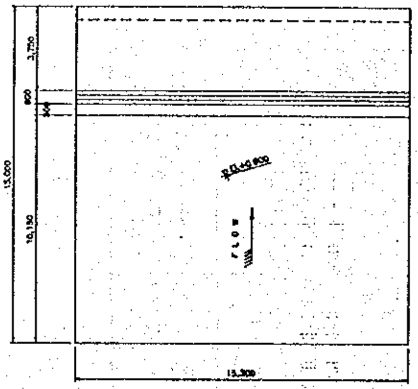
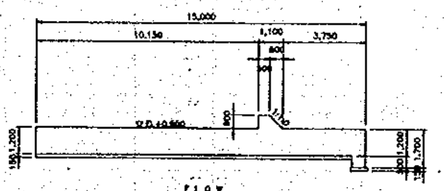
4.2.3.2 Apron (EL+0.900)

1) Loading Condition



PLAN



PROFILE

Design Condition

Item	Unit		Item	Unit	
Thickness at upstream of gate	m	1.200	Unit weight of concrete	tf / m^3	2.350
Thickness at downstream of gate	m	-	Unit weight of water	tf / m^3	1.000
Length of slab at flowing water	m	15.000	Unit weight of soil	tf / m^3	1.800
Width of slab at weir axis	m	15.300	Submerged unit weight	tf / m^3	1.000
Length of slab at upstream of gate	m	-	Angle of shearing resistance		30.000
Length of slope section	m	-	Horizontal seismic intensity		0.120
Length of slab at downstream of gate	m	-	Apparently horizontal seismic intensity		0.240
Width of muddy soil	m	0.000	Coefficient of earth pressure in Normal case		0.3085
Weight of flood discharge gate	tf/m	-	Coefficient of earth pressure in Seismic case above water		0.4107
Distance of installed gate position	m	-	Coefficient of earth pressure in seismic case below water		0.5089
Surcharge load in construction case	tf / m^2	1.000	Top elevation of slab	EL m	0.900
			Bottom elevation of slab	EL m	-0.300
			Normal water level	EL m	1.550
			Water level in seismic case	EL m	1.200
			Design high water level	EL m	8.000

1. Weight of body

	Weight W (tf)	Vertical length X (m)	Moment MX (tf-m)	Horizontal length Y (m)	Moment MY (tf-m)	Note
1	647.190	7.500	4853.925	0.600	388.314	Conc.
2.000	10.787	10.400	112.180	1.500	16.180	Conc.
3.000	6.472	10.850	70.220	1.400	9.061	
Total	664.448	7.580	5036.325	0.622	413.554	

2. Surcharge load

Construction	Weight W (tf)	Vertical length X (m)
	229.500	7.500

3. Weight of water

Normal case Seismic case	Weight W (tf)	Vertical length X (m)	Moment MX (tf-m)	Horizontal length Y (m)	Moment MY (tf-m)	Note
	68.850	5.075	349.414	1.350	92.948	
Total	68.850	5.075	349.414	1.350	92.948	

Design flooding case	Weight W (tf)	Vertical length X (m)	Moment MX (tf-m)	Horizontal length Y (m)	Moment MY (tf-m)	Note
	1629.450	7.500	12220.875	4.750	7739.888	
Total	1629.450	7.500	12220.875	4.750	7739.888	

4. Earth pressure

Normal case	(tf/m^2)		(tf/m)		(m)
Pa0=	0.000	E1=	3.398	Y1=	0.400
Pa1=	0.370				
Seismic case	(tf/m^2)		(tf/m)		(m)
Pea0=	0.000	Ee1=	5.606	Ye1=	0.400
Pea1=	0.611				

5. Hydrostatic pressure

Normal , Seismic			(tf/m)		(m)
Wa0=	0.300				
Wa1=	1.850	P1=	19.737	Y3=	0.456
Design flooding			(tf/m)		(m)
Wae0=	7.100				
Wae1=	8.300	Pe1=	141.372	Ye3=	0.584

6. Uplift

Normal , Seismic			(tf/m)		(m)
U1=	6.932	U=	-2487.967	X1=	8.401
U2=	14.750				
Design flooding					
Ue1=	8.300	Ue=	-1904.850	Xe1=	7.500
Ue2=	8.300				

Normal Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	664.448	7.580	5036.519			
Horizontal earthquake load (Main body)						
Weight of muddy soil	65.000	2.500	162.500			
Horizontal earthquake load (Muddy soil)						
Surcharge load						
Weight of water	68.850	5.075	349.414			
Earth pressure				3.398	0.400	1.359
Hydrostatic pressure						
Uplift	-447.715	7.154	-3203.083			
Total	285.583		2182.850	3.398		1.359

Acting force at toe of Concrete apron

V0=	285.583 tf
H0=	3.398 tf
M0=Mx+My=	2184.209 tf-m

Acting force at middle of bottom of Concrete apron

Vc=	285.583 tf
Hc=	3.398 tf
Mc=Mx+My=	0.502 tf-m

Construction Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	664.448	7.580	5036.519			
Horizontal earthquake load (Main body)						
Weight of muddy soil						
Horizontal earthquake load (Muddy soil)						
Surcharge load	229.500	7.500	1721.250			
Weight of water						
Earth pressure						
Hydrostatic pressure						
Uplift						
Total	893.948		6757.769	0.000		0.000

Acting force at toe of Concrete apron

V0=	893.948 tf
H0=	0.000 tf
M0=Mx+My=	6757.769 tf-m

Acting force at middle of bottom of Concrete apron

Vc=	893.948 tf
Hc=	0.000 tf
Mc=Mx+My=	80.936 tf-m

Design Flooding Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	664.448	7.580	5036.519			
Horizontal earthquake load (Main body)						
Weight of muddy soil						
Horizontal earthquake load (Muddy soil)						
Surcharge load						
Weight of water	1629.450	7.500	12220.875			
Earth pressure				3.398	0.400	1.359
Hydrostatic pressure						
Uplift	-1904.850	7.500	-14286.375			
Total	389.048		2971.019	3.398		1.359

Acting force at toe of Concrete apron

V0=	389.048 tf
H0=	3.398 tf
M0=Mx+My=	2972.378 tf-m

Acting force at middle of bottom of Concrete apron

Vc=	389.048 tf
Hc=	3.398 tf
Mc=Mx+My=	3.842 tf-m

Seismic Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	664.448	7.580	5036.519			
Horizontal earthquake load (Main body)				79.734	0.622	49.594
Weight of muddy soil						
Horizontal earthquake load (Muddy soil)						
Surcharge load						
Weight of water	68.850	5.075	349.414			
Earth pressure				5.606	0.400	2.242
Hydrostatic pressure						
Uplift	-447.715	7.154	-3203.083			
Total	285.583		2182.850	85.340		51.837

Acting force at toe of Concrete apron

V0=	285.583 tf
H0=	85.340 tf
M0=Mx+My=	2234.686 tf-m

Acting force at middle of bottom of Concrete apron

Vc=	285.583 tf
Hc=	85.340 tf
Mc=Mx+My=	-49.976 tf-m

2) Stability Analysis

Type of Pile

The prestressed concrete pile is adopted for the foundation pile of apron.

Refer to stability calculation of center pier.

Pile Diameter and Arrangement

There are many cases for the combination of pile diameter and pile arrangement (number of pile). Judging from the structural size, geological and soil mechanical conditions, the following three alternatives are selected for comparative study. It is noted that the maximum pile diameter that is available in this country, is 600 mm.

Alternative-1	PC Pile Dia.400 mm, type A	25 piles
Alternative-2	PC Pile Dia.450 mm, type A	20 piles
Alternative-3	PC Pile Dia.500 mm, type A	16 piles

The allowable bearing capacity of ground is shown in each alternative pile as follows.

Layer	Li (m)	N – Value Average	Fi (tf / m)	Li·Fi (tf / m)
As	5.50	17	3.40	18.70
Ac	3.50	16	9.60	33.60
Dc	1.40	35	15.00	21.00
Total	10.40			73.30

Alternative – 1 (Dia 400 mm)

$$A = \pi/4\, D^2 = \pi/4 \times (0.40)^2 = 0.126\ \text{m}^2$$

$$qd = 500\ \text{tf/m}^2 \times A = 63.00\ \text{tf}$$

$$U = \pi D = \pi \times 0.40 = 1.257\ \text{m}$$

$$Ru = 63.00 + 1.257 \times 73.30 = 155.14\ \text{tf/pile}$$

Allowable bearing capacity for PC pile (Dia 400 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	51.71
Seismic	2	77.57

Alternative – 2 (Dia 450 mm)

$$A = \pi/4\, D^2 = \pi/4 \times (0.45)^2 = 0.159\ m^2$$

qd = 500 tf / m²×A = 79.50 tf

U = π D = π ×0.45 = 1.414 m

Ru = 79.50 + 1.414×73.30 = 183.15 tf / pile

Allowable bearing capacity
for PC pile (Dia 450 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	61.05
Seismic	2	91.57

Alternative – 3 (Dia 500 mm)

$$A = \pi/4\, D^2 = \pi/4 \times (0.50)^2 = 0.196\ m^2$$

qd = 500 tf / m²×A = 98.00 tf

U = π D = π ×0.50 = 1.571 m

Ru = 98.00 + 1.571×73.30 = 213.15 tf / pile

Allowable bearing capacity
for PC pile (Dia 500 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	71.05
Seismic	2	106.58

Calculation Results

Pile stability analyses for Alternative-1, Alternative-2 and Alternative-3 were conducted based on the conditions mentioned above. As a result Alternative-2 (pile dia.=450mm, n=20 piles) was selected for the economical reason. The calculation results are shown as follows.

COMPARATIVE STUDY ON PILE FOUNDATION FOR APRON (EL+0.900)

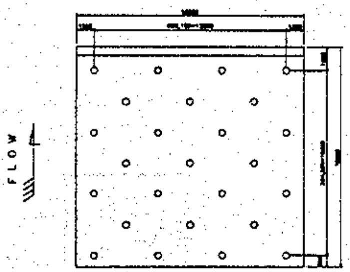
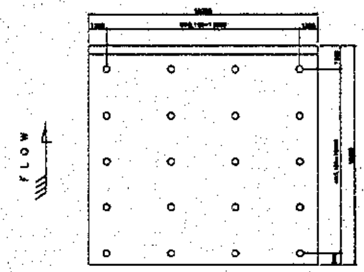
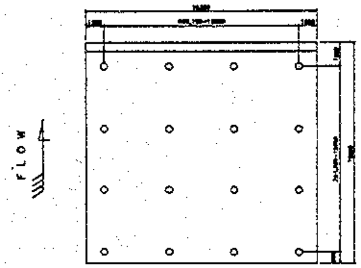
kind of pile		Alternative –1 Dia. 400 (A)			Alternative –2 Dia .450 (A)			Alternative –3 Dia. 500 (A)		
Pile Arrangement										
Number of necessary pile		25 piles (L=10.40m)			20 piles (L=10.40m)			16 piles (L=10.40m)		
Displacement (Horizontal)		Calculation (mm)	Allowable capacity (mm)		Calculation (mm)	Allowable capacity (mm)		Calculation (mm)	Allowable capacity (mm)	
Normal Case		0.03	10		0.02	10		0.04	10	
Design flooding Case		0.04	10		0.02	10		0.04	10	
Constructional Case		0.02	10		0.00	10		0.03	10	
Seismic Case		0.42	15		0.44	15		0.50	15	
Force / Moment Acting on Pile		Axial load (tf)	Bending moment (tf-m)		Axial load (tf)	Bending moment (tf-m)		Axial load (tf)	Bending moment (tf-m)	
			Calculation	Allowable capacity		Calculation	Allowable capacity		Calculation	Allowable capacity
Normal Case		9.248	0.072	2.80	12.530	0.177	3.97	15.013	0.141	5.44
Design flooding Case		12.654	0.061	3.03	17.103	0.188	4.32	20.528	0.121	5.90
Constructional Case		30.145	0.084	4.20	40.331	0.079	6.09	48.581	0.153	8.26
Seismic Case		7.855	2.109	4.34	12.639	3.045	6.25	12.998	4.037	8.41
Bearing capacity (tf)	Normal	51.71			61.05			71.05		
	Seismic	77.57			91.57			106.58		
Summary of cost		Rp 25.2 million			Rp 22.9 million			Rp 23.4 million		
Evaluation		Not adopted			Adopted			Not adopted		

TABLE OF STABILITY CALCULATION FOR APRON (EL+0.900)

Direction		Direction of flowing water				Direction of weir axis			
Case		Normal case	Design Flooding case	Construction case	Seismic case	Normal case	Design Flooding case	Construction case	Seismic case
Quantity of displacement for footing (m)	Horizontal (δ X m)	0.0000243	0.0000220	0.0000170	0.0004354	-	-	-	-
	Allowable	0.010	0.010	0.010	0.015	0.010	0.010	0.010	0.015
	Vertical (δ Y m)	0.0004138	0.0005637	0.0012934	0.0004136	-	-	-	-
	Allowable	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Axial force (tf/pile)	No.1	12.5300	17.1028	40.3314	12.6394	-	-	-	-
	No.2	13.4046	18.2776	42.5144	13.4593	-	-	-	-
	No.3	14.2791	19.4524	44.6974	14.2791	-	-	-	-
	No.4	15.1537	20.6272	46.8804	15.0990	-	-	-	-
	No.5	16.0283	21.8020	49.0634	15.9189	-	-	-	-
	No.6	-	-	-	-	-	-	-	-
	No.7	-	-	-	-	-	-	-	-
	No.8	-	-	-	-	-	-	-	-
	No.9	-	-	-	-	-	-	-	-
Allowable bearing capacity (tf/pile)		61.05	61.05	61.05	91.57	-	-	-	-
Shearing stress (tf)		0.1699	0.1699	0.0000	4.2670	-	-	-	-
Bending moment (tf-m/pile)		0.1768	0.1877	0.0793	3.0453	-	-	-	-
Allowable bending moment (tf-m/pile)		3.97	4.32	6.09	6.25	-	-	-	-

Number of piles: n=20 piles

Pile head condition: Fixing

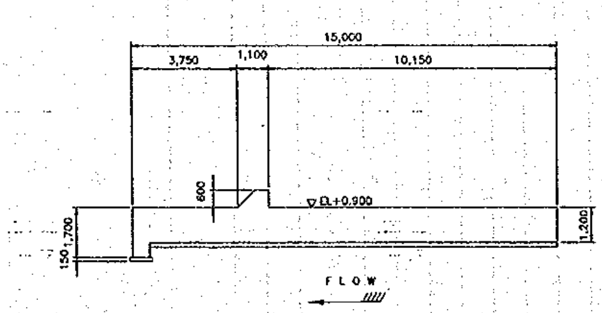
<u>Pile condition</u>

1. Diameter: Dia.450 mm
2. Geometrical moment of area: I = 0.00169800 m^4
3. Section area of pile A = 0.99300 m^2

3) Stress-Strain Calculation

(i) Main body

Stress-strain calculations of the structure are made to decide proper reinforcing bar arrangement. Described below are the bar arrangement for the center pier. Deformed steel bars are used for all parts of structure, and bar spacing will be 125 mm or 250 mm.



PROFILE

Loading calculation

W1 (Weight of body)	1.20×2.50 tf/m³	= 3.000 tf/m²
W2 (Weight of water)	0.60×1.00 tf/m³	= 0.600 tf/m²
W3 (Surcharge load)		= 1.000 tf/m²
W6-4 (Uplift)		= 2.219 tf/m²
		= 1.631 tf/m²

Horizontal pressure

<Normal case>

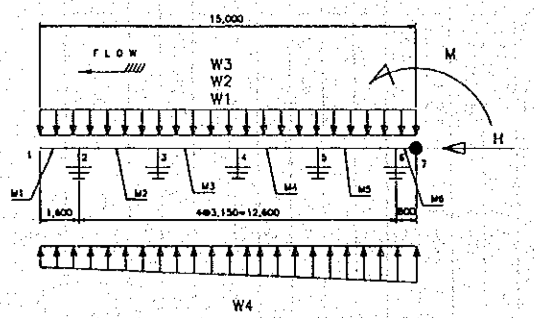
H = 0.222 tf/m (Refer to stability analysis.)

M = 0.222 tf/m×0.400 = 0.089 tf-m/m

<Construction case>

H = 0.000 tf/m (Refer to stability analysis)

M = 0.000 tf-m/m



Geometrical moment of inertia

Member	Calculation	Geometrical moment of inertia (m^4)
1~6	$\frac{1}{12} \times 1.00 \times 1.20^3$	0.1440

Section area

Member	Calculation	Area (m^2)
1~6	1.20×1.00	1.200

Axial spring constant

$$Kv = a\frac{Ap \times Ep}{L}$$

$a = 0.013 \times (L/D) + 0.61$ (for prestressed concrete pile)

a = 0.013×(10.40 / 0.45) + 0.61 = 0.91044
Ap = 0.099 m^2
Ep = 4.0×10^6 tf/m^2
Kv = 34666.75 tf/m
Kh = 1/3×Kv = 11555.58 tf/m

Summary of calculation results is shown as follows.

(Normal case)

Member	Condition	Distance (m)	Bending moment M (tf –m)	Shearing stress S (tf)	Axial Force N (tf)
M1	Maximum	0.000	0.000	0.000	0.000
	Minimum	1.600	-2.494	-3.100	0.000
M2	Maximum	1.688	0.160	0.000	0.000
	Minimum	0.000	-2.494	3.162	0.000
M3	Maximum	1.687	0.689	0.000	0.000
	Minimum	0.000	-1.785	2.952	0.000
M4	Maximum	1.697	1.198	0.000	0.000
	Minimum	0.000	-1.127	2.759	0.000
M5	Maximum	1.568	1.374	0.000	0.000
	Minimum	0.000	-0.463	2.360	0.000
M6	Maximum	0.800	0.000	0.000	0.000
	Minimum	0.000	-0.445	1.117	0.000

(Construction case)

Member	Condition	Distance (m)	Bending moment M (tf –m)	Shearing stress S (tf)	Axial Force N (tf)
M1	Maximum	0.000	0.000	0.000	0.000
	Minimum	1.600	-5.120	-6.400	0.000
M2	Maximum	1.673	0.476	0.000	0.000
	Minimum	0.000	-5.120	6.691	0.000
M3	Maximum	1.679	1.749	0.000	0.000
	Minimum	0.000	-3.889	6.716	0.000
M4	Maximum	1.698	3.188	0.000	0.000
	Minimum	0.000	-2.579	6.792	0.000
M5	Maximum	1.555	3.808	0.000	0.000
	Minimum	3.150	-1.280	-6.380	0.000
M6	Maximum	0.800	0.000	0.000	0.000
	Minimum	0.000	-1.280	3.200	0.000

(Design flooding case)

Member	Condition	Distance (m)	Bending moment M (tf－m)	Shearing stress S (tf)	Axial Force N (tf)
M1	Maximum	0.000	0.000	0.000	0.000
	Minimum	1.600	-2.304	-2.880	0.000
M2	Maximum	1.673	0.214	0.000	0.000
	Minimum	0.000	-2.304	3.011	0.000
M3	Maximum	1.679	0.787	0.000	0.000
	Minimum	0.000	-1.750	3.022	0.000
M4	Maximum	1.698	1.434	0.000	0.000
	Minimum	0.000	-1.161	3.056	0.000
M5	Maximum	1.555	1.713	0.000	0.000
	Minimum	3.150	-0.576	-2.871	0.000
M6	Maximum	0.800	0.000	0.000	0.000
	Minimum	0.000	-0.576	1.440	0.000

Results of strength calculation are shown as follows.

Table of strength calculation result at standard section

		Normal case		Construction case		Design flooding case	
		Top side	Bottom side	Top side	Bottom side	Top side	Bottom side
Member of shape		Rectangle	Rectangle	Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	-2.49	1.37	-5.12	3.81	-2.30	1.71
N	tf	0.00	0.00	0.00	0.00	0.00	0.00
S	tf	3.16	0.00	6.69	0.00	3.01	0.00
B	cm	100.00	100.00	100.00	100.00	100.00	100.00
D	cm	111.00	103.50	111.00	103.50	111.00	103.50
Ac	cm^2	11100.00	10350.00	11100.00	10350.00	11100.00	10350.00
As	cm^2	D16-250 =8.04	D16-250 =8.04	D16-250 =8.04	D16-250 =8.04	D16-250 =8.04	D16-250 =8.04
P=As/(B×D)		0.00072	0.00078	0.00072	0.00078	0.00072	0.00078
N=Es/Ec		15	15	15	15	15	15
X0	cm	15.2	14.6	15.2	14.6	15.2	14.6
K=X0/D		0.137	0.141	0.137	0.141	0.137	0.141
M/(B×D2)	kgf/cm^2	0.202	0.128	0.416	0.356	0.187	0.160
S/(B×D)	kgf/cm^2	0.285	0.000	0.603	0.000	0.271	0.000
(C)		15.303	14.839	15.303	14.839	15.303	14.839
(S)		96.442	90.068	96.442	90.068	96.442	90.068
(Z)		1.048	1.049	1.048	1.049	1.048	1.049
σ c	kgf/cm^2	3.10	1.90	6.40	5.30	2.90	2.40
σ s	kgf/cm^2	292.00	173.00	601.00	481.00	270.00	216.00
τ	kgf/cm^2	0.28	0.00	0.60	0.00	0.27	0.00
σ ca	kgf/cm^2	75.00	75.00	75.00	75.00	75.00	75.00
σ sa	kgf/cm^2	1600.00	1600.00	1600.00	1600.00	1600.00	1600.00
τ a	kgf/cm^2	3.80	3.80	3.80	3.80	3.80	3.80

(ii) Pile head treatment

h) Vertical bearing pressure for footing concrete

Pnmax = 49.063 tf/pile (in Construction case)

$$\sigma_{cv} = \frac{P_{N\max}}{\pi D^2/4} = \frac{49063}{\pi/4 \times 45^2} = 30.85 \text{ kgf/cm}^2$$

$\leqq \sigma$ ca = 60.0 kgf/cm² .... O.K

i) Punching shear stress for footing concrete

$$\tau_V = \frac{P_{N\max}}{\pi(D+h)h} = \frac{49063}{\pi(45+110)\times 110} = 0.92 \text{ kgf/cm}^2$$

$\leqq \tau$ ca3 = 8.8 kgf/cm² .... O.K

where

h : Height of between top of footing and pile head (cm)

j) Horizontal bearing pressure for footing concrete

$$\sigma_{ch} = \frac{H}{D\ell}$$

where

l : Stuffing length of pile (cm)
D : Pile diameter (cm)
H : Shearing pressure (kgf)

$P_N$max = 15.92 tf/pile (in Seismic case)
M = 3.05 tf-m
S = 4.27 tf

$$\sigma_{ch} = \frac{4370}{45\times 10} = 9.71 \text{ kgf/cm}^2 \leqq \sigma \text{ ca} = 60.0\times 1.5 = 90.0 \text{ kgf/cm}^2$$

.... O.K

k) Vertical punching shearing stress to pile on edge of footing

$$\tau_h = \frac{H}{h'(2\ell + D + 2h')}$$

where

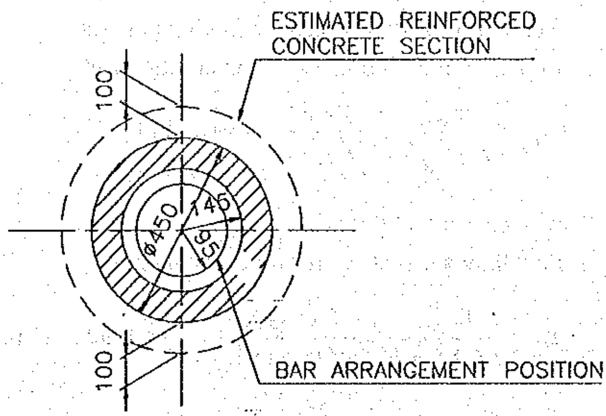
h' : Effective thickness to vertical punching stress on footing (cm)
l : Stuffing length of pile (cm)
D : Pile diameter (cm)
H : Shearing pressure (kgf)

h' = (80-1/2×45) = 57.5 cm

$$\tau_h = \frac{4370}{57.5\times(2\times 10 + 45 + 2\times 57.5)} = 0.42 \text{ kgf/cm}^2$$

$\leqq \tau$ ca3 = 8.8 kgf/cm² .... O.K

l) Strength of estimated reinforced concrete section



$P_N$min	= 12.64 tf/pile (in Seismic case)
M	= 3.05 tf-m
S	= 4.27 tf
D	= 45.00 + 10.00×2 = 65.00cm
a	= 14.50 cm×2 = 29.00 cm
d	= 23.00 cm

Result of strength calculation is shown as follows.

Member of shape			Circle		
M	tf-m	-3.05	X0	cm	12.70
N	tf	0.00	K= X0/H		0.196
S	tf	4.27	M/(B×H^2)	kgf/cm^2	1.111
B	cm	65.00	S/(B×H)	kgf/cm^2	1.011
H	cm	65.00	(C)		50.097
D	cm	42.00	(S)		115.465
DD	cm	23.00	(Z)		3.419
DG	cm	23.00	σ c	kgf/cm^2	55.60
B0 , R	cm	32.50	σ s	kgf/cm^2	1924.00
H0 , R0	cm	14.50	τ	kgf/cm^2	0.00
AC	cm^2	2657.8	σ ca	kgf/cm^2	112.50
AS , AS1	cm^2	6-D13 =7.98	σ sa	kgf/cm^2	2400.00
P , P1		0.003	τ a	kgf/cm^2	5.70
N= ES/EC		15			

m) Reinforcing bar at pile head treatment

Fixing length of reinforcing bar at footing

$$L_1 \geqq L_0$$

Where

L0 : 35 D (mm)

D : Diameter of reinforcing bar (mm)

$L_1 = 35 \times 13 = 455 \fallingdotseq 500$ mm

Fixing length of reinforcing bar at pile

$$L_2 \geqq 50\phi + L_0$$

Where

ϕ : Diameter of PC steel bar (mm)

$$L2 = 50 \times 9.0 + 500 = 950 \text{ mm}$$

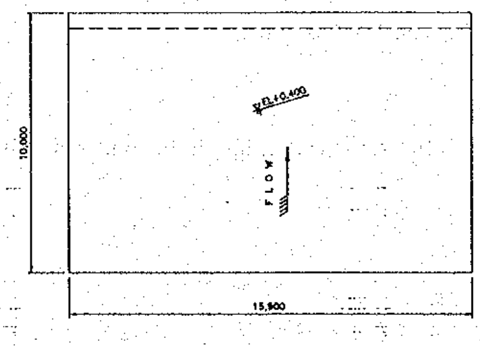
n) Depth of concrete filling

Depth of concrete filling is the same fixing length of reinforcing bar at pile.

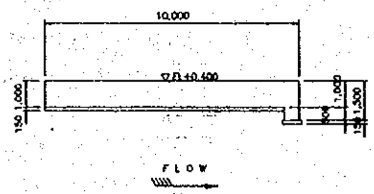
$$L_3 = 950 \text{ mm}$$

4.2.3.3 Apron (EL+0.400)

1) Loading Condition



PLAN



PROFILE

Design Condition

Item	Unit		Item	Unit	
Thickness at upstream of gate	m	1.000	Unit weight of concrete	tf / m³	2.350
Thickness at downstream of gate	m	-	Unit weight of water	tf / m³	1.000
Length of slab at flowing water	m	10.000	Unit weight of soil	tf / m³	1.800
Width of slab at weir axis	m	15.900	Submerged unit weight	tf / m³	1.000
Length of slab at upstream of gate	m	-	Angle of shearing resistance		30.000
Length of slope section	m	-	Horizontal seismic intensity		0.120
Length of slab at downstream of gate	m	-	Apparently horizontal seismic intensity		0.240
Width of muddy soil	m	0.000	Coefficient of earth pressure in Normal case		0.3085
Weight of flood discharge gate	tf/m	-	Coefficient of earth pressure in Seismic case above water		0.4107
Distance of installed gate position	m	-	Coefficient of earth pressure in seismic case below water		0.5089
Surcharge load in construction case	tf / m²	1.000	Top elevation of slab	EL m	0.400
			Bottom elevation of slab	EL m	-0.600
			Normal water level	EL m	1.050
			Water level in seismic case	EL m	0.700
			Design high water level	EL m	6.900

1. Weight of body

	Weight W (tf)	Vertical length X (m)	Moment MX (tf-m)	Horizontal length Y (m)	Moment MY(tf-m)	Note
1	373.650	5.000	1868.250	0.500	186.825	Conc.
Total	373.650	5.000	1868.250	0.500	186.825	

2. Surcharge load

Construction case	Weight W(tf)	Vertical length X (m)
	159.000	5.000

3. Weight of water

Normal case Sesimic case	Weight W (tf)	Vertical length X (m)	Moment MX (t-m)	Horizontal length Y (m)	Moment MY(tf-m)	Note
	47.700	5.000	238.500	1.150	54.855	
Total	47.700	5.000	238.500	1.150	54.855	

Design flooding case	Weight W (tf)	Vertical length X (m)	Moment MX (tf-m)	Horizontal length Y (m)	Moment MY(tf-m)	Note
	1033.500	5.000	5167.500	4.250	4392.375	
Total	1033.500	5.000	5167.500	4.250	4392.375	

4. Earth pressure

Normal case	(tf/m^2)		(tf/m)		(m)
Pa0=	0.000	E1=	2.452	Y1=	0.333
Pa1=	0.308				
Sesimic case	(tf/m^2)		(tf/m)		(m)
Pea0=	0.000	Ee1=	4.046	Ye1=	0.333
Pea1=	0.509				

5. Hydrostatic pressure

Normal ,Seismic					
Wa0=	0.300		(tf/m)		(m)
Wa1=	1.650	P1=	15.503	Y3=	0.385
Design flooding					
Wae0=	6.500		(tf/m)		(m)
Wae1=	7.500	Pe1=	111.300	Ye3=	0.488

6. Uplift

Normal ,Seismic			(tf/m)		(m)
U1=	0.000	U=	-360.453	X1=	6.667
U2=	4.534				
Design flooding			(tf/m)		(m)
Ue1=	7.500	Ue=	-1192.500	Xe1=	5.000
Ue2=	7.500				

Normal Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	373.650	5.000	1868.250			
Horizontal earthquake load (Main body)						
Weight of muddy soil						
Horizontal earthquake load (Muddy soil)						
Surcharge load						
Weight of water	47.700	5.000	238.500			
Earth pressure				2.452	0.333	0.817
Hydrostatic pressure						
Uplift	-195.608	4.354	-851.614			
Total	225.742		1255.136	2.452		0.817

Acting force at toe of Concrete apron

V0=	225.742 tf
H0=	2.452 tf
M0=Mx+My=	1255.953 tf-m

Acting force at middle of bottom of Concrete apron

Vc=	225.742 tf
Hc=	2.452 tf
Mc=Mx+My=	-127.241 tf-m

Construction Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	373.650	5.000	1868.250			
Horizontal earthquake load (Main body)						
Weight of muddy soil						
Horizontal earthquake load (Muddy soil)						
Surcharge load	159.000	5.000	795.000			
Weight of water						
Earth pressure						
Hydrostatic pressure						
Uplift						
Total	532.650		2663.250	0.000		0.000

Acting force at toe of Concrete apron

V0=	532.650 tf
H0=	0.000 tf
M0=Mx+My=	2663.250 tf-m

Acting force at middle of bottom of Concrete apron

Vc=	532.650 tf
Hc=	0.000 tf
Mc=Mx+My=	0.000 tf-m

Design flooding Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	373.650	5.000	1868.250			
Horizontal earthquake load (Main body)						
Weight of muddy soil						
Horizontal earthquake load (Muddy soil)						
Surcharge load						
Weight of water	1033.500	5.000	5167.500			
Earth pressure				2.452	0.333	0.817
Hydrostatic pressure						
Uplift	-1192.500	5.000	-5962.500			
Total	214.650		1073.250	2.452		0.817

Acting force at toe of Concrete apron
V0= 214.650 tf
H0= 2.452 tf
M0=Mx+My= 1074.067 tf-m
Acting force at middle of bottom of Concrete apron
Vc= 214.650 tf
Hc= 2.452 tf
Mc=Mx+My= -0.817 tf-m

Seismic Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	373.650	5.000	1868.250			
Horizontal earthquake load (Main body)				44.838	0.500	22.419
Weight of muddy soil						
Horizontal earthquake load (Muddy soil)						
Surcharge load						
Weight of water	47.700	5.000	238.500			
Earth pressure				4.046	0.333	1.349
Hydrostatic pressure						
Uplift	-195.608	4.354	-851.614			
Total	225.742		1255.136	48.884		23.768

Acting force at toe of Concrete apron
V0= 225.742 tf
H0= 48.884 tf
M0=Mx+My= 1278.904 tf-m
Acting force at middle of bottom of Concrete apron
Vc= 225.742 tf
Hc= 48.884 tf
Mc=Mx+My= -150.192 tf-m

2) Stability Analysis

Type of Pile

The prestressed concrete pile is adopted for the foundation pile of apron.

Refer to stability calculation of center pier.

Pile Diameter and Arrangement

There are many cases for the combination of pile diameter and pile arrangement (number of pile). Judging from the structural size, geological and soil mechanical conditions, the following three alternatives are selected for comparative study. It is noted that the maximum pile diameter that is available in this country, is 600 mm.

Alternative-1	PC Pile Dia.400 mm, type A	20 piles
Alternative-2	PC Pile Dia.450 mm, type A	16 piles
Alternative-3	PC Pile Dia.500 mm, type A	13 piles

The allowable bearing capacity of ground is shown in each alternative pile as follows.

Layer	Li (m)	N – Value Average	Fi (tf / m)	Li·Fi (tf / m)
As	5.30	17	3.40	18.02
Ac	3.50	16	9.60	33.60
Dc	1.40	35	15.00	21.00
Total	10.20			72.62

Alternative – 1 (Dia 400 mm)

$$A = \pi/4\, D^2 = \pi/4 \times (0.40)^2 = 0.126 \text{ m}^2$$

$$qd = 500 \text{ tf / m}^2 \times A = 63.00 \text{ tf}$$

$$U = \pi D = \pi \times 0.40 = 1.257 \text{ m}$$

$$Ru = 63.00 + 1.257 \times 72.620 = 154.28 \text{ tf / pile}$$

Allowable bearing capacity
for PC pile (Dia 400 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	51.43
Seismic	2	77.14

Alternative – 2 (Dia 450 mm)

$$A = \pi/4\, D^2 = \pi/4 \times (0.45)^2 = 0.159\ m^2$$

$qd = 500\ tf / m^2 \times A = 79.50\ tf$

$U = \pi D = \pi \times 0.45 = 1.414\ m$

$Ru = 79.50 + 1.414 \times 72.62 = 182.18\ tf / pile$

Allowable bearing capacity
for PC pile (Dia 450 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	60.73
Seismic	2	91.10

Alternative – 3 (Dia 500 mm)

$$A = \pi/4\, D^2 = \pi/4 \times (0.50)^2 = 0.196\ m^2$$

$qd = 500\ tf / m^2 \times A = 98.00\ tf$

$U = \pi D = \pi \times 0.50 = 1.571\ m$

$Ru = 98.00 + 1.571 \times 72.62 = 212.09\ tf / pile$

Allowable bearing capacity
for PC pile (Dia 500 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	70.70
Seismic	2	106.04

Calculation Results

Pile stability analyses for Alternative-1, Alternative-2 and Alternative-3 were conducted based on the conditions mentioned above. As a result Alternative-2 (pile dia.=450mm, n=16 piles) was selected for the economical reason. The calculation results are shown as follows.

COMPARATIVE STUDY ON PILE FOUNDATION FOR APRON (EL+0.400)

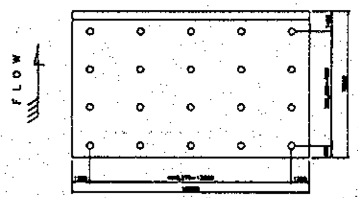
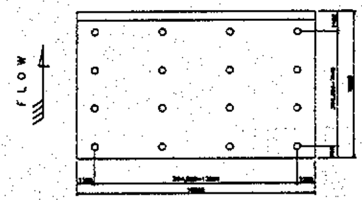
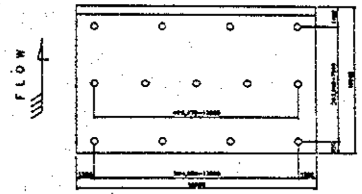
<table>
<tr><td colspan="2">kind of pile</td><td colspan="3">Alternative –1 Dia. 400 (A)</td><td colspan="3">Alternative –2 Dia. 450 (A)</td><td colspan="3">Alternative –3 Dia. 500 (A)</td></tr>
<tr><td colspan="2">Pile Arrangement</td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="2">Number of necessary pile</td><td colspan="3">20 piles (L=10.20m)</td><td colspan="3">16 piles (L=10.20m)</td><td colspan="3">13 piles (L=10.20m)</td></tr>
<tr><td colspan="2">Displacement (Horizontal)</td><td>Calculation (mm)</td><td colspan="2">Allowable capacity (mm)</td><td>Calculation (mm)</td><td colspan="2">Allowable capacity (mm)</td><td>Calculation (mm)</td><td colspan="2">Allowable capacity (mm)</td></tr>
<tr><td colspan="2">Normal Case</td><td>0.03</td><td colspan="2">10</td><td>0.06</td><td colspan="2">10</td><td>0.06</td><td colspan="2">10</td></tr>
<tr><td colspan="2">Design flooding Case</td><td>0.03</td><td colspan="2">10</td><td>0.06</td><td colspan="2">10</td><td>0.06</td><td colspan="2">10</td></tr>
<tr><td colspan="2">Constructional Case</td><td>0.00</td><td colspan="2">10</td><td>0.00</td><td colspan="2">10</td><td>0.00</td><td colspan="2">10</td></tr>
<tr><td colspan="2">Seismic</td><td>0.33</td><td colspan="2">15</td><td>0.63</td><td colspan="2">15</td><td>0.68</td><td colspan="2">15</td></tr>
<tr><td colspan="2" rowspan="2">Force / Moment Acting on Pile</td><td rowspan="2">Axial load (tf)</td><td colspan="2">Bending moment (tf-m)</td><td rowspan="2">Axial load (tf)</td><td colspan="2">Bending moment (tf-m)</td><td rowspan="2">Axial load (tf)</td><td colspan="2">Bending moment (tf-m)</td></tr>
<tr><td>Calculation</td><td>Allowable capacity</td><td>Calculation</td><td>Allowable capacity</td><td>Calculation</td><td>Allowable capacity</td></tr>
<tr><td colspan="2">Normal Case</td><td>15.786</td><td>-</td><td></td><td>19.733</td><td>-</td><td></td><td>15.784</td><td>-</td><td></td></tr>
<tr><td colspan="2">Design flooding Case</td><td>12.237</td><td>-</td><td></td><td>15.297</td><td>-</td><td></td><td>12.237</td><td>-</td><td></td></tr>
<tr><td colspan="2">Constructional Case</td><td>30.320</td><td>-</td><td></td><td>37.900</td><td>-</td><td></td><td>30.320</td><td>-</td><td></td></tr>
<tr><td colspan="2">Seismic Case</td><td>16.316</td><td>-</td><td></td><td>20.395</td><td>-</td><td></td><td>16.316</td><td>-</td><td></td></tr>
<tr><td rowspan="2">Bearing capacity (tf)</td><td>Normal</td><td colspan="3">51.43</td><td colspan="3">60.73</td><td colspan="3">70.70</td></tr>
<tr><td>Seismic</td><td colspan="3">77.14</td><td colspan="3">91.10</td><td colspan="3">106.04</td></tr>
<tr><td colspan="2">Summary of cost</td><td colspan="3">Rp 20.7 million</td><td colspan="3">Rp 18.0 million</td><td colspan="3">Rp 18.6 million</td></tr>
<tr><td colspan="2">Evaluation</td><td colspan="3">Not adopted</td><td colspan="3">Adopted</td><td colspan="3">Not adopted</td></tr>
</table>

TABLE OF STABILITY CALCULATION FOR APRON (EL+0.400)

Direction		Direction of flowing water				Direction of weir axis			
Case		Normal case	Design Flooding case	Construction case	Seismic case	Normal case	Design Flooding case	Construction case	Seismic case
Quantity of displacement for footing (m)	Horizontal (δ X m)	0.0000562	0.0000562	0.0000000	0.0006311	-	-	-	-
	Allowable	0.010	0.010	0.010	0.015	0.010	0.010	0.010	0.015
	Vertical (δ Y m)	0.0002081	0.0003165	0.0007873	0.0001855	-	-	-	-
	Allowable	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Axial force (tf/pile)	No.1	8.4849	11.5345	28.6812	7.8228	-	-	-	-
	No.2	12.2342	12.7886	31.7541	12.0135	-	-	-	-
	No.3	15.9835	14.0427	34.8271	16.2042	-	-	-	-
	No.4	19.7329	15.2967	37.9001	20.3949	-	-	-	-
	No.5	-	-	-	-	-	-	-	-
	No.6	-	-	-	-	-	-	-	-
	No.7	-	-	-	-	-	-	-	-
	No.8	-	-	-	-	-	-	-	-
	No.9	-	-	-	-	-	-	-	-
Allowable bearing capacity (tf/pile)		60.73	60.73	60.73	91.10	-	-	-	-
Shearing stress (tf)		0.1532	0.1532	0.0000	3.0553	-	-	-	-
Bending moment (tf-m/pile)		-	-	-	-	-	-	-	-
Allowable bending moment (tf-m/pile)		-	-	-	-	-	-	-	-

Number of piles: n = 16 piles

Pile head condition: Hinge

Pile condition

1. Diameter: Dia.450 mm
2. Geometrical moment of area: $I = 0.00169800\ m^4$
3. Section area of pile $A = 0.99300\ m^2$

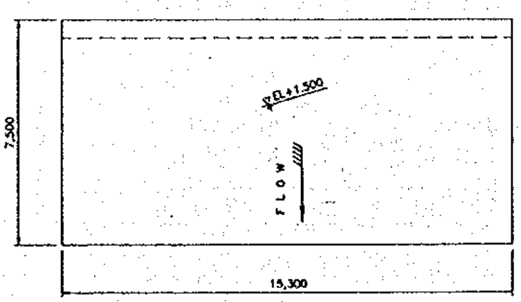
3) Stress-Strain Calculation

Stress-strain calculations of the structure are made to decide proper reinforcing bar arrangement. Described below are the bar arrangement for apron (EL+0.400).

Structural Part	Diameter of Re. Bars (mm)	Interval of Bars (mm)	Side of structure	Particular
Apron (EL+0.400)	D16	250	Lower	Flow direction
- ditto -	D16	250	Upper	- ditto -
- ditto -	D16	250	Lower	Gate axis
- ditto -	D16	250	Upper	- ditto -

4.2.3.4 Apron (EL+1.500)

1) Loading Condition



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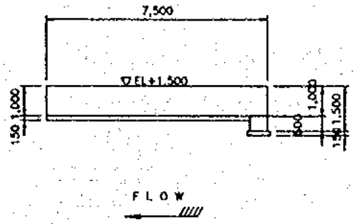


PROFILE

Design Condition

Item	Unit		Item	Unit	
Thickness at upstream of gate	m	1.000	Unit weight of concrete	tf/m^3	2.350
Thickness at downstream of gate	m	-	Unit weight of water	tf/m^3	1.000
Length of slab at flowing water	m	7.500	Unit weight of soil	tf/m^3	1.800
Width of slab at weir axis	m	15.300	Submerged unit weight	tf/m^3	1.000
Length of slab at upstream of gate	m	-	Angle of shearing resistance		30.000
Length of slope section	m	-	Horizontal seismic intensity		0.120
Length of slab at downstream of gate	m	-	Apparently horizontal seismic intensity		0.240
Width of muddy soil	m	1.000	Coefficient of earth pressure in Normal case		0.3085
Weight of flood discharge gate	tf/m	-	Coefficient of earth pressure in Seismic case above water		0.4107
Distance of installed gate position	m	-	Coefficient of earth pressure in seismic case below water		0.5089
Surcharge load in construction case	tf/m^2	1.000	Top elevation of slab	EL m	1.500
			Bottom elevation of slab	EL m	0.500
			Normal water level	EL m	5.850
			Water level in seismic case	EL m	5.200
			Design high water level	EL m	8.000

1. Weight of body

	Weight W(tf)	Vertical length X (m)	Moment MX (tf-m)	Horizontal length Y (m)	Moment MY (tf-m)	Note
1	269.663	3.750	1011.234	0.500	134.831	Conc.
Total	269.663	3.750	1011.234	0.500	134.831	

2.Weight of muddy soil

Normal case Seismic case	Weight W (tf)	Vertical length X (m)	Moment MX (tf-m)	Horizontal length Y (m)	Moment MY (tf-m)
	114.750	3.750	430.313	1.500	172.125

3. Surcharge load

Construction case	Weight W (tf)	Vertical length X(m)
	114.750	3.750

4. Weight of water

Normal case Sesimic case	Weight W (tf)	Vertical length X (m)	Moment MX (tf-m)	Horizontal length Y (m)	Moment MY (tf-m)	Note
	424.575	3.750	1592.156	2.850	1210.039	
Total	424.575	3.750	1592.156	2.850	1210.039	

Design flooding case	Weight W (tf)	Vertical length X (m)	Moment MX (tf-m)	Horizontal length Y (m)	Moment MY (tf-m)	Note
	745.875	3.750	2797.031	4.250	3169.969	
Total	745.875	3.750	2797.031	4.250	3169.969	

5. Earth pressure

Normal case	(tf/m^2)		(tf/m)		(m)
Pa0=	0.000	E1=	2.360	Y1=	0.333
Pa1=	0.308				
Seismic case	(tf/m^2)		(tf/m)		(m)
Pea0=	0.000	Ee1=	3.893	Ye1=	0.333
Pea1=	0.509				

6. Hydrostatic pressure

Normal, Seismic			(tf/m)		(m)
Wa0=	3.700				
Wa1=	5.350	P1=	69.233	Y3=	0.470
Design flooding			(tf/m)		(m)
Wae0=	6.500				
Wae1=	7.500	Pe1=	107.100	Ye3=	0.488

Normal Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	269.663	3.750	1011.234			
Horizontal earthquake load (Main body)						
Weight of muddy soil	114.750	3.750	430.313			
Horizontal earthquake load (Muddy soil)						
Surcharge load						
Weight of water	424.575	3.750	1592.156			
Earth pressure				2.360	0.333	0.787
Hydrostatic pressure						
Uplift	-592.382	3.252	-1926.512			
Total	216.606		1107.191	2.360		0.787

Acting force at toe of Concrete Apron

V0= 216.606 Tf
H0= 2.360 Tf
M0=Mx+My= 1107.977 tf-m

Construction Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	269.663	3.750	1011.234			
Horizontal earthquake load (Main body)						
Weight of muddy soil						
Horizontal earthquake load (Muddy soil)						
Surcharge load	114.750	3.750	430.313			
Weight of water						
Earth pressure						
Hydrostatic pressure						
Uplift						
Total	384.413		1441.547	0.000		0.000

Acting force at toe of Concrete Apron

V0= 384.413 tf
H0= 0.000 tf
M0=Mx+My= 1441.547 tf-m

Design flooding Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	269.663	3.750	1011.234			
Horizontal earthquake load (Main body)						
Weight of muddy soil						
Horizontal earthquake load (Muddy soil)						
Surcharge load						
Weight of water	745.875	3.750	2797.031			
Earth pressure				2.360	0.333	0.787
Hydrostatic pressure						
Uplift	-860.625	3.750	-3227.344			
Total	154.913		580.922	2.360		0.787

Acting force at toe of Concrete Apron

V0= 154.913 tf
H0= 2.360 tf
M0=Mx+My= 581.709 tf-m

Seismic Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	269.663	3.750	1011.234			
Horizontal earthquake load (Main body)				32.360	0.500	16.180
Weight of muddy soil	114.750	3.750	430.313			
Horizontal earthquake load (Muddy soil)				13.770	1.500	20.655
Surcharge load						
Weight of water	424.575	3.750	1592.156			
Earth pressure				3.893	0.333	1.298
Hydrostatic pressure						
Uplift	-592.382	3.252	-1926.512			
Total	216.606	5.112	1107.191	50.023		38.132

Acting force at toe of Concrete Apron

V0= 216.606 tf
H0= 50.023 tf
M0=Mx+My= 1145.323 tf-m

2) Stability Analysis

Type of Pile

The prestressed concrete pile is adopted for the foundation pile of apron.

Refer to stability calculation of center pier.

Pile Diameter and Arrangement

There are many cases for the combination of pile diameter and pile arrangement (number of pile). Judging from the structural size, geological and soil mechanical conditions, the following three alternatives are selected for comparative study. It is noted that the maximum pile diameter that is available in this country, is 600 mm.

Alternative-1	PC Pile Dia.350 mm, type A	14 piles
Alternative-2	PC Pile Dia.400 mm, type A	11 piles
Alternative-3	PC Pile Dia.450 mm, type A	12 piles

The allowable bearing capacity of ground is shown in each alternative pile as follows.

Layer	Li (m)	N – Value Average	Fi (tf / m)	Li·Fi (tf / m)
As	6.40	17	3.40	21.76
Ac	3.50	16	9.60	33.60
Dc	1.40	35	15.00	21.00
Total	11.30			76.36

Alternative – 1 (Dia 350 mm)

$$A = \pi/4\, D^2 = \pi/4 \times (0.35)^2 = 0.096\ \mathrm{m}^2$$

$$qd = 500\ \mathrm{tf/m^2} \times A = 48.00\ \mathrm{tf}$$

$$U = \pi D = \pi \times 0.35 = 1.100\ \mathrm{m}$$

$$Ru = 48.00 + 1.100 \times 76.36 = 132.00\ \mathrm{tf/pile}$$

Allowable bearing capacity
for PC pile (Dia 350 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	44.00
Seismic	2	66.00

Alternative – 2 (Dia 400 mm)

$$A = \pi/_4 D^2 = \pi/_4 \times (0.40)^2 = 0.126 \text{ m}^2$$

$$qd = 500 \text{ tf / m}^2 \times A = 63.00 \text{ tf}$$

$$U = \pi D = \pi \times 0.40 = 1.257 \text{ m}$$

$$Ru = 63.00 + 1.257 \times 76.36 = 158.98 \text{ tf / pile}$$

Allowable bearing capacity
for PC pile (Dia 400 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	52.99
Seismic	2	79.49

Alternative – 3 (Dia 450 mm)

$$A = \pi/_4 D^2 = \pi/_4 \times (0.45)^2 = 0.159 \text{ m}^2$$

$$qd = 500 \text{ tf / m}^2 \times A = 79.50 \text{ tf}$$

$$U = \pi D = \pi \times 0.45 = 1.414 \text{ m}$$

$$Ru = 79.50 + 1.414 \times 76.36 = 187.47 \text{ tf / pile}$$

Allowable bearing capacity
for PC pile (Dia 450 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	62.49
Seismic	2	93.74

Calculation Results

Pile stability analyses for Alternative-1, Alternative-2 and Alternative-3 were conducted based on the conditions mentioned above. As a result Alternative-2 (pile dia.=400mm, n=11 piles) was selected for the economical reason. The calculation results are shown as follows.

COMPARATIVE STUDY ON PILE FOUNDATION FOR APRON (EL+1.500)

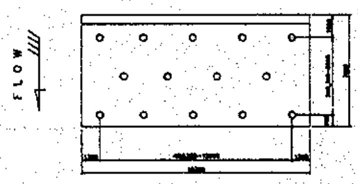
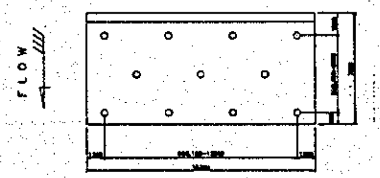
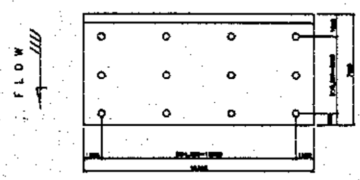
kind of pile	Alternative –1 Dia. 350 (A)			Alternative –2 Dia. 400 (A)			Alternative –3 Dia. 450 (A)		
Pile Arrangement									
Number of necessary pile	14 piles (L=11.30m)			11 piles (L=11.30m)			12 piles (L=11.30m)		
Displacement (Horizontal)	Calculation (mm)	Allowable capacity (mm)		Calculation (mm)	Allowable capacity (mm)		Calculation (mm)	Allowable capacity (mm)	
Normal Case	0.08	10		0.09	10		0.10	10	
Design flooding Case	0.08	10		0.09	10		0.10	10	
Constructional Case	0.00	10		0.00	10		0.00	10	
Seismic Case	1.00	15		1.08	15		1.15	15	
Force / Moment Acting on Pile	Axial load (tf)	Bending moment (tf-m)		Axial load (tf)	Bending moment (tf-m)		Axial load (tf)	Bending moment (tf-m)	
		Calculation	Allowable capacity		Calculation	Allowable capacity		Calculation	Allowable capacity
Normal Case	23.929	-		30.263	-		23.929	-	
Design flooding Case	13.120	-		16.652	-		13.120	-	
Constructional Case	32.633	-		41.415	-		32.633	-	
Seismic Case	25.366	-		32.059	-		25.366	-	
Bearing capacity (tf) Normal	44.00			52.99			62.49		
Bearing capacity (tf) Seisimic	66.00			79.49			93.74		
Summary of cost	Rp 12.4 million			Rp 11.9 million			Rp 14.0 million		
Evaluation	Not adopted			Adopted			Not adopted		

TABLE OF STABILITY CALCULATION FOR APRON (EL+1.500)

Direction		Direction of flowing water				Direction of weir axis			
Case		Normal case	Design Flooding case	Construction case	Seismic case	Normal case	Design Flooding case	Construction case	Seismic case
Quantity of displacement for footing (m)	Horizontal (δ X m)	0.0000902	0.0000902	0.0000000	0.0010777	-	-	-	-
	Allowable	0.010	0.010	0.010	0.015	0.010	0.010	0.010	0.015
	Vertical (δ Y m)	0.0001066	0.0006401	0.0015935	0.000067	-	-	-	-
	Allowable	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Axial force (tf/pile)	No.1	9.1197	16.6520	41.4152	7.3242	-	-	-	-
	No.2	19.6915	14.0830	34.9466	19.6915	-	-	-	-
	No.3	30.2632	11.5140	28.4781	32.0587	-	-	-	-
	No.4	-	-	-	-	-	-	-	-
	No.5	-	-	-	-	-	-	-	-
	No.6	-	-	-	-	-	-	-	-
	No.7	-	-	-	-	-	-	-	-
	No.8	-	-	-	-	-	-	-	-
	No.9	-	-	-	-	-	-	-	-
Allowable bearing capacity (tf/pile)		52.99	52.99	52.99	79.49	-	-	-	-
Shearing stress (tf)		0.2145	0.2145	0.0000	4.5475	-	-	-	-
Bending moment (tf-m/pile)		-	-	-	-	-	-	-	-
Allowable bending moment (tf-m/pile)		-	-	-	-	-	-	-	-

Number of piles: n = 11 piles

Pile head condition: Hinge

<u>Pile condition</u>

1. Diameter: Dia.400 mm
2. Geometrical moment of area: $I = 0.00109000\ m^4$
3. Section area of pile $A = 0.081900\ m^2$

3) Stress-Strain Calculation

Stress-strain calculations of the structure are made to decide proper reinforcing bar arrangement. Described below are the bar arrangement for apron (EL+1.500).

Structural Part	Diameter of Re. Bars (mm)	Interval of Bars (mm)	Side of structure	Particular
Apron (EL+1.500)	D16	250	Lower	Flow direction
- ditto -	D16	250	Upper	- ditto -
- ditto -	D16	250	Lower	Gate axis
- ditto -	D16	250	Upper	- ditto -