(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=	747660 kg	Load Combination: 7
Diameter of Pile	D=	170 cm	
Vertical bearing stress	σ_{cv}	32.94 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=	747660 kg	Load Combination: 7
Diameter of Pile	D=	170 cm	
Depth from pile head to upper surface of pile cap	h=	100 cm	
Punching shear stress	τ_c=	8.81 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=	51680 kg	Load Combination: 7
Diameter of Pile	D=	170 cm	
Embedded Length of Pile	l=	200 cm	
Horizontal bearing stress	σ_{ch}	1.52 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=	51680 kg	Load Combination: 7
Diameter of Pile	D=	170 cm	
Distance from side of pile to the nearest edge of pile cap	h'=	75 cm	
Embedded Length of Pile	l=	200 cm	
Punching shear stress	τ_c=	0.96 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

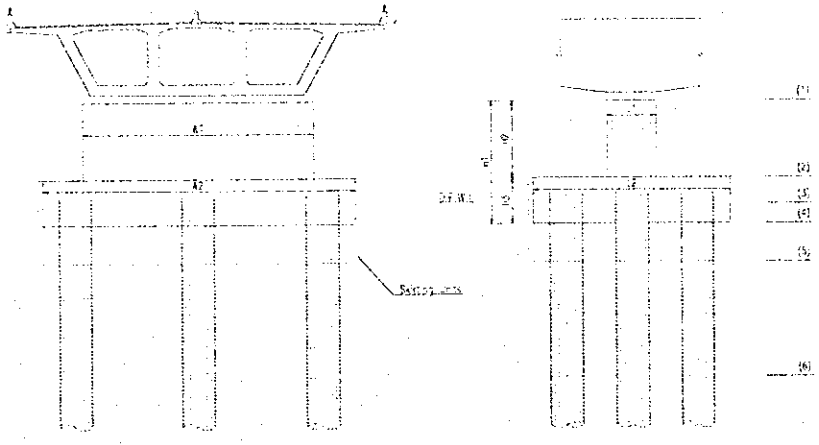
τ_c <= τ_a --> OK

5.3.3 Design of P37(P40) pier

(1) Stability Calculation

1) Dimension of Pier

(Figure)		(m)			(Level)	(m)	
Portion	Length	Portion	Length	Portion	Level	Portion	Level
H1	6.42	L1	3.00	(1)	+6.92	(5)	-2.00
H2	3.42	W2	19.00	(2)	+3.50	(6)	-4.74
H3	3.00	L2	14.00	(3)	+1.78		
W1	14.00			(4)	+0.50		



2) Summary of Loads Combiation Force at the Bottom of Pile Cap

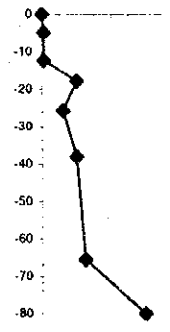
Load Combination		V (tf)	Longitudinal		Transverse	
			H (tf)	M (tf.m)	H (tf)	M (tf.m)
1	STRENGTH I-1	9883.0	0.0	0.0	0.0	0.0
2	STRENGTH I-2	5877.1	0.0	0.0	0.0	0.0
3	STRENGTH III	8868.1	22.2	80.8	9.6	27.7
4	STRENGTH IV	10584.1	0.0	0.0	0.0	0.0
5	STRENGTH V-1	9651.0	6.3	23.1	2.7	7.9
6	STRENGTH V-2	5920.9	6.3	23.1	2.7	7.9
7	EXTREME EVENT I-1	9144.7	879.7	4144.5	879.7	4144.5
8	EXTREME EVENT I-2	6000.7	879.7	4144.5	879.7	4144.5
9	EXTREME EVENT II	9154.9	437.4	558.1	874.7	1116.2
10	SERVICE I-1	7504.9	4.7	17.3	2.1	5.9
11	SERVICE I-2	6815.4	4.7	17.3	2.1	5.9

3) pile Capacity

INPUT DATA

BoreHole			BRD17
Pile Diameter	D1	=	2200 mm
	D2	=	2000 mm
Factor of Safety	FS	=	3
Pile length	L	=	78.00 m
	L0	=	5.24 m
	L1	=	9.76 m
	L2	=	63.00 m
Pile Embedded Length	Le	=	72.76 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	=	135 t/m2
Soil Type of Bearing Layer			2 (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)
1-1	9.76	2	Clay	0.70	1.0	1.0	67
1-2	5.16	2	Clay	1.00	1.0	1.0	32
2	5.60	2	Clay	0.90	20.0	1.0	35
3	10.40	2	Clay	1.00	12.0	2.0	131
4	14.10	2	Clay	0.90	20.0	1.0	89
5	27.74	2	Clay	1.00	25.0	15.0	2614
Total L =	72.76	m				Total Qs =	2969

END BEARING CAPACITY Formula: Qt = qu* Ab

Type of Pile		Soil Type of B.P	End Bearing Capacity		
Cast-in-situ	Friction & Bearing	Clay		424 tonne	

Ultimate Bearibg Capacity (Qult)

* Qult = Qt + Qs 3392.9 tonne

Replaced Effective Weight of Soil (Ws)

221.1 tonne

Buoyant Weight of Pile (W)

402.3 tonne

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

* $Qall_1$ = (Qult - Ws) / FS + Ws - W 876.0 tonne

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

* $Qall_2$ = (Qult - Ws) / FS + Ws - W 1404.7 tonne

FS= 2

Design Uplift Caacity for Service Load Combinations (Qup_1)

* Qup_1 = Qs / FS + W 897.1 tonne

FS = 6

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

* Qup_2 = Qs / FS + W 1391.9 tonne

FS= 3

4) Reaction of Pile

a) Displacement

Load Combination		Longitudinal			Transverse			δ xa(cm)	Remark
		δf x(cm)	δ y(cm)	α (rad)	δf x(cm)	δ y(cm)	α (rad)		
1	STRENGTH I-1	0.00	1.10	0.00000	0.00	1.10	0.00000	3.00	OK
2	STRENGTH I-2	0.00	0.65	0.00000	0.00	0.65	0.00000	3.00	OK
3	STRENGTH III	0.03	0.99	0.00002	0.01	0.99	0.00000	3.00	OK
4	STRENGTH IV	0.00	1.18	0.00000	0.00	1.18	0.00000	3.00	OK
5	STRENGTH V-1	0.01	1.08	0.00000	0.00	1.08	0.00000	3.00	OK
6	STRENGTH V-2	0.01	0.66	0.00000	0.00	0.66	0.00000	3.00	OK
7	EXTREME EVENT	1.36	1.02	0.00066	1.23	1.02	0.00032	2.00	OK
8	EXTREME EVENT	1.36	0.67	0.00066	1.23	0.67	0.00032	2.00	OK
9	EXTREME EVENT	0.64	1.02	0.00024	1.15	1.02	0.00023	2.00	OK
10	SERVICE I-1	0.01	0.84	0.00000	0.00	0.84	0.00000	1.50	OK
11	SERVICE I-2	0.01	0.76	0.00000	0.00	0.76	0.00000	1.50	OK

b) Bearing and Uplift forces of piles

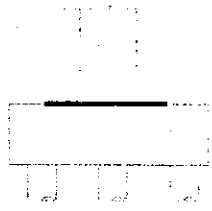
Load Combination		Longitudinal		Transverse		Allowable Capacitie		Checking	
		PNmax(tf)	PNmin(tf)	PNmax(tf)	PNmin(tf)	Bearing (tf)	Uplift (tf)	Bearing	Uplift
1	STRENGTH I-1	1098.11	1098.11	1098.11	1098.11	1404.7	-1391.9	OK	OK
2	STRENGTH I-2	653.01	653.01	653.00	653.00	1404.7	-1391.9	OK	OK
3	STRENGTH III	992.97	977.72	987.57	983.12	1404.7	-1391.9	OK	OK
4	STRENGTH IV	1176.01	1176.01	1176.01	1176.01	1404.7	-1391.9	OK	OK
5	STRENGTH V-1	1074.50	1070.16	1072.96	1071.70	1404.7	-1391.9	OK	OK
6	STRENGTH V-2	660.05	655.71	658.51	657.25	1404.7	-1391.9	OK	OK
7	EXTREME EVENT	1345.60	686.56	1253.67	778.49	1404.7	-1391.9	OK	OK
8	EXTREME EVENT	996.22	337.27	904.33	429.16	1404.7	-1391.9	OK	OK
9	EXTREME EVENT	1137.75	896.67	1186.39	848.03	1404.7	-1391.9	OK	OK
10	SERVICE I-1	835.70	832.05	834.42	833.33	876.0	-897.1	OK	OK
11	SERVICE I-2	759.09	755.44	757.81	756.72	876.0	-897.1	OK	OK

(2) Section Calculation of Pier Column

1) Sectional forces

Load Combination		V	Longitudinal		Transverse	
		(tf)	H (tf)	M (tf.m)	H (tf)	M (tf.m)
1	STRENGTH I-1	7458.2	0.0	0.0	0.0	0.0
2	STRENGTH I-2	4247.7	0.0	0.0	0.0	0.0
3	STRENGTH III	6443.4	13.0	22.2	2.8	4.8
4	STRENGTH IV	7591.4	0.0	0.0	0.0	0.0
5	STRENGTH V-1	7226.3	3.7	6.3	0.8	1.4
6	STRENGTH V-2	4291.5	3.7	6.3	0.8	1.4
7	EXTREME EVENT I-1	6720.0	607.1	2005.8	607.1	2005.8
8	EXTREME EVENT I-2	4371.2	607.1	2005.8	607.1	2005.8
9	SERVICE I-1	5648.2	2.8	4.8	0.6	1.0
10	SERVICE I-2	4958.8	2.8	4.8	0.6	1.0

2) Section Analysis



a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	14000	oblong,
Height	H	mm	3000	rounded-end shape
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 Main Reinforcement	Mu	kN.mm	19670391	EXTREME EVENT I-2
Corresponding Compressive force	$Nu_{corr.}$	kN	42867	
Maximum Shear Force				
Shear force	Vu	kN	5953	EXTREME EVENT I-2
Corresponding Compressive force	$Nu_{corr.}$	kN	42867	
Corresponding moment	$Mu_{corr.}$	kN.mm	19670391	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Main Reinforcement				
Diameter	ϕbot.	mm	32	
Area of 1 bar	A1's	mm2	804.2	
Total numbers of Rebar	n's	nos	246	@125
Shear Reinforcement				
Diameter	ϕv.	mm	16	
Area of 1 bar	A1v	mm2	201.1	
Numbers of Rebar in section	nv	nos	23	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	4624.4	

d) Checking for Flexural - Axial Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Bending Moment	Mu	kN.mm	19670391	
Compressive force	Nu	kN	42867	
Depth of Compressive Area	c	mm	2558	
Flexural Resistance	Mr	kN.mm	242126339	
Compressive Resistance	Nr	kN	527627	
Checking Resistance			**OK**	
Checking Reinforcement Ratio				
Numbers of Tensile bar	n_{tens}	nos	103	
$\rho st = As_{tensile}/A_g$		%	0.207	
$\rho min = 0.03fc/fy$		%	**0.185**	OK

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

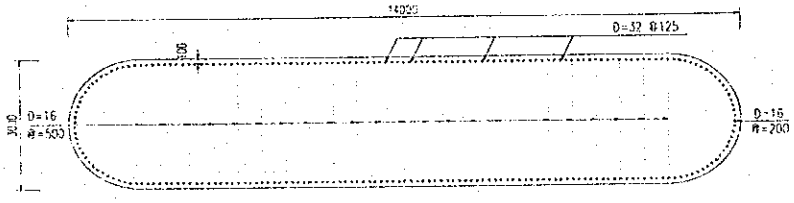
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	5953152.92	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2160	
Effective web width	b_v	mm	13356	
Spacing of stirrups	s	mm	500	
Angle of inclination of transverse reinf.	α	degrees	90	
Factor indicating ability of diagonally	α			
cracked concrete to transmit tension	β		5.0	
Area of shear reinf. within a distance s	A_v	mm^2	4624	
Strain in the tensile reinforcement	ε_x		-0.000012	
Inclination angle of diagonal comp. stress	θ	degrees	27.00	
Shear stress on the concrete	v	MPa	0.229	
Area of Conc. on flexural tensile side	Act	mm^2	20034291.74	
Nominal Resistance of Concrete	V_c	N	58652996	
Nominal Resistance of Reinforcement	V_s	N	15291150	
Nominal Resistance	Vn	N	73,944,147	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	66,549,732	
Checking			**OK**	

f) Checking for Flexural Stress

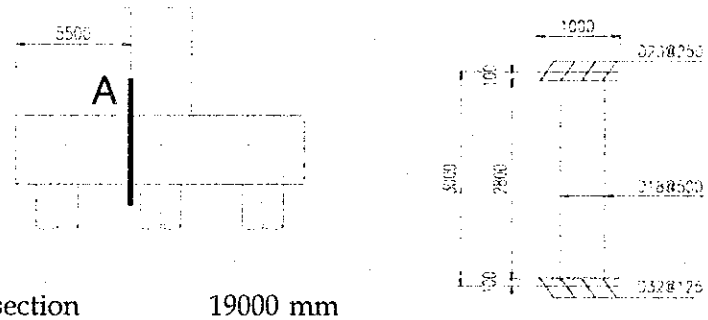
Item	Notation	Unit	Value	Remark
Factored Forces				
SERVICE I-1	Mu	kN.mm	46668.6	
	Nu	kN	55389.6	
SERVICE I-2	Mu	kN.mm	46668.6	
	Nu	kN	48628.6	
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			1.34	
SERVICE I-2			1.18	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			10.14	
SERVICE I-2			8.9	
Checking Stress of Steel			OK	

REINFORCEMENT OF COLUMN



(3) Section Calculation of Pile Cap

1) Section Analysis "A"



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	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	354206	EXTREME EVENT I-2
for Calculating Bottom Reinforcement	$Mu_{bot.}$	kN.mm	5429434	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	1406	EXTREME EVENT I-1
Corresponding moment	$Mu_{corr.}$	kN.mm	5429434	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	20	Structural Reinf.
Area of 1 bar	A1s	mm2	314.2	
Numbers of Rebar	ns	nos	4	
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	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	-354206	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{top}	kN.mm	6415080	
Checking Resistance			**OK**	
Checking Reinforcement Ratio				
ρst = $As_{tensile}$/(H.W)		%	**0.042**	
ρmin=0.03fc/fy		%	**0.185**	**AILURE**
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	5429434	
Depth of Compressive Area	c	mm	133.74	
Flexural Resistance	Mr_{bot}	kN.mm	6413400	
Checking Resistance			**OK**	
Checking Reinforcement Ratio				
ρst = $As_{tensile}$/(H.W)		%	**0.214**	
ρmin=0.03fc/fy		%	**0.185**	**OK**

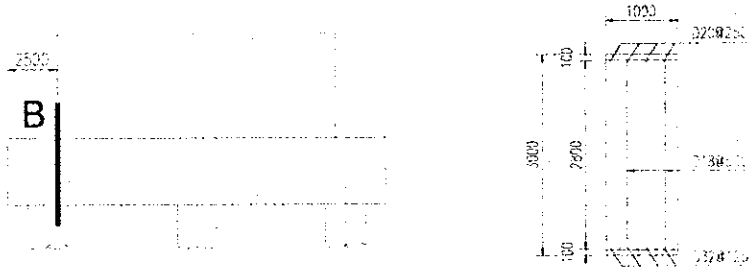
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	1406101	
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	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	0.723	
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	919512	
Nominal Resistance	Vn	N	2,412,603	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,171,343	
Checking			**OK**	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			2944173	Tensile at bottom
SERVICE I-2			2528990	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			1.86	
SERVICE I-2			1.6	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-12.93	
SERVICE I-2			-11.11	
Checking Stress of Steel			OK	

2) Section Analysis of "B"



Total width of section 14000 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	Mutop	kN.mm	146457	EXTREME EVENT I-2
for Calculating Bottom Reinforcem	Mubot.	kN.mm	932331	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	2327	EXTREME EVENT I-1
Corresponding moment	Mucorr.	kN.mm	932331	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	20	Structural Reinf.
Area of 1 bar	A1s	mm2	314.2	
Numbers of Rebar	ns	nos	4	
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	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	-146457	
Depth of Compressive Area	c	mm	133.74	
Flexural Resistance	Mr_{top}	kN.mm	6413400	
Checking Resistance			**OK**	
Checking Reinforcement Ratio				
ρst = $As_{tensile}$/(H.W)		%	**0.042**	
ρmin=0.03fc/fy		%	**0.185**	**AILURE**
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	932331	
Depth of Compressive Area	c	mm	133.74	
Flexural Resistance	Mr_{bot}	kN.mm	6413400	
Checking Resistance			**OK**	
Checking Reinforcement Ratio				
ρst = $As_{tensile}$/(H.W)		%	**0.214**	
ρmin=0.03fc/fy		%	**0.185**	**OK**

Notes: Reinforcement selection is controlled by the Minimum Reinforcement Ratio Requiren

e) Checking for Shear Resistance (AASHTO 5.8.3.3)

Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	2326553	
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	509	
Strain in the tensile reinforcement	ε_x		0.001409	
Inclination angle of diagonal comp. stress	θ	degrees	40.09	
Shear stress on the concrete	v	MPa	1.197	
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	1018626	
Nominal Resistance	Vn	N	2,775,204	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	2,497,683	
Checking			**OK**	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			549283	Tensile at bottom
SERVICE I-2			468788	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			0.35	
SERVICE I-2			0.3	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-2.41	
SERVICE I-2			-2.06	
Checking Stress of Steel			OK	

(4) Section Calculation of Pile

Dia : D1 = 2200 mm L1 = 15.0 m
D2 = 2000 mm L2 = 63.0 m
Length : 78.0 m
Number : 9 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	0.00	1098.11	0.00	0.00	1098.11	0.00
STRENGTH I-2	0.00	653.01	0.00	0.00	653.00	0.00
STRENGTH III	16.45	977.72	0.00	8.07	983.12	0.00
STRENGTH IV	0.00	1176.01	0.00	0.00	1176.01	0.00
STRENGTH V-1	4.67	1070.16	0.00	2.27	1071.70	0.00
STRENGTH V-2	4.67	655.71	0.00	2.27	657.25	0.00
EXTREME EVENT I-1	637.89	686.56	0.00	727.44	778.49	0.00
EXTREME EVENT I-2	637.74	337.27	0.00	727.44	429.16	0.00
EXTREME EVENT II	339.78	896.67	0.00	721.87	848.03	0.00
SERVICE I-1	4.16	832.05	0.00	2.06	833.33	0.00
SERVICE I-2	4.16	755.44	0.00	2.06	756.72	0.00

2) 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	28	
Number of Rebars	n_{st}	nos	26	
Total Area of Reinforcement	A_{st}	mm2	16010	

3) Section Calculation

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

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

b) Checking Resistance (AASHTO 5.7.2)

i) In longitudinal Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	1098.11	912.33	8230.97	185.78	2220.0	OK
	M (tf.m)	0.00	0.00	0.00	0.00	0.00	OK
STRENGTH I-2	PN (tf)	653.01	542.53	8732.83	110.48	2220.0	OK
	M (tf.m)	0.00	0.00	0.00	0.00	0.00	OK
STRENGTH III	PN (tf)	977.72	812.31	8209.19	165.41	2119.5	OK
	M (tf.m)	16.45	11.62	117.58	4.83	61.83	OK
STRENGTH IV	PN (tf)	1176.01	977.05	8143.13	198.96	2220.0	OK
	M (tf.m)	0.00	0.00	0.00	0.00	0.00	OK
STRENGTH V-1	PN (tf)	1070.16	889.11	8219.01	181.05	2193.1	OK
	M (tf.m)	4.67	3.30	30.45	1.37	16.59	OK
STRENGTH V-2	PN (tf)	655.71	544.77	8649.52	110.94	2176.4	OK
	M (tf.m)	4.67	3.30	52.60	1.37	26.88	OK
EXTREME EVENT I-1	PN (tf)	686.56	570.40	2336.35	116.16	613.4	OK
	M (tf.m)	637.89	450.77	1,846.44	187.12	988.17	OK
EXTREME EVENT I-2	PN (tf)	337.27	280.21	619.30	57.06	350.7	OK
	M (tf.m)	637.74	450.66	996.01	187.08	1149.75	OK
EXTREME EVENT II	PN (tf)	896.67	744.97	5557.59	151.70	1073.4	OK
	M (tf.m)	339.78	240.11	1,791.12	99.67	705.2	OK

ii) In Transverse Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	1098.11	912.33	8230.97	185.78	2220.0	OK
	M (tf.m)	0.00	0.00	0.00	0.00	0.00	OK
STRENGTH I-2	PN (tf)	653.00	542.52	8732.85	110.48	2220.0	OK
	M (tf.m)	0.00	0.00	0.00	0.00	0.00	OK
STRENGTH III	PN (tf)	983.12	816.79	8271.06	166.33	2169.8	OK
	M (tf.m)	8.07	5.70	57.40	2.37	30.88	OK
STRENGTH IV	PN (tf)	1176.01	977.05	8143.13	198.96	2220.0	OK
	M (tf.m)	0.00	0.00	0.00	0.00	0.00	OK
STRENGTH V-1	PN (tf)	1071.70	890.39	8241.36	181.31	2206.9	OK
	M (tf.m)	2.27	1.60	14.64	0.67	8.10	OK
STRENGTH V-2	PN (tf)	657.25	546.05	8692.92	111.20	2198.6	OK
	M (tf.m)	2.27	1.60	25.35	0.67	13.17	OK
EXTREME EVENT I-1	PN (tf)	778.49	646.78	2286.79	131.71	610.9	OK
	M (tf.m)	727.44	514.05	1,817.51	213.39	989.72	OK
EXTREME EVENT I-2	PN (tf)	429.16	356.55	747.57	72.61	384.2	OK
	M (tf.m)	727.44	514.05	1,077.79	213.39	1129.14	OK
EXTREME EVENT II	PN (tf)	848.03	704.56	2630.72	143.47	653.0	OK
	M (tf.m)	721.87	510.11	1,904.57	211.76	963.8	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	691.28	2.94	1192.07	-23861	180.29	1101	OK
	Transverse	692.34	1.46	1,201.02	-23861	179.18	1101	
SERVICE I-2	Horizontal	627.63	2.94	1081.01	-23861	163.94	1101	OK
	Transverse	628.69	1.46	1,089.96	-23861	162.83	1101	

d) Checking Minimum Steel Ratio

Item	Notation	Unit	Value	Remark
Total Area of Reinforcement	A_{st}	mm2	16010	
Gross Area of Section	Ag	mm2	3801327	
Reinforcement Ratio	ρst	%	**0.42**	
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=	1345600 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Vertical bearing stress	σ_{cv}	35.40 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=	1345600 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=	7.72 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=	97740 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Embedded Length of Pile	l=	200 cm	
Horizontal bearing stress	σ_{ch}	2.22 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=	97740 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=	1.36 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

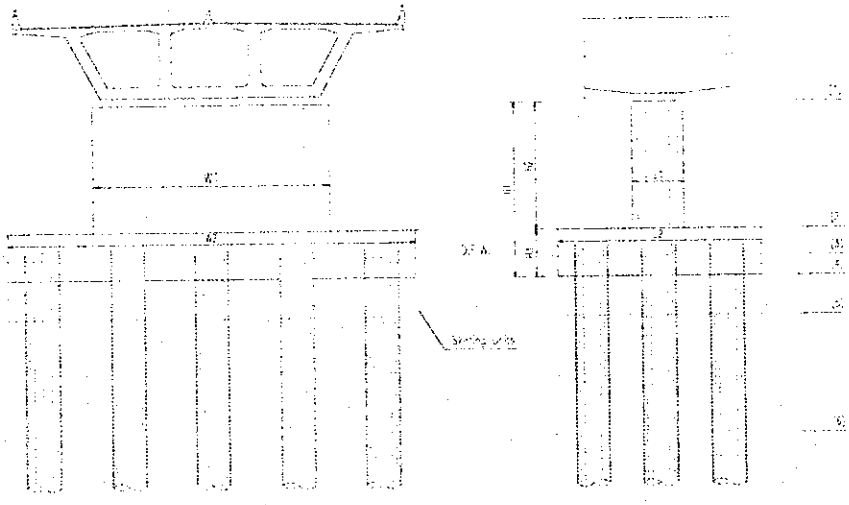
τ_c <= τ_a --> OK

5.3.4 Design of P38(P39) pier

(1) Stability Calculation

1) Dimension of Pier

(Figure)	(m)			(Level)	(m)		
Portion	Length	Portion	Length	Portion	Level	Portion	Level
H1	8.02	L1	3.00	(1)	+8.52	(5)	-2.00
H2	5.02	W2	24.00	(2)	+3.50	(6)	-7.76
H3	3.00	L2	14.00	(3)	+1.78		
W1	14.00			(4)	+0.50		



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

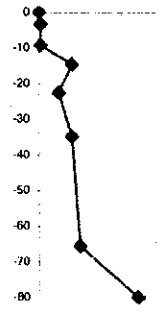
Load Combination		V	Longitudinal		Transverse	
		(tf)	H (tf)	M (tf.m)	H (tf)	M (tf.m)
1	STRENGTH I-1	10892.5	347.1	2783.4	96.8	-59.2
2	STRENGTH I-2	6285.7	29.3	235.0	96.8	-59.2
3	STRENGTH III	9836.2	256.6	1942.7	107.7	-22.1
4	STRENGTH IV	11756.8	253.8	2035.5	96.8	-59.2
5	STRENGTH V-1	10651.0	328.1	2598.7	99.9	-48.6
6	STRENGTH V-2	6385.8	71.4	540.0	99.9	-48.6
7	EXTREME EVENT I-1	10094.1	1817.7	8432.3	1720.4	6816.8
8	EXTREME EVENT I-2	6554.7	1690.7	7414.2	1720.4	6816.8
9	EXTREME EVENT II	10136.1	856.8	2402.0	1422.4	1632.1
10	SERVICE I-1	8273.9	400.3	3185.4	99.2	-51.3
11	SERVICE I-2	7420.0	247.6	1961.1	99.2	-51.3

3) Pile Capacity

INPUT DATA

BoreHole			BRD17
Pile Diameter	D1	=	2200 mm
	D2	=	2000 mm
Factor of Safety	FS	=	3
Pile length	L	=	74.00 m
	L0	=	8.34 m
	L1	=	6.66 m
	L2	=	59.00 m
Pile Embedded Length	Le	=	65.66 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	=	135 t/m2
Soil Type of Bearing Layer			2 (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)
1-1	6.66	2	Clay	0.70	1.0	1.0	46
1-2	5.16	2	Clay	0.70	1.0	1.0	32
2	5.60	2	Clay	0.90	20.0	1.0	35
3	10.40	2	Clay	1.00	12.0	2.0	131
4	14.10	2	Clay	0.90	20.0	1.0	89
5	23.74	2	Clay	1.00	25.0	15.0	2237
Total L =	65.66	m				Total Qs =	2570

END BEARING CAPACITY Formula: Qt = qu* Ab

Type of Pile		Soil Type of B.P	End Bearing Capacity		
Cast-in-situ	Friction & Bearing	Clay		424 tonne	

Ultimate Bearibg Capacity (Qult)

* Qult = Qt + Qs **2994.5** tonne

Replaced Effective Weight of Soil (Ws)

194.4 tonne

Buoyant Weight of Pile (W)

395.3 tonne

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

* $Qall_1$ = (Qult - Ws) / FS + Ws - W **732.5** tonne

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

* $Qall_2$ = (Qult - Ws) / FS + Ws - W **1199.2** tonne

FS= 2

Design Uplift Caacity for Service Load Combinations (Qup_1)

* Qup_1 = Qs / FS + W **823.7** tonne

FS = 6

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

* Qup_2 = Qs / FS + W **1252.1** tonne

FS= 3

4) Reaction of Pile

a) Displacement

Load Combination		Longitudinal			Transverse			δ xa(cm)	Remark
		δf x(cm)	δ y(cm)	α (rad)	δf x(cm)	δ y(cm)	α (rad)		
1	STRENGTH I-1	0.39	0.76	0.00023	0.09	0.76	0.00001	3.00	OK
2	STRENGTH I-2	0.03	0.44	0.00002	0.09	0.44	0.00001	3.00	OK
3	STRENGTH III	0.29	0.69	0.00017	0.10	0.69	0.00001	3.00	OK
4	STRENGTH IV	0.29	0.82	0.00017	0.09	0.82	0.00001	3.00	OK
5	STRENGTH V-1	0.37	0.75	0.00022	0.09	0.74	0.00001	3.00	OK
6	STRENGTH V-2	0.08	0.45	0.00005	0.09	0.45	0.00001	3.00	OK
7	EXTREME EVENT	1.97	0.71	0.00099	1.65	0.71	0.00032	2.00	OK
8	EXTREME EVENT	1.82	0.46	0.00091	1.65	0.46	0.00032	2.00	OK
9	EXTREME EVENT	0.91	0.71	0.00041	1.34	0.71	0.00021	3.00	OK
10	SERVICE I-1	0.66	0.58	0.00029	0.14	0.58	0.00001	1.50	OK
11	SERVICE I-2	0.41	0.52	0.00018	0.14	0.52	0.00001	1.50	OK

b) Bearing and Uplift forces of piles

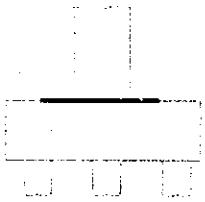
Load Combination		Longitudinal		Transverse		Allowable Capacities		Checking	
		PNmax(tf)	PNmin(tf)	PNmax(tf)	PNmin(tf)	Bearing (tf)	Uplift (tf)	Bearing	Uplift
1	STRENGTH I-1	837.16	615.17	737.86	714.47	1199.2	-1252.1	OK	OK
2	STRENGTH I-2	428.42	409.68	430.74	407.35	1199.2	-1252.1	OK	OK
3	STRENGTH III	735.77	575.72	669.32	642.17	1199.2	-1252.1	OK	OK
4	STRENGTH IV	864.95	702.62	795.48	772.09	1199.2	-1252.1	OK	OK
5	STRENGTH V-1	814.41	605.72	716.30	691.84	1199.2	-1252.1	OK	OK
6	STRENGTH V-2	448.46	402.98	437.95	413.49	1199.2	-1252.1	OK	OK
7	EXTREME EVENT	1145.59	200.29	981.34	364.54	1199.2	-1252.1	OK	OK
8	EXTREME EVENT	869.03	4.93	745.38	128.58	1199.2	-1252.1	OK	OK
9	EXTREME EVENT	870.73	480.75	879.58	471.90	1199.2	-1252.1	OK	OK
10	SERVICE I-1	689.95	413.24	565.33	537.85	732.5	-823.7	OK	OK
11	SERVICE I-2	580.08	409.25	508.41	480.93	732.5	-823.7	OK	OK

(2) Section Calculation of Pier Column

1) Sectional forces

Load Combination		V (tf)	Longitudinal		Transverse	
			H (tf)	M (tf.m)	H (tf)	M (tf.m)
1	STRENGTH I-1	7860.6	347.1	1742.3	0.0	0.0
2	STRENGTH I-2	4247.3	29.3	147.1	0.0	0.0
3	STRENGTH III	6804.3	245.1	1182.7	4.1	10.3
4	STRENGTH IV	8015.3	253.8	1274.1	0.0	0.0
5	STRENGTH V-1	7619.2	324.9	1617.1	1.2	2.9
6	STRENGTH V-2	4347.4	68.2	328.5	1.2	2.9
7	EXTREME EVENT I-1	7062.2	1477.0	7263.3	1283.0	6289.1
8	EXTREME EVENT I-2	4516.3	1350.1	6626.0	1283.0	6289.1
9	SERVICE I-1	5951.6	397.8	1986.7	0.9	2.2
10	SERVICE I-2	5097.7	245.1	1220.4	0.9	2.2

2) Section Analysis



a) Section Dimensions & Material Properties

Item	Notation	Unit	Value	Remark
Section Dimension				
Width	W	mm	14000	oblong,
Height	H	mm	3000	rounded-end shape
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 Main Reinforcement	Mu	kN.mm	71228184	EXTREME EVENT I-2
Corresponding Compressive force	$Nu_{corr.}$	kN	69256	
Maximum Shear Force				
Shear force	Vu	kN	14485	EXTREME EVENT I-2
Corresponding Compressive force	$Nu_{corr.}$	kN	69256	
Corresponding moment	$Mu_{corr.}$	kN.mm	71228184	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Main Reinforcement				
Diameter	ϕbot.	mm	32	
Area of 1 bar	A1's	mm2	804.2	
Total numbers of Rebar	n's	nos	246	@125
Shear Reinforcement				
Diameter	ϕv.	mm	16	
Area of 1 bar	A1v	mm2	201.1	
Numbers of Rebar in section	nv	nos	23	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	4624.4	

d) Checking for Flexural - Axial Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Bending Moment	Mu	kN.mm	71228184	
Compressive force	Nu	kN	69256	
Depth of Compressive Area	c	mm	2558	
Flexural Resistance	Mr	kN.mm	309953538	
Compressive Resistance	Nr	kN	301362	
Checking Resistance			OK	
Checking Reinforcement Ratio				
Numbers of Tensile bar	n_{tens}	nos	121	
$\rho st = As_{tensile}/A_g$		%	0.243	
$\rho min=0.03fc/fy$		%	0.185	OK

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

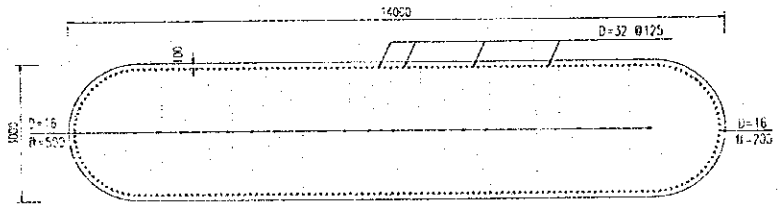
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	14484762	
Shear Resistance	Vr	N		
Effective shear Depth	d_v	mm	2160	
Effective web width	b_v	mm	13356	
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		2.5	
Area of shear reinf. within a distance s	A_v	mm^2	4624	
Strain in the tensile reinforcement	ε_x		0.000560	
Inclination angle of diagonal comp. stress	θ	degrees	29.97	
Shear stress on the concrete	v	MPa	0.558	
Area of Conc. on flexural tensile side	Act	mm^2	20034291.74	
Nominal Resistance of Concrete	V_c	N	29326498	
Nominal Resistance of Reinforcement	V_s	N	13511139	
Nominal Resistance	Vn	N	42,837,637	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	38,553,874	
Checking			OK	

f) Checking for Flexural Stress

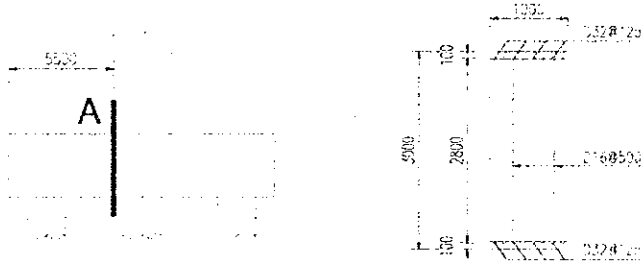
Item	Notation	Unit	Value	Remark
Factored Forces				
SERVICE I-1	Mu	kN.mm	19482770	
	Nu	kN	58365	
SERVICE I-2	Mu	kN.mm	11967830	
	Nu	kN	49991	
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			2.83	
SERVICE I-2			2.08	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			0.65	
SERVICE I-2			2.99	
Checking Stress of Steel			OK	

REINFORCEMENT OF COLUMN



(3) Section Calculation 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	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	-1438354	EXTREME EVENT I-2
for Calculating Bottom Reinforcement	$Mu_{bot.}$	kN.mm	6328749	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	1663	EXTREME EVENT I-1
Coincidental moment	$Mu_{coin.}$	kN.mm	6328749	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	32	
Area of 1 bar	A1s	mm2	804.2	
Numbers of Rebar	ns	nos	8	
Bottom Reinforcement				
Diameter	ϕbot.	mm	32	
Area of 1 bar	A1's	mm2	804.2	
Numbers of Rebar	n's	nos	8	
Shear Reinforcement				
Diameter	ϕv.	mm	16	
Area of 1 bar	A1v	mm2	201.1	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	402.1	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	1438354	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{top}	kN.mm	6415080	
Checking Resistance			OK	
Checking Reinforcement Ratio				
ρst = $As_{tensile}$/(H.W)		%	0.214	
ρmin=0.03fc/fy		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	6328749	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{bot}	kN.mm	6415080	
Checking Resistance			OK	
Checking Reinforcement Ratio				
ρst = $As_{tensile}$/(H.W)		%	0.214	
ρmin=0.03fc/fy		%	0.185	OK

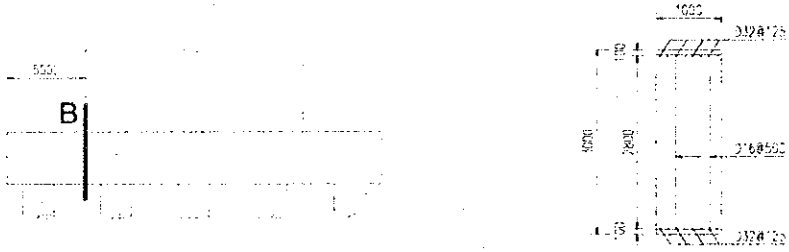
e) Checking for Shear Resistance (AASHTO 5.8.3.3)

Item	Notation	Unit	Value	Remark
Factored Shear	Vu	N	1663048	
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	402	
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	0.855	
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	726528	
Nominal Resistance	Vn	N	2,219,619	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	1,997,657	
Checking			OK	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			3348737	Tensile at bottom
SERVICE I-2			2563096	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			2.04	
SERVICE I-2			1.56	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-14.45	
SERVICE I-2			-11.06	
Checking Stress of Steel			OK	

2) Section Analysis of "B"



Total width of section	14000	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	Mutop	kN.mm	-407258	EXTREME EVENT I-2
for Calculating Bottom Reinforcen	Mubot.	kN.mm	4646969	EXTREME EVENT I-1
Maximum Shear Force				
Shear force	Vu	kN	1446	EXTREME EVENT I-1
Coincidental moment	Mucoin.	kN.mm	4646969	

c) Bar Arrangement

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Diameter	ϕtop	mm	32	Structural Reinf.
Area of 1 bar	A1s	mm2	804.2	
Numbers of Rebar	ns	nos	8	
Bottom Reinforcement				
Diameter	ϕbot.	mm	32	
Area of 1 bar	A1's	mm2	804.2	
Numbers of Rebar	n's	nos	8	
Shear Reinforcement				
Diameter	ϕv.	mm	16	
Area of 1 bar	A1v	mm2	201.1	
Numbers of Rebar in section	nv	nos	2	
Spacing of Shear Reinf.	s	mm	500	
Total Area of Shear Reinf. within s	Av	mm2	402.1	

d) Checking for Flexural Resistance (AASHTO 5.7.3.2)

Item	Notation	Unit	Value	Remark
Top Reinforcement				
Bending Moment	Mu_{top}	kN.mm	407258	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{top}	kN.mm	6415080	
Checking Resistance			OK	
Checking Reinforcement Ratio				
ρst = $As_{tensile}$/(H.W)		%	0.214	
ρmin=0.03fc/fy		%	0.185	OK
Bottom Reinforcement				
Bending Moment	Mu_{bot}	kN.mm	4646969	
Depth of Compressive Area	c	mm	115.25	
Flexural Resistance	Mr_{bot}	kN.mm	6415080	
Checking Resistance			OK	
Checking Reinforcement Ratio				
ρst = $As_{tensile}$/(H.W)		%	0.214	
ρmin=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	1446347	
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	402	
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	0.744	
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	726528	
Nominal Resistance	Vn	N	2,219,619	
Resistance factor for shear	φ		0.9	
Factored Resistance	Vr	N	1,997,657	
Checking			**OK**	

f) Checking for Flexural Stress

Item	Notation	Unit	Value	Remark
Factored Moments	Mu	kN.mm		
SERVICE I-1			2254184	Tensile at bottom
SERVICE I-2			1895346	Tensile at bottom
Factored Comp. Stress of Concrete	σcu	MPa		
SERVICE I-1			1.37	
SERVICE I-2			1.21	
Checking Stress of Concrete			OK	
Factored Tensile Stress of Steel	σsu	MPa		
SERVICE I-1			-9.73	
SERVICE I-2			-8.57	
Checking Stress of Steel			OK	

(4) Section Calculation of Pile

Dia : D1 =	2200 mm	L1 =	15.0 m
D2 =	2000 mm	L2 =	59.0 m
Length :	74.0 m		
Number :	15 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	184.42	615.17	0.00	62.432	714.47	0.00
STRENGTH I-2	15.57	409.68	0.00	62.43	407.35	0.00
STRENGTH III	137.23	575.72	0.00	69.34	642.17	0.00
STRENGTH IV	134.85	702.62	0.00	62.43	772.09	0.00
STRENGTH V-1	174.58	605.72	0.00	64.34	691.84	0.00
STRENGTH V-2	39.79	402.98	0.00	64.34	413.49	0.00
EXTREME EVENT I-1	1013.36	200.29	0.00	1087.56	364.54	0.00
EXTREME EVENT I-2	945.88	4.93	0.00	1087.56	128.58	0.00
EXTREME EVENT II	489.84	480.75	0.00	910.38	471.90	0.00
SERVICE I-1	248.83	413.24	0.00	72.12	537.85	0.00
SERVICE I-2	153.97	409.25	0.00	72.12	480.93	0.00

2) 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	25	
Number of Rebars	n_{st}	nos	52	
Total Area of Reinforcement	A_{st}	mm2	25525	

3) 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	
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) Checking Resistance (AASHTO 5.7.2)

i) In longitudinal Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	615.17	511.09	6618.09	104.08	1203.2	OK
	M (tf.m)	184.42	130.32	1,687.52	54.10	625.41	OK
STRENGTH I-2	PN (tf)	409.68	340.37	8965.41	69.31	2005.2	OK
	M (tf.m)	15.57	11.00	290.13	4.57	132.11	OK
STRENGTH III	PN (tf)	575.72	478.32	7168.86	97.40	1327.8	OK
	M (tf.m)	137.23	96.97	1,453.07	40.25	548.76	OK
STRENGTH IV	PN (tf)	702.62	583.75	7426.68	118.87	1440.6	OK
	M (tf.m)	134.85	95.29	1,212.45	39.56	479.38	OK
STRENGTH V-1	PN (tf)	605.72	503.24	6723.91	102.48	1224.9	OK
	M (tf.m)	174.58	123.36	1,648.02	51.21	612.09	OK
STRENGTH V-2	PN (tf)	402.98	334.80	8487.71	68.18	1736.6	OK
	M (tf.m)	39.79	28.12	712.77	11.67	297.32	OK
EXTREME EVENT I-1	PN (tf)	200.29	166.40	223.37	33.89	145.5	OK
	M (tf.m)	1,013.36	716.10	961.27	297.26	1275.98	OK
EXTREME EVENT I-2	PN (tf)	4.93	**4.10**	**5.00**	0.83	4.1	OK
	M (tf.m)	945.88	**668.41**	**814.58**	277.47	1362.92	OK
EXTREME EVENT II	PN (tf)	480.75	399.41	2358.02	81.34	573.3	OK
	M (tf.m)	489.84	346.15	2,043.56	143.69	1012.8	OK

ii) In Transverse Direction

Load Case	Forces	Total	RC	Allowable	Casing	Allowable	Remark
STRENGTH I-1	PN (tf)	714.47	593.59	8245.99	120.88	1781.3	OK
	M (tf.m)	62.43	44.12	612.59	18.31	269.88	OK
STRENGTH I-2	PN (tf)	407.35	338.43	8034.48	68.92	1550.2	OK
	M (tf.m)	62.43	44.12	1,047.27	18.31	411.96	OK
STRENGTH III	PN (tf)	642.17	533.52	8160.56	108.65	1702.0	OK
	M (tf.m)	69.34	49.00	749.46	20.34	318.64	OK
STRENGTH IV	PN (tf)	772.09	641.46	8233.90	130.63	1807.9	OK
	M (tf.m)	62.43	44.12	566.54	18.31	253.48	OK
STRENGTH V-1	PN (tf)	691.84	574.79	8225.57	117.05	1758.9	OK
	M (tf.m)	64.34	45.47	651.05	18.87	283.62	OK
STRENGTH V-2	PN (tf)	413.49	343.53	8009.08	69.96	1543.1	OK
	M (tf.m)	64.34	45.47	1,059.76	18.87	416.33	OK
EXTREME EVENT I-1	PN (tf)	364.54	302.87	431.16	61.67	235.9	OK
	M (tf.m)	1,087.56	768.53	1,094.06	319.03	1220.34	OK
EXTREME EVENT I-2	PN (tf)	128.58	106.83	124.29	21.75	89.4	OK
	M (tf.m)	1,087.56	768.53	894.11	319.03	1310.48	OK
EXTREME EVENT II	PN (tf)	471.90	392.06	812.90	79.84	344.8	OK
	M (tf.m)	910.38	643.33	1,333.88	267.05	1153.4	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	343.33	175.84	-239.36	-23861	248.10	1101	OK
	Transverse	446.85	50.97	528.22	-23861	159.88	1101	
SERVICE I-2	Horizontal	340.01	108.81	71.35	-23861	185.83	1101	OK
	Transverse	399.56	50.97	446.85	-23861	147.91	1101	

d) Checking Minimum Steel Ratio

Item	Notation	Unit	Value	Remark
Total Area of Reinforcement	A_{st}	mm2	25525	
Gross Area of Section	Ag	mm2	3801327	
Reinforcement Ratio	ρst	%	0.67	
Minimum Reinforcement ratio	ρmin	%	0.40	OK

(5) Calculation of Footing Concret Stress that Pile connect

1) Vertical bearing stress of footing concrete

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

Reaction force of pile	P=	1145590 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Vertical bearing stress	σ_{cv}	30.14 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=	1145590 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=	6.57 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=	121180 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Embedded Length of Pile	l=	200 cm	
Horizontal bearing stress	σ_{ch}	2.75 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=	121180 kg	Load Combination: 7
Diameter of Pile	D=	220 cm	
Distance from side of pile to the nearest edge of pile cap	h'=	110 cm	
Embedded Length of Pile	l=	200 cm	
Punching shear stress	τ_c=	1.31 kg/cm^2	
Allowable punching shear stress	τ_a=	9.00 kg/cm^2	

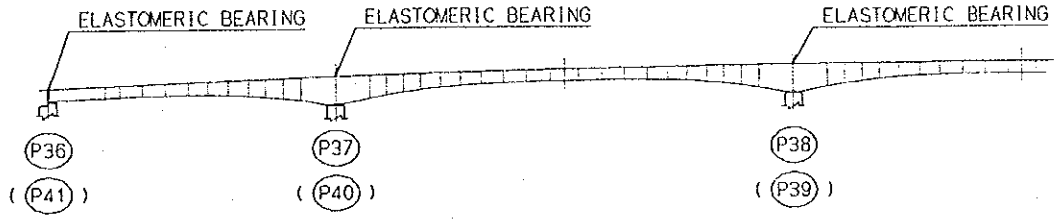
τ_c <= τ_a --> OK

5.4 Design of Accessories

5.4.1 Design of Bearing

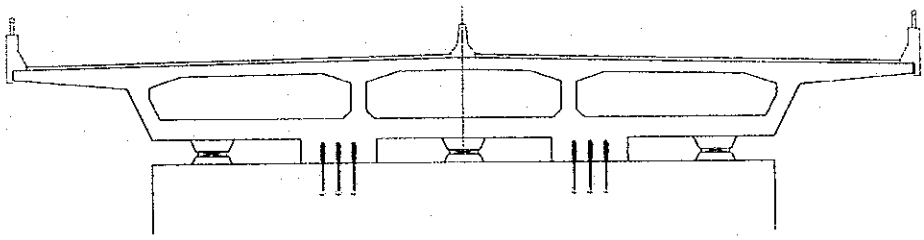
(1) Design Condition

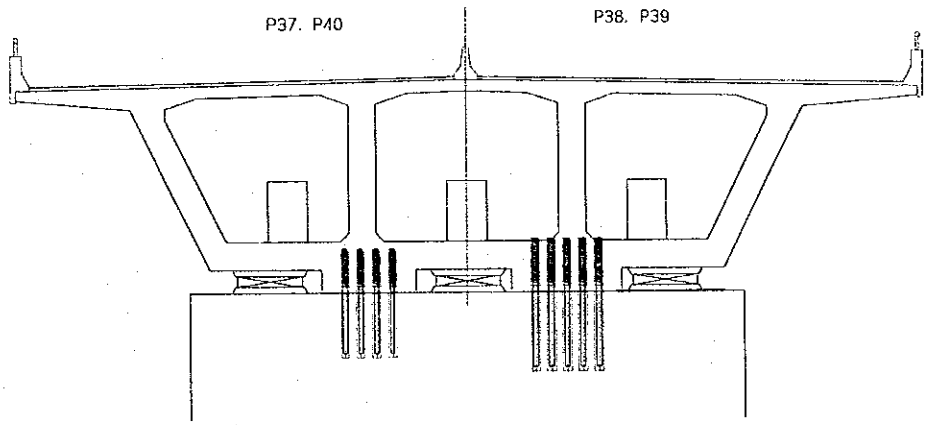
1) Arrangement of Bearing



	Bearing Condition	Type of Bearing	Nos of Bearing
P36 (P41)	Movable	Elastomeric Bearing	3
P37 (P40)	Movable	Elastomeric Bearing	3
P38 (P39)	Hinge	Elastomeric Bearing	3

P36, P41





2) Loading and Displacement

a) Loading (each Bearings)

		P36	P37	P38	P39	P40	P41
Virtical Load	Dead Load (DC+DW+CR+SH)	2119	15364	15824	15826	15354	2123
	Live Load (LL + IM)	2748	4226	4232	4151	3942	2967
Horizontal Load (EQ)		254	1844	-----	-----	1842	255

Unit : kN

b) Displacement

		P36	P37	P38	P39	P40	P41
Temperature alteration	+15deg	9.7	5.6	0.0	0.0	5.7	9.8
	-15deg	-28.2	-21.2	0.0	0.0	-21.2	-28.1
Earthquake		26.5	26.6	0.0	0.0	26.6	26.5

Unit : mm

3) Dimension

Table Dimension of Bearing

	Sign	Unit	P36	P37	P38	P39	P40	P41
Width of Bearing								
Longitusinal	b	(mm)	700	1600	1600	1600	1600	700
Transverse	a	(mm)	700	1600	1600	1600	1600	700
Rubber								
Thickness of each Rubber Layer	te	(mm)	20	34	34	34	34	20
Numbers of Rubber Layer	n		5	6	6	6	6	5
Total Thickness	Σte	(mm)	100	204	204	204	204	100
Reinforce Parts	ts	(mm)	3.0	4.5	4.5	4.5	4.5	3.0

(2) Calculation Result

Calculation Result at P36 (each Bearing)

		Sign	Unit	Longitudinal	Transverse	Allowable	
Bearing Area	Effective	A	m^2	0.4900	0.4900	-----	
	Ordinaty	Ao	m^2	0.4637	-----	-----	
Strain	Effective	δ	mm	1.28	-----	-----	
	Ordinaty	δo	mm	1.35	-----	-----	
Maximum Compressive Stress	Ordinaty	σmax.o	N/mm^2	6.71	-----	≦	8.0
Minimum Compressive Stress	Ordinaty	σmin	N/mm^2	3.55	-----	≧	1.5
Range of Compressive Stress	Ordinaty	⊿σ	N/mm^2	3.16	-----	≦	5.0
Rotation Strain	Ordinaty	δr	mm	1.17	-----	-----	
Compressive Strain	Ordinaty	δc	mm	1.28	-----	≧	1.17
Local Shear Strain	Virtical	γc	%	100.4	-----	-----	
	Horizontal	γs	%	37.6	-----	≦	70
	Rotation	γr	%	40.8	-----	-----	
	Total	γt	%	178.8	-----	≦	333.3

Calculation Result at P37 (each Bearing)

		Sign	Unit	Longitudinal	Transverse	Allowable	
Bearing Area	Effective	A	m^2	2.5600	2.5600	-----	
	Ordinaty	Ao	m^2	2.5148	-----	-----	
Strain	Effective	δ	mm	1.54	-----	-----	
	Ordinaty	δ o	mm	1.56	-----	-----	
Maximum Compressive Stress	Ordinaty	σ max.o	N/mm^2	6.86	-----	≦	8.0
Minimum Compressive Stress	Ordinaty	σ min	N/mm^2	5.86	-----	≧	1.5
Range of Compressive Stress	Ordinaty	⊿σ	N/mm^2	1.00	-----	≦	5.0
Rotation Strain	Ordinaty	δ r	mm	1.33	-----	-----	
Compressive Strain	Ordinaty	δ c	mm	1.54	-----	≧	1.33
Local Shear Strain	Virtical	γ c	%	76.6	-----	-----	
	Horizontal	γ s	%	13.9	-----	≦	70
	Rotation	γ r	%	30.8	-----	-----	
	Total	γ t	%	121.3	-----	≦	333.3

Calculation Result at P38, P39 (each Bearing)

		Sign	Unit	Longitudinal	Transverse	Allowable	
Bearing Area	Effective	A	m^2	2.5600	2.5600	-----	
	Ordinaty	Ao	m^2	2.5600	-----	-----	
Strain	Effective	δ	mm	1.58	-----	-----	
	Ordinaty	δ o	mm	1.58	-----	-----	
Maximum Compressive Stress	Ordinaty	σ max.o	N/mm^2	6.95	-----	≦	8.0
Minimum Compressive Stress	Ordinaty	σ min	N/mm^2	6.04	-----	≧	1.5
Range of Compressive Stress	Ordinaty	⊿σ	N/mm^2	0.91	-----	≦	5.0
Rotation Strain	Ordinaty	δ r	mm	1.33	-----	-----	
Compressive Strain	Ordinaty	δ c	mm	1.58	-----	≧	1.33
Local Shear Strain	Virtical	γ c	%	77.6	-----	-----	
	Horizontal	γ s	%	0.0	-----	≦	70
	Rotation	γ r	%	30.8	-----	-----	
	Total	γ t	%	108.4	-----	≦	333.3

Calculation Result at P40 (each Bearing)

		Sign	Unit	Longitudinal	Transverse	Allowable	
Bearing Area	Effective	A	m^2	2.5600	2.5600	-----	
	Ordinaty	Ao	m^2	2.5150	-----	-----	
Strain	Effective	δ	mm	1.54	-----	-----	
	Ordinaty	δ o	mm	1.56	-----	-----	
Maximum Compressive Stress	Ordinaty	σ max.d	N/mm^2	6.86	-----	$\leqq$	8.0
Minimum Compressive Stress	Ordinaty	σ min	N/mm^2	5.86	-----	$\geqq$	1.5
Range of Compressive Stress	Ordinaty	$\Delta\sigma$	N/mm^2	1.00	-----	$\leqq$	5.0
Rotation Strain	Ordinaty	δ r	mm	1.33	-----	-----	
Compressive Strain	Ordinaty	δ c	mm	1.54	-----	$\geqq$	1.33
Local Shear Strain	Virtical	γ c	%	76.6	-----	-----	
	Horizontal	γ s	%	13.9	-----	$\leqq$	70
	Rotation	γ r	%	30.8	-----	-----	
	Total	γ t	%	121.2	-----	$\leqq$	333.3

Calculation Result at P41 (each Bearing)

		Sign	Unit	Longitudinal	Transverse	Allowable	
Bearing Area	Effective	A	m^2	0.4900	0.4900	-----	
	Ordinaty	Ao	m^2	0.4638	-----	-----	
Strain	Effective	δ	mm	1.28	-----	-----	
	Ordinaty	δ o	mm	1.35	-----	-----	
Maximum Compressive Stress	Ordinaty	σ max.d	N/mm^2	6.71	-----	$\leqq$	8.0
Minimum Compressive Stress	Ordinaty	σ min	N/mm^2	3.56	-----	$\geqq$	1.5
Range of Compressive Stress	Ordinaty	$\Delta\sigma$	N/mm^2	3.16	-----	$\leqq$	5.0
Rotation Strain	Ordinaty	δ r	mm	1.17	-----	-----	
Compressive Strain	Ordinaty	δ c	mm	1.28	-----	$\geqq$	1.17
Local Shear Strain	Virtical	γ c	%	100.5	-----	-----	
	Horizontal	γ s	%	37.4	-----	$\leqq$	70
	Rotation	γ r	%	40.8	-----	-----	
	Total	γ t	%	178.8	-----	$\leqq$	333.3

5.4.2 Design of Expansion Joint

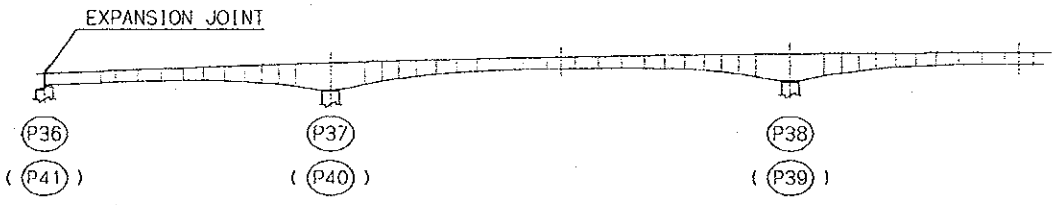
(1) Design Conditions

Displacement at P36, P41

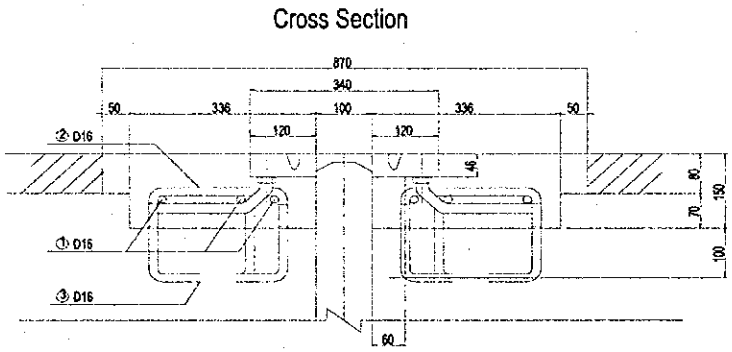
Unit : mm

Cause		P36		P41	
		I-Gieder	PC-Box	PC-Box	I-Girder
Creep (at the end)		7.33	-8.66	8.67	-3.66
Thermal Effect	+15 deg	11.99	-25.24	25.24	-5.99
	-15 deg	-11.99	25.24	-25.24	5.99
Sub-Total CR+T(+)	+15 deg	19.32	-33.9	33.91	-9.65
CR+T(-)	-15 deg	-4.66	16.58	-16.57	2.33
Total		53.22		43.56	
		21.24		18.90	

Displace from P36 to P41 : Plus
P41 to P36 : Minus



(2) Detail of Expansion Joint



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