14.92	337.33	0.00	40.06	327.36	0.00
EXTREME EVENT I-1	1106.79	-190.49	0.00	1162.64	-120.40	0.00
EXTREME EVENT I-2	1082.79	-355.10	0.00	1162.64	-305.49	0.00
EXTREME EVENT II	562.78	341.48	0.00	1136.28	204.32	0.00
SERVICE I-1	88.67	381.32	0.00	37.79	433.56	0.00
SERVICE I-2	36.21	374.17	0.00	37.79	384.11	0.00

2) Section Calculation

a) General Condition

Item	Notation	Unit	Value	Remark
Diameter of pile	D	mm	2200	
Steel Casing			Yes	
Number of Reinf. layers	n_{layer}	nos	1	
Concrete cover	cv	m	250	
Diameter of Rebars	d	mm	32	
Number of Rebars	n_{st}	nos	46	
Total Area of Reinforcement	A_{st}	mm2	36995	

b) Distribution of Axial Force and Bending Moment in Composite Section

Diameter of Pile 2.20 m

Thickness of Casing 0.014 m (2mm corrosion assumed)

Es= 20000000

Ec= 2500000

n=Es/Ec= 8.00

As0= 0.096761 m2

Ac= 3.801327 m2

Atrans= 4.575416 m2

Is0= 0.059668 m4

Itrans= 1.627242 m4

* Casing: - Axial 16.92%

- Bending 29.33%

* RC: - Axial 83.08%

- Bending 70.67%

c) Checking Resistance (AASHTO 5.7.2)

i) In longitudinal Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	519.07	431.25	8129.16	87.82	1529.9	OK
	M (tf.m)	83.07	0.00	1,106.31	24.37	424.51	OK
STRENGTH I-2	PN (tf)	343.00	284.97	9715.37	58.03	2201.6	OK
	M (tf.m)	1.02	0.00	24.88	0.30	11.35	OK
STRENGTH III	PN (tf)	481.69	400.20	8505.57	81.49	1658.7	OK
	M (tf.m)	57.82	0.00	868.31	16.96	345.23	OK
STRENGTH IV	PN (tf)	611.99	508.45	9102.88	103.54	2054.6	OK
	M (tf.m)	17.48	0.00	221.44	5.13	101.75	OK
STRENGTH V-1	PN (tf)	509.18	423.03	8169.79	86.15	1540.8	OK
	M (tf.m)	79.63	0.00	1,086.82	23.36	417.79	OK
STRENGTH V-2	PN (tf)	337.33	280.26	9295.94	57.07	1973.9	OK
	M (tf.m)	14.92	0.00	349.97	4.38	151.38	OK
EXTREME EVENT I-1	PN (tf)	-190.49	-158.26	-189.60	-32.23	-127.7	OK
	M (tf.m)	1,106.79	0.00	936.99	324.67	1286.87	OK
EXTREME EVENT I-2	PN (tf)	-355.10	**-295.02**	**-321.69**	-60.08	-231.3	**OK**
	M (tf.m)	1,082.79	**0.00**	**834.33**	317.63	1223.15	**OK**
EXTREME EVENT II	PN (tf)	341.48	283.71	1304.93	57.77	393.2	OK
	M (tf.m)	562.78	0.00	1,829.17	165.09	1123.6	OK

ii) In Transverse Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	578.29	480.45	8999.97	97.84	1962.6	OK
	M (tf.m)	26.91	0.00	356.21	7.89	158.35	OK
STRENGTH I-2	PN (tf)	331.39	275.32	8995.61	56.07	1806.5	OK
	M (tf.m)	26.91	0.00	621.73	7.89	254.35	OK
STRENGTH III	PN (tf)	487.89	405.35	8390.54	82.54	1615.0	OK
	M (tf.m)	64.84	0.00	948.45	19.02	372.14	OK
STRENGTH IV	PN (tf)	622.27	516.99	9085.85	105.28	2051.0	OK
	M (tf.m)	18.19	0.00	225.93	5.34	103.95	OK
STRENGTH V-1	PN (tf)	554.49	460.68	8820.08	93.81	1844.4	OK
	M (tf.m)	40.06	0.00	542.07	11.75	231.04	OK
STRENGTH V-2	PN (tf)	327.36	271.98	8651.08	55.38	1650.6	OK
	M (tf.m)	40.06	0.00	900.59	11.75	350.23	OK
EXTREME EVENT I-1	PN (tf)	-120.40	-100.03	-120.37	-20.37	-78.7	OK
	M (tf.m)	1,162.64	0.00	988.64	341.05	1317.06	OK
EXTREME EVENT I-2	PN (tf)	-305.49	-253.81	-270.22	-51.68	-189.3	OK
	M (tf.m)	1,162.64	0.00	874.69	341.05	1249.02	OK
EXTREME EVENT II	PN (tf)	204.32	**169.75**	**261.21**	34.57	133.1	**OK**
	M (tf.m)	1,136.28	**0.00**	**1,235.59**	333.32	1283.6	**OK**

d) Checking Stress in RC portion

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	316.81	0.00	298.10	-23861	247.23	1101	OK
	Transverse	360.21	0.00	745.34	-23861	196.36	1101	
SERVICE I-2	Horizontal	310.87	0.00	620.01	-23861	174.31	1101	OK
	Transverse	319.12	0.00	632.53	-23861	179.76	1101	

e) Checking Minimum Steel Ratio

Item	Notation	Unit	Value	Remark
Total Area of Reinforcement	A_{st}	mm2	36995	
Gross Area of Section	Ag	mm2	3801327	
Reinforcement Ratio	ρst	%	**0.97**	
Minimum Reinforcement ratio	ρmin	%	**0.40**	OK

(5) Calculation of Footing Concrete Stress that Pile connected

1) Vertical bearing stress of footing concrete

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

Reaction force of pile	P=	1250140 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Vertical bearing stress	σ_{cv}	32.89 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

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

Reaction force of pile	P=	1250140 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Depth from pile head to upper surface of pile cap	h=	150 cm	
Punching shear stress	τ_c=	7.17 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

τ_c <= τ_a --> OK

3) Horizontal Bearing stress

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

Horizontal force at pile head	H=	89610 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Embedded Length of Pile	l=	200 cm	
Horizontal bearing stress	σ_{ch}	2.04 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

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

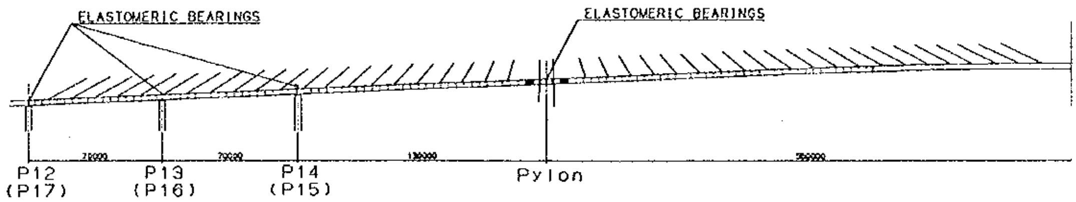
Horizontal force at pile head	H=	89610 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Distance from side of pile to the nearest edge of pile cap	h'=	90 cm	
Embedded Length of Pile	l=	200 cm	
Punching shear stress	τ_c=	1.24 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

τ_c <= τ_a --> OK

3.14 Design of Bearings

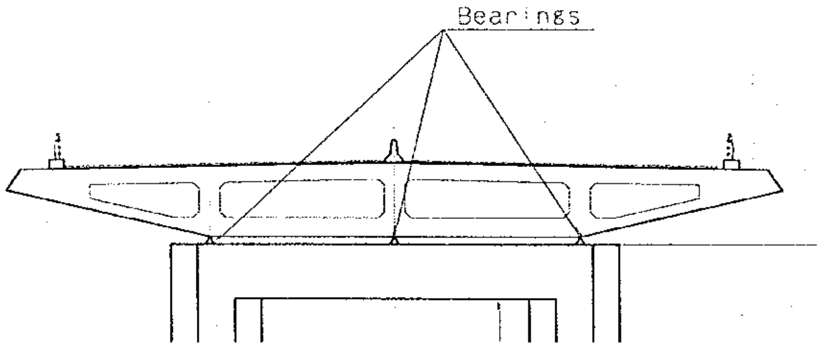
3.14.1 Design Condition

(1) Arrangement of Bearings

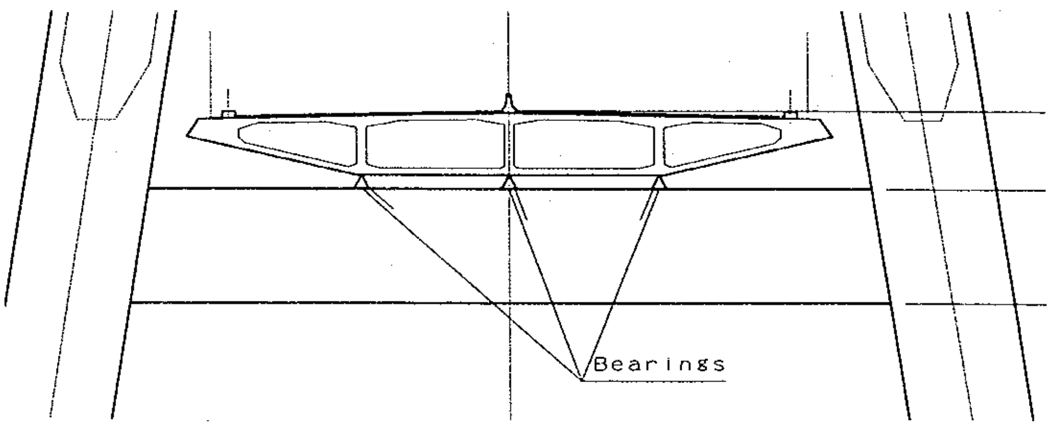


	Type of Bearings	Nos of Bearings
P12 (P17)	Elastomeric Bearings	3
P13 (P16)	Elastomeric Bearings	3
P14 (P15)	Elastomeric Bearings	3
Pylon (North, South)	Elastomeric Bearings	3

P12,P13,P14 (P15,P16,P17)



Pylon (Northern, Southern)



(2) Reaction and Displacement

1) Reaction (each Bearings)

		P12(P17)	P13(P16)	P14(P15)	Pylon
Virtical Load	Dead Load (DC+DW+CR+SH)	2180	7630	5441	10144
	Live Load (LL + IM)	3432	3994	4110	3204
Horizontal Load (EQ)		1258	1361	1226	3308

Unit : kN

2) Displacement

		P12(P17)	P13(P16)	P14(P15)	Pylon
Temperature Effect	+15deg	62.7	47.85	-3.3	3.0
	-15deg	-186.8	-170.6	-190.4	-126.6
Earthquake		400	400	400	400.0

Unit : mm

(3) Specification

Table Specification of Bearings

		Sign	Unit	P12(P17)	P13(P16)	P14(P15)	Pylon
Classificaion of Rubber				NR	NR	NR	NR
Elastic Module		G	N/mm^2	0.78	0.78	0.78	1.18
Breaking Elongation		γu	%	500	500	500	400
Shape Factor		S	-----	9.17	10	9.82	12.08
Appearent Elastic Module		E	N/mm^2	433.6	515.6	497.4	137.2
Stiffeness of Bearings	Horizontal	KB	kN/mm	3.15	3.4	3.06	8.27
	Virtical	KV	kN/mm	1749.00	2250	1954	7970.00

(4) Dimension

Table Dimension of Bearings

	Sign	Unit	P12(P17)	P13(P16)	P14(P15)	Pylon
Width of Bearings						
Longitusinal	b	(mm)	1100	1200	1100	1450
Transverse	a	(mm)	1100	1200	1100	1450
Rubber						
Thickness of each Rubber Layer	te	(mm)	30	30	28	30
Numbers of Rubber Layer	n		10	11	11	10
Total Thickness	Σte	(mm)	300	330	308	300
Reinforce Parts	ts	(mm)	4.5	4.5	4.5	4.5

3.14.2 Calculation Result

Calculation Result at P12, P17 (each Bearings)

		Sign	Unit	Longitudinal	Transverse	Allowable	
Bearing Area	Effective	A	m^2	1.2100	1.2100	-----	
	Ordinaty	Ao	m^2	1.0730	-----	-----	
	Eathquake	Ae	m^2	0.7584	1.2100	-----	
Strain	Effective	δ	mm	1.90	-----	-----	
	Ordinaty	δo	mm	2.14	-----	-----	
Maximum Compressive Stress	Ordinaty	σmax.o	N/mm^2	3.09	-----	≦	8.0
	Earthquake	σmax.e	N/mm^2	2.96	1.91		12.0
Minimum Compressive Stress	Ordinaty	σmin	N/mm^2	1.48	-----	-----	
Range of Compressive Stress	Ordinaty	⊿σ	N/mm^2	1.62	-----	≦	5.0
Buckling Stress	Ordinaty	σcra	N/mm^2	10.49	-----	≧	3.09
Rotation Strain	Ordinaty	δr	mm	1.83	-----	-----	
Compressive Strain	Ordinaty	δc	mm	1.90	-----	≧	1.83
Local Shear Strain	Virtical	γc	%	55.5	-----	-----	
	Horizontal	γs	%	41.5	-----	≦	70
	Rotation	γr	%	22.4	-----	-----	
	Total	γt	%	119.4	-----	≦	333.3
Local Shear Strain (EQ)	Horizontal	γse	%	136.8	0.0	≦	150

Calculation Result at P13, P16 (each Bearings)

		Sign	Unit	Longitudinal	Transverse	Allowable	
Bearing Area	Effective	A	m^2	1.4400	1.4400	-----	
	Ordinaty	Ao	m^2	1.3035	-----	-----	
	Eathquake	Ae	m^2	0.9482	1.4400	-----	
Strain	Effective	δ	mm	4.36	-----	-----	
	Ordinaty	δo		4.81	-----	-----	
Maximum Compressive Stress	Ordinaty	σmax.o	N/mm^2	7.52	-----	≦	8.0
	Earthquake	σmax.e	N/mm^2	8.29	5.63		12.0
Minimum Compressive Stress	Ordinaty	σmin	N/mm^2	4.40	-----	-----	
Range of Compressive Stress	Ordinaty	⊿σ	N/mm^2	3.12	-----	≦	5.0
Buckling Stress	Ordinaty	σcra	N/mm^2	11.35	-----	≧	7.52
Rotation Strain	Ordinaty	δr	mm	1.00	-----	-----	
Compressive Strain	Ordinaty	δc	mm	4.36	-----	≧	1.00
Local Shear Strain	Virtical	γc	%	123.9	-----	-----	
	Horizontal	γs	%	34.5	-----	≦	70
	Rotation	γr	%	12.1	-----	-----	
	Total	γt	%	170.5	-----	≦	333.3
Local Shear Strain (EQ)	Horizontal	γse	%	124.2	0.0	≦	150

Calculation Result at P14, P15 (each Bearings)

		Sign	Unit	Longitudinal	Transverse	Allowable	
Bearing Area	Effective	A	m^2	1.2100	1.2100	-----	
	Ordinaty	Ao	m^2	1.7040	-----	-----	
	Eathquake	Ae	m^2	0.7340	1.2100	-----	
Strain	Effective	δ	mm	3.95	-----	-----	
	Ordinaty	δo	mm	4.46	-----	-----	
Maximum Compressive Stress	Ordinaty	σmax.o	N/mm^2	7.20	-----	≦	8.0
	Earthquake	σmax.e	N/mm^2	7.64	4.77		12.0
Minimum Compressive Stress	Ordinaty	σmin	N/mm^2	2.74	0.00	-----	
Range of Compressive Stress	Ordinaty	⊿σ	N/mm^2	4.46	0.00	≦	5.0
Buckling Stress	Ordinaty	σcra	N/mm^2	10.94	-----	≧	7.20
Rotation Strain	Ordinaty	δr	mm	0.92	-----	-----	
Compressive Strain	Ordinaty	δc	mm	3.95	-----	≧	0.92
Local Shear Strain	Virtical	γc	%	120.9	-----	-----	
	Horizontal	γs	%	41.2	-----	≦	70
	Rotation	γr	%	11.7	-----	-----	
	Total	γt	%	173.8	-----	≦	333.3
Local Shear Strain (EQ)	Horizontal	γse	%	140.5	0.0	≦	150

Calculation Result at Northen Pylon, Southern Pylon (each Bearings)

		Sign	Unit	Longitudinal	Transverse	Allowable	
Bearing Area	Effective	A	m^2	2.1025	2.1025	-----	
	Ordinaty	Ao	m^2	1.9801	-----	-----	
	Eathquake	Ae	m^2	1.5127	2.1025	-----	
Strain	Effective	δ	mm	1.34	-----	-----	
	Ordinaty	δo	mm	1.43	-----	-----	
Maximum Compressive Stress	Ordinaty	σmax.o	N/mm^2	5.40	-----	≦	8.0
	Earthquake	σmax.e	N/mm^2	6.91	5.12		12.0
Minimum Compressive Stress	Ordinaty	σmin	N/mm^2	4.82	-----	-----	
Range of Compressive Stress	Ordinaty	⊿σ	N/mm^2	0.58	-----	≦	5.0
Buckling Stress	Ordinaty	σcra	N/mm^2	27.57	-----	≧	5.40
Rotation Strain	Ordinaty	δr	mm	1.21	-----	-----	
Compressive Strain	Ordinaty	δc	mm	1.34	-----	≧	1.21
Local Shear Strain	Virtical	γc	%	48.8	-----	-----	
	Horizontal	γs	%	28.1	-----	≦	70
	Rotation	γr	%	19.5	-----	-----	
	Total	γt	%	96.4	-----	≦	266.7
Local Shear Strain (EQ)	Horizontal	γse	%	135.6	0.0	≦	150

3.15 Design of Expansion Joint

3.15.1 Design Conditions

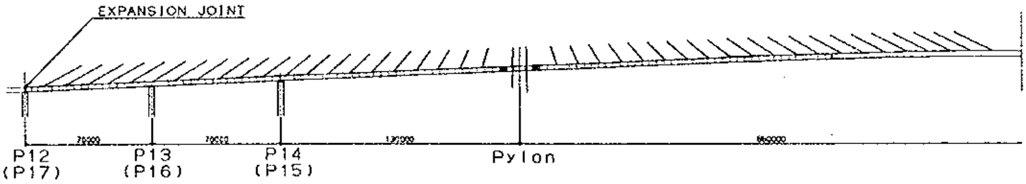
Type of Expansion Joint : Maurer Joint

Displacement at P12, P17

Cause		P12		P17	
		PC I-Girder	Cable Stayed Bridge	Cable Stayed Bridge	PC I-Girder
Creep (at the end)		3.66	-8.99	6.2	-7.33
Temperature Effect	+15 deg	5.99	-124.86	125.55	-11.99
	-15 deg	-5.99	124.86	-125.55	11.99
Sub-Total	+15 deg	9.65	-133.85	131.75	-19.31
	-15 deg	-2.33	115.87	-119.35	4.66
Total	+15 deg	143.50		151.06	
	-15 deg	118.20		124.01	

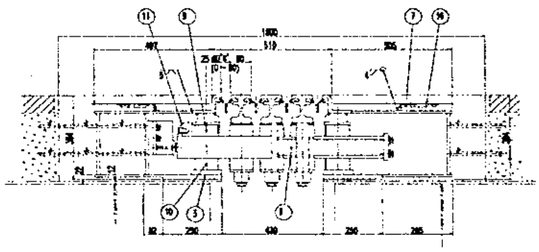
Displace from P12 to P17 : Plus
P17 to P12 : Minus

Expansion Spacing : 160 mm (P12)
160 mm (P17)

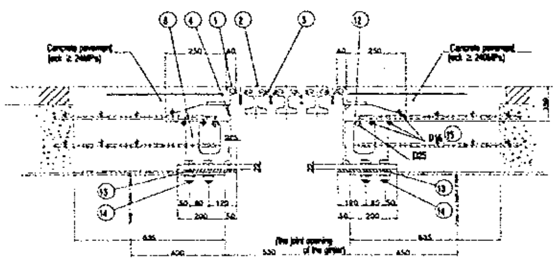


3.15.2 Detail of Expansion Joint

At the Support Beam



Intermediate



1. End Beam
2. Middle Beam
3. Sealing Rubber
4. Web
5. Lower Flange
6. Rib
7. Support Wire-net
8. Support Beam
9. Upper Bearing
10. Lower Bearing
11. Stopper
12. Anchor
13. Liner
14. HTB
15. Bars
16. Welded Wire-net