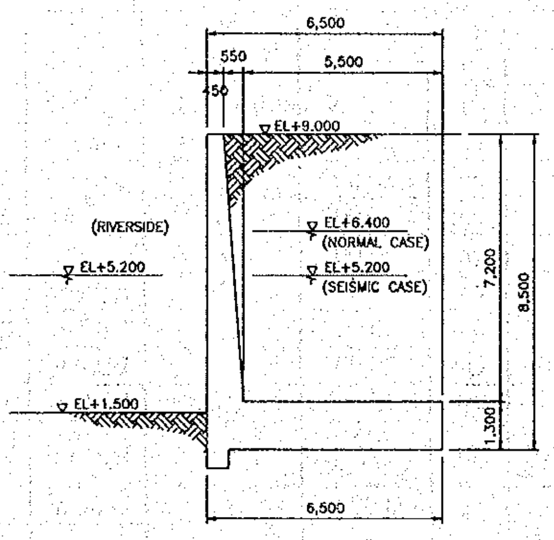
4.2.4.4 Approach Wall (H=8.50m) at Upstream of Weir

1) Loading Condition



Design Condition

Item	Unit		Item	Unit	
Height of wall	m	7.200	Unit weight of concrete	tf / m³	2.500
Height of footing	m	1.300	Unit weight of water	tf / m³	1.000
Total height of wall	m	8.500	Unit weight of soil	tf / m³	1.800
Crown width	m	0.450	Submerged unit weight	tf / m³	1.000
Slope of behind side		0.076	Angle of shearing resistance		30.000
Width of bottom section Length at wall	m	0.550	Horizontal seismic intensity		0.120
Width of bottom section at footing	m	5.500	Apparently horizontal seismic intensity		0.240
Total width of wall (m)	m	6.500	Coefficient of earth pressure in Normal case		0.297
Surcharge load in Normal case	tf/m²	1.000	Coefficient of earth pressure in Seismic case above water		0.383
Surcharge load in Seismic case	tf/m²	0.500	Coefficient of earth pressure in seismic case below water		0.492
Top elevation of wall				EL m	9.000
Bottom elevation of slab				EL m	0.500
Water level at land side in Normal case				EL m	6.400
Water level at riverside in Normal case				EL m	5.200
Water level at riverside in Seismic case				EL m	5.200
Water level at land side in Seismic case				EL m	5.200

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	8.100	0.225	1.823	4.900	39.690	Conc.
2	4.950	0.633	3.135	3.700	18.315	Conc.
3	3.250	0.500	1.625	0.650	2.113	Conc.
4	0.000	2.833	0.000	1.300	0.000	Conc.
5	17.875	3.750	67.031	0.650	11.619	Conc.
Total	34.175	2.154	73.614	2.099	71.736	
		1.321	(for pile foundation)			

1'. Weight of earth

Normal case	Weight W (tf)	Vertical length X (m)	Moment MX(tf-m)	Horizontal length Y (m)	Moment MY(tf-m)
1	2.109	0.901	1.900	7.295	15.388
2	0.808	0.883	0.714	4.367	3.529
3	25.740	3.750	96.525	7.200	185.328
4	25.300	3.750	94.875	3.600	91.080
5	0.000	4.667	0.000	1.300	0.000
Total	53.957	3.596	194.013	5.473	295.325
		-0.121	(for pile foundation)		

Seismic case	Weight W (tf)	Vertical length X (m)	Moment MX(tf-m)	Horizontal length Y (m)	Moment MY(tf-m)
1	2.769	0.855	2.367	6.827	18.906
2	0.442	0.913	0.403	3.567	1.575
3	37.620	3.750	141.075	6.600	248.292
4	18.700	3.750	70.125	3.000	56.100
5	0.000	4.667	0.000	1.300	0.000
Total	59.531	3.594	213.971	5.457	324.873
		-0.119	(for pile foundation)		

Construction case	Weight W (tf)	Vertical length X (m)	Moment MX(tf-m)	Horizontal length Y (m)	Moment MY(tf-m)
1	3.564	0.817	2.911		
2	71.280	3.750	267.300		
3	0.000	4.667	0.000		
4					
5					
Total	74.844	3.610	270.211	0.000	0.000
		-0.135	(for pile foundation)		

2. Surcharge load

	Weight W(tf)	Vertical length X(m)		
Normal, Construction	6.050	3.475	0.000	(for pile foundtion)
Seismic	3.025	3.475	0.000	(for pile foundtion)

3. Weight of water

Normal case	Weight W (tf)	Vertical length X (m)	Moment MX(tf-m)	Horizontal length Y (m)	Moment MY(tf-m)
9	0.808	0.883	0.714	4.367	3.529
10	25.300	3.750	94.875	3.600	91.080
11	0.000	4.667	0.000	1.300	0.000
Total	26.108	3.661	95.589	3.624	94.609
		-0.186	(for pile foundation)		

Seismic case	Weight W (tf)	Vertical length X (m)	Moment MX(tf-m)	Horizontal length Y (m)	Moment MY(tf-m)
9	0.442	0.913	0.403	3.567	1.575
10	18.700	3.750	70.125	3.000	56.100
11	0.000	4.667	0.000	1.300	0.000
Total	19.142	3.685	70.528	3.013	57.675
		-0.210	(for pile foundation)		

4. Earth pressure

Normal case	(tf/m²)		(tf/m)		(m)
Pa0=	0.297	E1=	2.581	Y1=	6.896
Pa1=	1.688				
Pa2=	1.070	E2=	13.310	Y2=	2.433
Pa3=	3.442				
Total			15.891	Σy=	3.158
Seismic case	(tf/m²)		(tf/m)		(m)
Pea0=	0.192	Ee1=	5.707	Ye1=	6.047
Pea1=	2.812				
Pea2=	2.364	Ee2=	19.486	Ye2=	2.013
Pea3=	5.928				
			25.193		2.927
Construction case	(tf/m²)		(tf/m)		(m)
Pca0=	0.297	Ec=	21.852	Yc=	2.997
Pca1=	4.844				

5. Hydrostatic pressure

Normal case					
Land side	(tf/m²)		(tf/m)		(m)
Wa0=	0.000				
Wa1=	5.900	P1=	17.405	Y3=	1.967
River side	(tf/m²)		(tf/m)		(m)
Wp0=	0.000				
Wp1=	4.700	P2=	-11.045	Y4=	1.567
Seismic case					
Land side	(tf/m²)		(tf/m)		(m)
Wae0=	0.000				
Wae1=	4.700	Pe1=	11.045	Ye3=	1.567
River side	(tf/m²)		(tf/m)		(m)
Wpe0=	0.000				
Wpe1=	4.700	Pe2=	-11.045	Ye4=	1.567

6. Hydrodynamic force

Seismic case

	(tf/m)		(m)
P=	1.546	Hg=	1.880

7. Uplift

Normal case	(tf/m^2)		(tf/m)		(m)
U1=	4.700	U=	-34.450	X1=	3.373
U2=	5.900		(for pile foundation)		0.102
Seismic case	(tf/m^2)		(tf/m)		(m)
Ue1=	4.700	Ue=	-30.550	Xe1=	3.250
Ue2=	4.700		(for pile foundation)		0.225

Normal Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	34.175	2.154	73.613			
Weight of earth	53.957	3.596	194.031			
Surcharge load	6.050	3.475	21.024			
Weight of water	26.108	3.661	95.589			
Earth pressure				15.891	3.158	50.183
Hydrostatic pressure (Land side)				17.405	1.967	34.230
Hydrostatic pressure (Riverside)				-11.045	1.567	-17.304
Hydrodynamic pressure						
Uplift	-34.450	3.373	-116.188			
Total	85.841		268.069	22.251		67.109

Action force at toe of retaining wall

V0=	85.841 tf / m
H0=	22.251 tf / m
M0=| Mx − My |=	200.959 tf-m / m

Action force at middle of bottom slab of retaining wall

Vc=	85.841 tf / m
Hc=	22.251 tf / m
Mc=| Mx − My |=	78.023 tf-m / m

Seismic Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	34.175	2.154	73.613	4.101	2.099	8.608
Weight of earth	59.531	3.594	213.954	7.144	3.013	21.524
Surcharge load	3.025	3.475	10.512			
Weight of water	19.142	3.685	70.528			
Earth pressure				25.193	2.927	73.741
Hydrostatic pressure (Land side)				11.045	1.567	17.304
Hydrostatic pressure (Riverside)				-11.045	1.567	-17.304
Hydrodynamic pressure				1.546	1.880	2.907
Uplift	-30.550	3.250	-99.288			
Total	85.322		269.319	37.984		106.780

Action force at toe of retaining wall

Ve0=	85.322 tf / m
He0=	37.984 tf / m
Me0=| Mx − My |=	162.539 tf-m / m

Action force at middle of bottom slab of retaining wall

Vce=	85.322 tf / m
Hce=	37.984 tf / m
Mce=| Mx − My |=	114.759 tf-m / m

Construction Case

	Vertical			Horizontal		
	V (tf)	X (m)	Mx (tf-m)	H (tf)	Y (m)	My (tf-m)
Weight of body	34.175	2.154	73.613			
Weight of earth	74.844	3.610	270.187			
Surcharge load	6.050	3.475	21.024			
Weight of water						
Earth pressure				21.852	2.997	65.492
Hydrostatic pressure (Land side)						
Hydrostatic pressure (Riverside)						
Hydrodynamic pressure						
Uplift						
Total	115.069		364.824	21.852		65.492

Action force at toe of retaining wall

Vc0=	115.069 tf / m
Hc0=	21.852 tf / m
Mc0=| Mx − My |=	299.332 tf-m / m

Action force at middle of bottom slab of retaining wall

Vcc=	115.069 tf / m
Hcc=	21.852 tf / m
Mcc=| Mx − My |=	74.642 tf-m / m

2) Stability Analysis

Type of Pile

The prestressed concrete pile is adopted for the foundation pile of retaining wall.

Refer to stability calculation of center pier.

Pile Diameter and Arrangement

Pile diameter of 600 mm is adopted for the foundation pile of retaining wall. (Refer to Approach wall H = 5.40 m)

PC Pile Dia.600 mm, type A 15 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	7.60	31	6.20	47.12
Ac	2.80	13	7.80	21.84
Dc	1.10	22	13.20	14.52
Total	11.50			83.48

$$A = \pi/4\, D^2 = \pi/4 \times (0.60)^2 = 0.283\ m^2$$

$qd = 500\ tf / m^2 \times A = 141.50\ tf$

$U = \pi D = \pi \times 0.60 = 1.885\ m$

$Ru = 141.50 + 1.885 \times 83.48 = 298.86\ tf / pile$

Allowable bearing capacity
for PC pile (Dia 600 mm)

Case	Safety factor	Allowable bearing capacity (tf / pile)
Normal	3	99.62
Seismic	2	149.43

Calculation Results

The calculation results are shown as follows.

TABLE OF STABILITY CALCULATION FOR UPSTREAM APPROACH WALL (EL+9.000: RIGHT BANK)

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)	-	-	-	-	0.0011958	-	0.0011857	0.0012037
	Allowable	0.010	0.010	0.010	0.015	0.010	0.010	0.010	0.015
	Vertical (δ Y m)	-	-	-	-	0.0009230	-	0.0012157	0.0009428
	Allowable	0.015	0.010	0.015	0.015	0.015	0.015	0.015	0.015
Axial force (tf/pile)	No.1	-	-	-	-	79.9445	-	95.2252	93.4131
	No.2	-	-	-	-	42.9205	-	57.5345	42.6610
	No.3	-	-	-	-	5.8966	-	19.8439	-8.0911
	No.4	-	-	-	-	-	-	-	-
	No.5	-	-	-	-	-	-	-	-
	No.6	-	-	-	-	-	-	-	-
	No.7	-	-	-	-	-	-	-	-
	No.8	-	-	-	-	-	-	-	-
	No.9	-	-	-	-	-	-	-	-
Allowable bearing capacity (tf/pile)		-	-	-	-	99.62	-	99.62	149.43
Shearing stress (tf)		-	-	-	-	11.1255	-	10.9260	18.9920
Bending moment (tf-m/pile)		-	-	-	-	6.7061	-	6.4517	8.5247
Allowable bending moment (tf-m/pile)		-	-	-	-	7.57	-	9.02	11.38

Number of piles: n = 15 piles

Pile head condition: Fixing

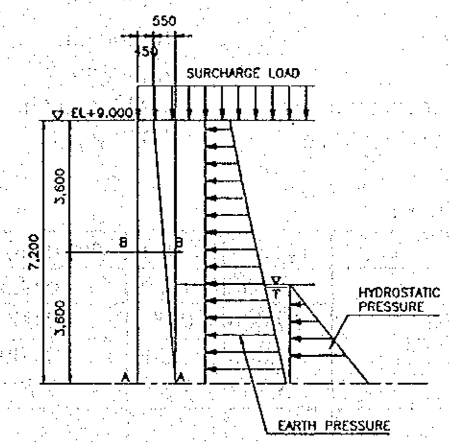
Pile condition

1. Diameter: Dia.600 mm
2. Geometrical moment of area: $I = 0.00522000\ m^4$
3. Section area of pile $A = 0.167800\ m^2$

3) Stress-Strain Calculation

(i) Wall section

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.



Position of A - A

(Normal Condition)

	H (tf)	Y (m)	My (tf-m)	Remark
Earth pressure-1	2.581	5.596	14.441	(Aerial)
Earth pressure-2	9.176	1.945	17.843	(Underwater)
Hydrostatic pressure-1	10.580	1.533	16.223	(Active side)
Hydrostatic pressure-2	-5.780	1.133	-6.551	(Passive side)
Total	16.556		41.956	

B = 100.00 cm
H = 100.00 cm
Bending moment = 41.956 tf-m / m
Shearing force = 16.556 tf /m

(Seismic Condition)

	H (tf)	Y (m)	My (tf-m)	Remark
Earth pressure-1	5.707	4.747	27.092	(Aerial)
Earth pressure-2	12.420	1.500	18.630	(Underwater)
Hydrostatic pressure-1	5.780	1.133	6.551	(Active side)
Hydrostatic pressure-2	-5.780	1.133	-6.551	(Passive side)
Hydrodynamic force	0.238	1.360	0.324	
Seismic force	8.710	3.975	34.623	
Total	27.074		80.668	

B = 100.00 cm
H = 100.00 cm
Bending moment = 80.668 tf-m / m
Shearing force = 27.074 tf /m

Position of B - B

(Normal Condition)

	H (tf)	Y (m)	My (tf-m)	Remark
Earth pressure-1	2.581	1.996	5.152	(Aerial)
Earth pressure-2	1.271	0.474	0.602	(Underwater)
Water pressure	0.500	0.333	0.167	
Total	4.352		5.920	

B = 100.00 cm
H = 72.50 cm
Bending moment = 5.920 tf-m / m
Shearing force = 4.352 tf /m

(Seismic Condition)

	H (tf)	Y (m)	My (tf-m)	Remark
Earth pressure-1	5.158	1.280	6.603	(Aerial)
Earth pressure-2	0.000	0.000	0.000	(underwater)
Water pressure	0.000	0.000	0.000	
Seismic force	5.232	1.872	9.794	
Total	10.390		16.397	

B = 100.00 cm
H = 72.50 cm
Bending moment = 16.397 tf-m / m
Shearing force = 10.390 tf /m

Results of strength calculation are shown as follows.

		Section A - A		Section B - B	
Case		Normal	Seismic	Normal	Seismic
Member of shape		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	41.96	80.67	5.92	10.39
N	tf	0.00	0.00	0.00	0.00
S	tf	16.56	27.07	4.35	16.40
B	cm	100.00	100.00	100.00	100.00
D	cm	91.00	91.00	63.50	63.50
Ac	cm^2	9100.00	9100.00	6350.00	6350.00
As	cm^2	D29-125 = 52.88	D29-125 = 52.88	D29-250 = 26.44	D29-250 = 26.44
P=As/(B×D)		0.00581	0.00581	0.00416	0.00416
N=Es/Ec		15	15	15	15
X0	cm	30.90	30.90	18.80	18.80
K=X0/D		0.339	0.339	0.296	0.296
M/(B×D2)	kgf/cm^2	5.067	9.742	1.468	2.577
S/(B×D)	kgf/cm^2	1.820	2.975	0.685	2.583
(C)		6.645	6.645	7.486	7.486
(S)		12.936	12.936	17.767	17.767
(Z)		1.128	1.128	1.110	1.110
σ c	kgf/cm^2	33.70	64.70	11.00	19.30
σ s	kgf/cm^2	983.00	1890.00	391.00	687.00
τ	kgf/cm^2	1.82	2.97	0.69	2.58
σ ca	kgf/cm^2	75.00	112.50	75.00	112.50
σ sa	kgf/cm^2	1600.00	2400.00	1600.00	2400.00
τ a	kgf/cm^2	3.80	5.70	3.80	5.70

(ii) Footing Section

Loading calculation

W1 (Weight of body) 1.30×2.50 tf/m^3 = 3.250 tf/m^2

W2 (Weight of earth: Aerial) = 4.680 tf/m2

W3 (Weight of earth: Underwater) = 4.600 tf/m2

W4 (Weight of water) = 4.600 tf/m^2

W5 (Surcharge load) = 1.000 tf/m^2

W6 (Uplift) = 4.700 tf/m^2

= 5.900 tf/m^2

Horizontal pressure

<Normal case>

H = 22.251 tf/m (Refer to stability analysis.)

M = 22.251 tf/m×3.016 = 67.109 tf-m/m

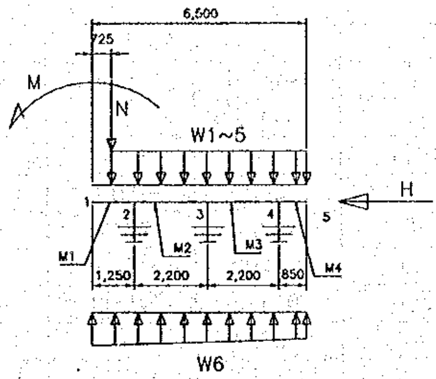
N = (0.45 +1.00)×1/2×7.20×2.50 tf/m^3 = 13.050 tf/m

<Seismic case>

H = 37.984 tf/m (Refer to stability analysis)

M = 37.984 tf/m×2.811 = 106.773 tf-m/m

N = 13.050 tf/m



Geometrical moment of inertia

Member	Calculation	Geometrical moment of inertia (m^4)
1~4	$\frac{1}{12}\times 1.00\times 1.30^3$	0.18308

Section area

Member	Calculation	Area (m^2)
1~3	1.00×1.30	1.300

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×(11.50 / 0.60) + 0.61 = 0.859166
Ap = 0.1678 m^2
Ep = 4.0×10^6 tf/m^2
Kv = 50145.41 tf/m
Kh = 1/3×Kv = 16715.14 tf/m

Summary of calculation results is shown as follows.

(Normal case: Top of footing)

Member	Condition	Distance (m)	Bending moment M (tf –m)	Shearing stress S (tf)	Axial Force N (tf)
M1	Maximum	0.725	0.341	0.469	0.000
	Minimum	1.250	-49.067	-17.006	16.556
M2	Maximum	2.019	-22.666	0.000	10.936
	Minimum	0.000	-49.067	26.275	10.936
M3	Maximum	1.766	-3.265	0.000	5.438
	Minimum	0.000	-22.876	22.305	5.438
M4	Maximum	0.850	0.000	0.000	0.000
	Minimum	0.000	-4.437	10.462	0.000

(Normal case: Bottom of footing)

Member	Condition	Distance (m)	Bending moment M (tf –m)	Shearing stress S (tf)	Axial Force N (tf)
M1	Maximum	0.840	0.368	0.000	0.000
	Minimum	1.250	-0.260	-3.956	0.000
M2	Maximum	1.164	8.579	0.000	0.000
	Minimum	0.000	-0.260	15.234	0.000
M3	Maximum	0.878	6.530	0.000	0.000
	Minimum	2.200	-4.437	-16.537	0.000
M4	Maximum	0.850	0.000	0.000	0.000
	Minimum	0.000	-4.437	10.462	0.000

(Seismic case: Top of footing)

Member	Condition	Distance (m)	Bending moment M (tf –m)	Shearing stress S (tf)	Axial Force N (tf)
M1	Maximum	0.725	0.362	0.914	0.000
	Minimum	1.250	-87.648	-16.826	27.074
M2	Maximum	2.200	-39.075	8.120	17.884
	Minimum	0.000	-87.648	36.038	17.884
M3	Maximum	2.200	-4.584	1.719	8.893
	Minimum	0.000	-39.075	29.637	8.893
M4	Maximum	0.850	0.000	0.000	0.000
	Minimum	0.000	-4.584	10.787	0.000

(Seismic case: Bottom of footing)

Member	Condition	Distance (m)	Bending moment M (tf –m)	Shearing stress S (tf)	Axial Force N (tf)
M1	Maximum	0.898	0.449	0.000	0.000
	Minimum	1.250	-0.129	-3.776	0.000
M2	Maximum	1.159	8.395	0.000	0.000
	Minimum	0.000	-0.129	14.709	0.000
M3	Maximum	0.881	6.449	0.000	0.000
	Minimum	2.200	-4.584	-16.734	0.000
M4	Maximum	0.850	0.000	0.000	0.000
	Minimum	0.000	-4.584	10.787	0.000

Results of strength calculation are shown as follows.

Position		Normal case		Seismic case	
		Top Section	Bottom Section	Top Section	Bottom Section
Member of shape		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	-49.07	8.58	-87.65	8.39
N	tf	0.00	0.00	0.00	0.00
S	tf	26.28	0.00	36.04	0.00
B	cm	100.00	100.00	100.00	100.00
D	cm	121.00	113.50	121.00	113.50
Ac	cm^2	12100.00	11350.00	12100.00	11350.00
As	cm^2	D25-125 = 39.28	D19-125 = 22.72	D25-125 = 39.28	D19-125 = 22.72
P=As/(B×D)		0.00325	0.002	0.00325	0.002
N=Es/Ec		15	15	15	15
X0	cm	32.30	24.60	32.30	24.60
K=X0/D		0.267	0.217	0.267	0.217
M/(B×D2)	kgf/cm^2	3.352	0.666	5.987	0.651
S/(B×D)	kgf/cm^2	2.172	0.000	2.979	0.000
(C)		8.218	9.941	8.218	9.941
(S)		22.544	35.899	22.544	35.899
(Z)		1.098	1.078	1.098	1.078
σ c	kgf/cm^2	27.50	6.60	49.20	6.50
σ s	kgf/cm^2	1133.00	359.00	2024.00	351.00
τ	kgf/cm^2	2.17	0.00	2.98	0.00
σ ca	kgf/cm^2	75.00	75.00	112.50	112.50
σ sa	kgf/cm^2	1600.00	1600.00	2400.00	2400.00
τ a	kgf/cm^2	3.80	3.80	5.70	5.70

(iv) Pile head treatment

h) Vertical bearing pressure for footing concrete

Pnmax = 95.225 tf/pile (in Construction case)

$$\sigma_{cv} = \frac{P_{N\max}}{\pi D^2/4} = \frac{95225}{\pi/4 \times 60^2} = 33.68 \text{ kgf/cm}^2$$

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

i) Punching shear stress for footing concrete

$$\tau_V = \frac{P_{N\max}}{\pi(D+h)h} = \frac{95225}{\pi(60+120)\times 120} = 1.40 \text{ kgf/cm}^2$$

$\leqq \tau$ 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 = 93.41 tf/pile (in Seismic case)
M = 8.52 tf-m
S = 18.99 tf

$$\sigma_{ch} = \frac{18990}{60\times 10} = 31.65 \text{ kgf/cm}^2 \leqq \sigma \text{ca} = 60.0\times 1.5 = 90.0 \text{ kgf/cm}^2$$

.... O.K

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

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

where

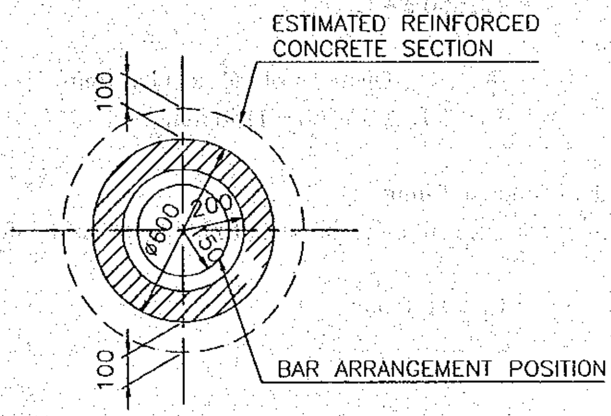
h' : Effective thickness to vertical punching stress on footing (cm)
l : Stuffing length of pile (cm)
D : Pile diameter (cm)
H : Shearing pressure (kgf)

h' = (75-1/2×60) = 45.0 cm

$$\tau_h = \frac{18990}{45.0\times(2\times 10+60+2\times 45.0)} = 2.48 \text{ kgf/cm}^2$$

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

l) Strength of estimated reinforced concrete section



$P_N$min = -8.09 tf/pile (in Seismic case)
M = 8.52 tf-m
S = 18.99 tf
D = 60.00 + 10.00×2 = 80.00cm
a = 20.00 cm×2 = 40.00 cm
d = 25.00 cm

Result of strength calculation is shown as follows.

Member of shape		Circle			
M	tf-m	-8.525	X0	cm	18.50
N	tf	-8.091	K= X0/H		0.231
S	tf	18.992	$M/(B\times H^2)$	kgf/cm^2	1.665
B	cm	80.00	$S/(B\times H)$	kgf/cm^2	2.968
H	cm	80.00	(C)		36.084
D	cm	55.00	(S)		71.171
DD	cm	25.00	(Z)		3.660
DG	cm	25.00	Σc	kgf/cm^2	60.10
B0 , R	cm	40.00	Σs	kgf/cm^2	1778.00
H0 , R0	cm	20.00	τ	kgf/cm^2	0.00
AC	cm^2	3769.9	Σca	kgf/cm^2	112.50
AS , AS1	cm^2	10-D19 = 28.40	Σsa	kgf/cm^2	2400.00
P , P1		0.00753	Ta	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)

$L_1 = 35\times 19 = 665 \fallingdotseq 700$ mm

Fixing length of reinforcing bar at pile

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

Where

ϕ : Diameter of PC steel bar (mm)

$L_2 = 50\times 9.0 + 700 = 1150$ mm

n) Depth of concrete filling

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

$L_3 = 1150$ mm

4.3 INTAKE STRUCTURE

4.3.1 Left Bank Intake Structure

4.3.1.1 Design Condition

Material of unit weight

(a) Concrete

Reinforced concrete	γc	= 2.50 tf/m³
Plain concrete	γc'	= 2.35 tf/m³

(b) Backfill material

Wet unit weight	γt	= 1.80 tf/m³
Submerged unit weight	γ'	= 1.00 tf/m³

Design Load

(a) Earth pressure

Coefficient of active earth pressure Ka = 0.5

(b) Surcharge load

Normal condition	q	= 1.00 tf/m³
Construction	q	= 1.00 tf/m³
Design flood condition	q	= 1.00 tf/m³
Earthquake condition	q	= 0.50 tf/m³

(c) Design high water level (land side)

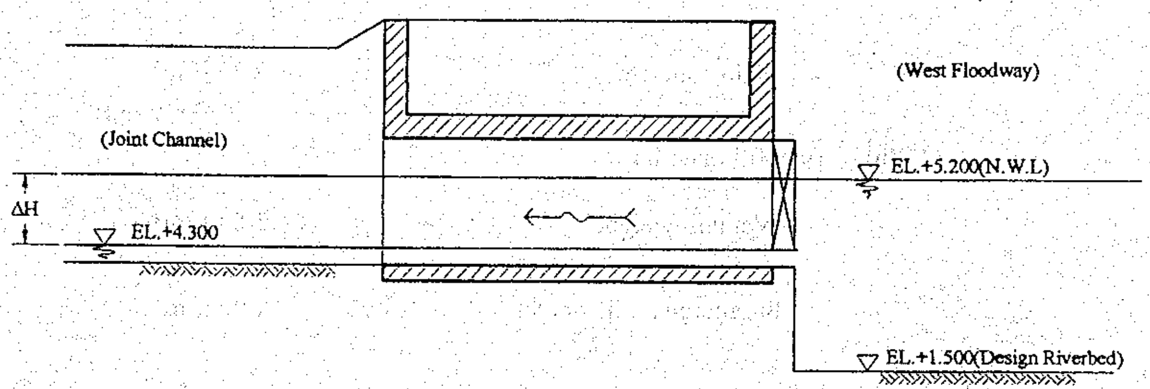
Normal condition	EL	+ 4.900 m
Design flood condition	EL	+ 6.700 m
Earthquake condition	EL	+ 4.900 m

Description

The high water level at land side to be assumed as 2/3 ΔH higher than the downstream water level.

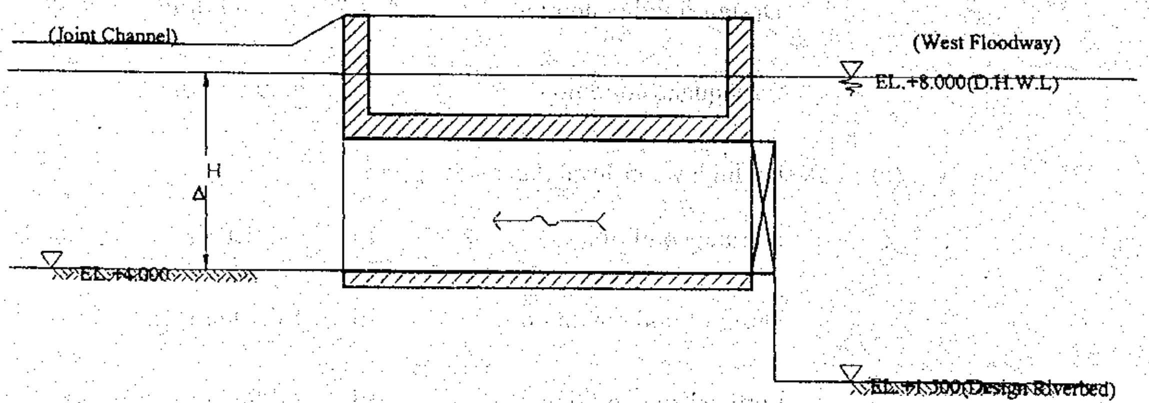
Normal and Earthquake condition

West Floodway water level	=	EL +5.200 m
Joint channel water level	=	EL +4.300 m
Water level at the land side	=	EL +4.300 + 2/3 (5.200 – 4.300)
	=	EL + 4.900 m



Design flood condition

West Floodway water level	=	EL +8.000 m (D.H.W.L)
Joint Channel water level	=	EL +4.000 m
Water level at the land side	=	+4.000 + 2/3 (8.000 – 4.000)
	=	+ 6.666 m □ 6.700 m



4.3.1.2 Standard Box Culvert

<u>Normal Case</u>

Q	= 1 x 12.4	= 12.400	tf/m
Weight of soil I	= 2.5 x 12.4 x 1.8	= 55.800	tf/m
Weight of soil II	= 1.6 x(12.4 - 6.35)x 1.8	= 17.424	tf/m
Weight of soil III	= 0.9 x(12.4 – 6.35)x 2	= 10.890	tf/m
Weight of top slab	= 0.5 x 6.35 x 2.5	= 7.9375	tf/m
Weight of side wall	= 2 x(2 x 0.75)x 2.5	= 7.500	tf/m
Weight of center wall	= 0.85 x 2 x 2.5	= 4.250	tf/m
Weight of other concrete	$= \frac{0.15 \times 0.15}{2} \times 10 \times 2.5$	= 0.281	tf/m
		= 116.483	tf/m

$$q_R = \frac{116.483}{12.4} = 9.394 \text{ tf/m}^2$$

$$q_1 = 1 + (2.5 \times 1.8) + (0.5 \times 2.5) = 6.75 \text{ tf/m}^2$$

$$q_2 = 1 + (4.1 \times 1.8) + (0.9 \times 2) = 10.18 \text{ tf/m}^2$$

$$M_{FG} = \frac{\frac{1}{12} \times 1 \times 0.5^3 \times E}{2.800} = 0.00372 \text{ E}$$

$$M_{FB} = \frac{\frac{1}{12} \times 1 \times 0.75^3 \times E}{2.675} = 0.01314 \text{ E}$$

$$M_{BC} = \frac{\frac{1}{12} \times 1 \times 0.85^3 \times E}{2.000} = 0.01828 \text{ E}$$

Joint F

$$Kfg = \frac{0.00372}{0.00372 + 0.01314} = 0.2206$$

$$Kfb = \frac{0.01314}{0.00372 + 0.01314} = 0.7794$$

Joint B

$$Kbf = \frac{0.01314}{0.01314 + 0.01828} = 0.4182$$

$$Kbc = \frac{0.01828}{0.01314 + 0.01828} = 0.5818$$

$M_{BA} =$ $\frac{1}{2}$ x(10.18 – 9.394)x 3.4^2 = 4.5431 tf.m

$M_{GF} = -M_{FG}$ = $\frac{1}{12}$ x 6.75 x 2.8^2 = 4.4100 tf.m

$M_{BC} = -M_{CB}$ = $\frac{1}{12}$ x 9.394 x 2.8^2 = 6.1374 tf.m

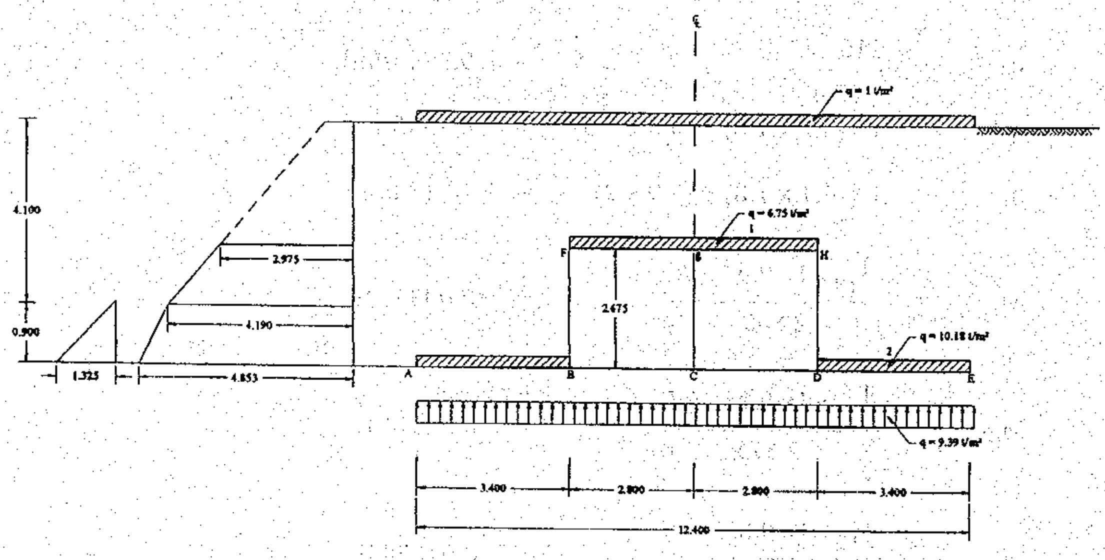
$$M_{BF} = -2.675 \times (2 \times 2.975 + 3 \times 5.3825)/60 - \frac{0.7955}{2.675^2} \times \left\{\tfrac{1}{2} \times 2.675^2 \times (1.325^2 - 0^2) - \tfrac{2}{3} \times 2.675 \times (1.325^3 - 0^3) - \tfrac{1}{4} \times (1.325^4 - 0^{4)}\right\}$$

= -2.9583 t.f.m

$$M_{FB} = 2.675 \times (2 \times 5.3825 + 3 \times 2.975/60) + \frac{0.7955}{2.675^2} \times \left\{\tfrac{1}{2} \times 2.675^2 \times (2.675^2 - 1.35^2) - \tfrac{2}{3} \times 2.675 \times (2.675^3 - 4.35^3) + \tfrac{1}{4} \times (2.675^4 - 4.35^{4)}\right\}$$

= -2.4933 tf.m

<u>Load Diagram for Normal Case</u>



C	B			F		G
CB	BC	BA	BF	FB	FG	GF
-	0.5818	-	0.4182	0.7794	0.2206	-
-6.1374	+6.1374	+4.5431	-2.9583	+2.4933	-4.4100	+4.4100
-2.2464	-4.4928	-	-3.2294	-1.6147		
			+1.3762	+2.7524	+0.7790	+0.3895
-0.4003	-0.8007		-0.5755	-0.2878		

			+0.1122	+0.2243	+0.0635	+0.0317
-0.0326	-0.0653		-0.0469	-0.0235		
			+0.0092	+0.0183	+0.0052	+0.0026
-0.0027	-0.0054		-0.0038	-0.0019		
			+0.0007	+0.0015	+0.0004	+0.0002
-0.0002	-0.0004		-0.0003			
-8.8196	0.7728	+4.5431	-5.3159	+3.5619	-3.5619	+4.834

<u>Top Slab FG</u>

$S_{FG} = {}^{2.8}\!/_{2} \times 6.75 - \frac{4.0834 - 3.5619}{2.8} = 8.996$ tf.m

$S_{GF} = {}^{2.8}\!/_{2} \times 6.75 - \frac{3.5064 - 4.834}{2.8} = 9.904$ tf.m

$S = 0 \rightarrow 8.996 - 6.75x = 0 \rightarrow x = 1.332$ m

$M_{max} = 8.996 \times 1.332 - \frac{1}{2} \times 6.75 \times 1.332^2 - 3.564 = 2.341$ tf.m

<u>Bottom Slab BC</u>

$S_{BC} = {}^{2.8}\!/_{2} \times 9.364 - \frac{8.8196 - 0.7728}{2.8} = 10.236$ tf.m

$S_{CB} = {}^{2.8}\!/_{2} \times 9.364 - \frac{0.7728 - 8.8196}{2.8} = 15.984$ tf.m

$S = 0 \rightarrow 10.236 - 9.34x = 0 \rightarrow x = 1.096$ m

$M_{max} = 10.236 \times 1.096 - \frac{1}{2} \times 9.364 \times 1.096^2 - 0.7728 = 4.822$ tf.m

<u>Side Wall BF</u>

$$S_{AF} = \frac{2.0125 \times 1.054}{2.675} + \frac{2 \times 5.3825 + 2.975}{6} \times 2.675 - \frac{3.5619 - 5.3159}{2.675}$$

$= 7.574$ tf.m

$$S_{FA} = \frac{0.6625 \times 1.054}{2.675} + \frac{2 \times 2.975 + 25.3825}{6} \times 2.675 - \frac{5.3159 - 3.5619}{2.675}$$

$= 4.658$ t.m

$$S = 0 \rightarrow 4.658 - 5.3825x - \frac{9.03825 - 2.975}{2 \times 2.675} \times 3x^2 = 0$$

$$-0.45x^2 - 5.3825x + 4.658 = 0$$

$$x^2 + 11.691x - 10.351 = 0$$

$$x = \frac{-11.9611 + \sqrt{11.9611^2 + 10.391 \times 4}}{2}$$

$$x = 0.810 \text{ m}$$

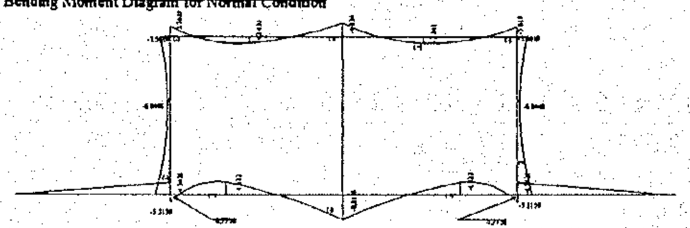
$$M_{max} = 4.6558 \times 0.810 - \frac{2.975}{2} \times 0.810^2 - \frac{5.3825 - 2.975}{6 \times 2.675} \times 0.810^3$$

$$= 43.5619 \qquad = -0.8446 \text{ tf.m}$$

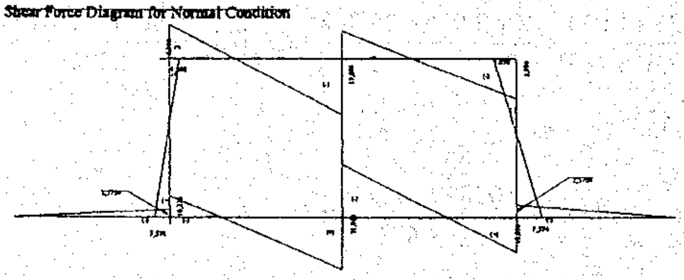
<u>Bending Moment, Shear Force and Axial Load</u>

Location		M (tf.m)	S (tf)	N (tf)
Slab BA	BA	4.5431	2.5704	-
Top Slab	F = H	-3.5619	8.996	4.658
	Center	+2.431	-	4.658
	G	-4.834	9.904	4.658
Bottom Slab	B = D	-0.7188	10.236	7.574
	Center	+4.822	-	7.574
	C	-8.8196	15.983	7.574
Side Wall	B = D	-5.3159	7.574	10.236
	Center	-0.8446	-	10.236
	F = H	-3.5619	4.658	8.998
Center Wall	C	-	-	15.984
	Center	-	-	15.984
	G	-	-	15.984

Bending Moment Diagram for Normal Condition



Shear Force Diagram for Normal Condition



Flooding Case

Q	= 1 x 12.4	= 12.400 tf/m
Weight of soil I	= 2.3 x 12.4 x 1.8	= 51.336 tf/m
Weight of soil II	= 0.2 x 12.4 x 2.0	= 4.960 tf/m
Weight of soil III	= (12.4 – 6.35)x 2.5 x 2	= 30.250 tf/m
Weight of top slab	= 0.5 x 6.35 x 2.5	= 7.937 tf/m
Weight of side wall	= 2 x(2 x 0.75)x 2.5	= 7.500 tf/m
Weight of center wall	= 0.85 x 2 x 2.5	= 4.250 tf/m
Weight of other concrete	= $\frac{0.15 \times 0.15}{2} \times 10 \times 2.5$	= 0.281 tf/m
		= 118.915 tf/m

$q_R = \frac{118.915}{12.4} = 9.5899\ tf/m^2$

$q_1 = 1 + (2.5 \times 1.8) + (0.2 \times 2) + (0.5 \times 2.5) = 6.79\ tf/m^2$

$q_2 = 1 + (2.3 \times 1.8) + (2.7 \times 2) = 10.54\ tf/m^2$

$M_{BA} = \frac{1}{2} \times (10.54 - 9.5899) \times 3.4^2 = 5.4916\ t.m$

$M_{gF} = -M_{Fg} = \frac{1}{12} \times 6.79 \times 2.8^2 = 4.4361\ t.m$

$M_{BC} = -M_{CB} = \frac{1}{12} \times 9.5899 \times 2.8^2 = 6.2654\ t.m$

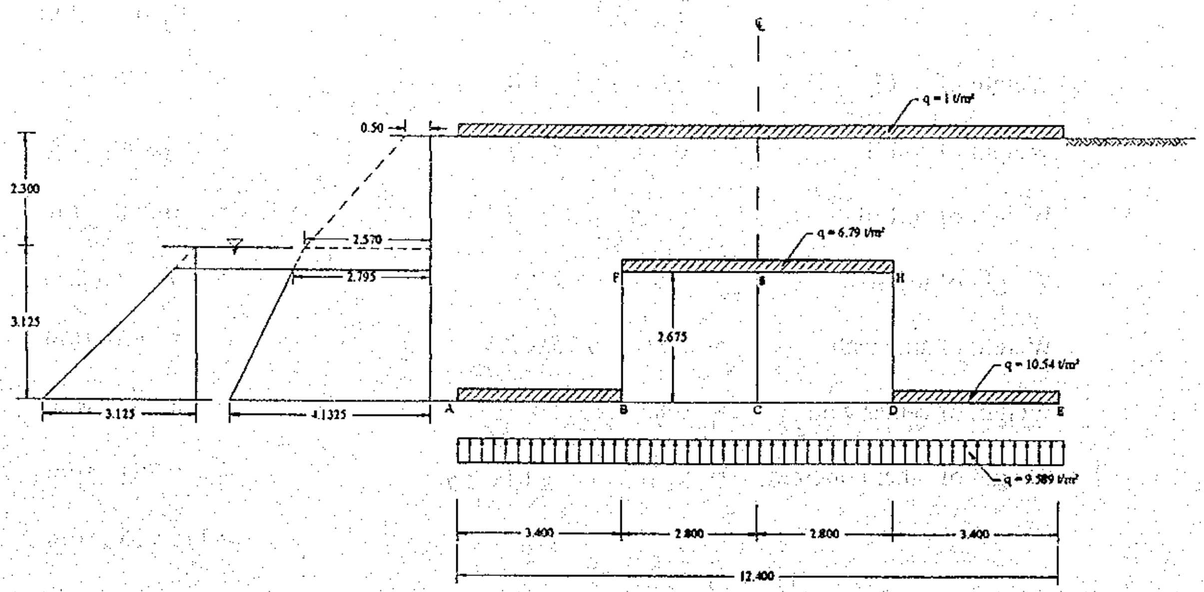
$$M_{BF} = \frac{-2.675^2 \times (2 \times 3.245 + 3 \times 3.2575)}{60}$$

$= -3.3706\ tf.m$

$$M_{FB} = \frac{-2.675^2 \times (2 \times 7.2575 + 3 \times 3.245)}{60}$$

$= +3.8921\ tf.m$

Load Diagram for Flooding Case



C	B			F		G
CB	BC	BA	BF	FB	FG	GF
-	0.5818	-	0.4182	0.7794	0.2206	-
-6.2654	+6.2654	+5.4916	-3.3706	+2.8921	-4.4361	+4.4361
-2.4396	-4.8792	-	-3.5072	-1.7536		
			+1.2851	+2.5701	+0.7275	+0.3637
-0.3738	-0.7477		-0.5374	-0.2687		
			+0.1047	+0.2094	+0.0593	+0.0296
-0.0305	-0.0609		-0.0438	-0.0219		
			+0.0085	+0.0171	+0.0048	+0.0024
-0.0024	-0.0049		-0.0036	-0.0018		
			+0.0007	+0.0014	+0.0004	+0.0002
-0.0002	-0.0004		-0.0003			
-9.1119	0.5723	+5.4916	-6.0639	+3.6441	-3.6441	+4.832

Top Slab FG

$$S_{FG} = {}^{2.8}\!/_{2} \times 6.79 - \frac{4.8320 - 3.6441}{2.8} = 9.082 \text{ tf.m}$$

$$S_{GF} = {}^{2.8}\!/_{2} \times 6.79 - \frac{3.6441 - 4.8320}{2.8} = 9.930 \text{ tf.m}$$

$$S = 0 \rightarrow 9.082 - 6.79x = 0 \rightarrow x = 1.338 \text{ m}$$

$$M_{max} = 9.08 \times 1.338 - \tfrac{1}{2} \times 6.79 \times 1.338^2 - 3.6441 = 2.430 \text{ tf.m}$$

Bottom Slab BC

$$S_{BC} = {}^{2.8}\!/_2 \text{ x } 9.5899 - \frac{9.1119 - 0.5725}{2.8} = 10.376 \text{ tf.m}$$

$$S_{CB} = {}^{2.8}\!/_2 \text{ x } 9.5899 - \frac{0.5723 - 9.1119}{2.8} = 15.984 \text{ tf.m}$$

$S = 0 \quad \rightarrow \quad 10.37 - 9.5899x = 0 \quad \rightarrow \quad x = 1.082$ m

$M_{max} = 10.376 \text{ x } 1.082 - ½ \text{ x } 9.5899 \text{ x } 1.082^2 - 0.5723 = 5.041$ tf.m

Side Wall BF

$$S_{AF} = \frac{2 \text{ x } 7.2575 + 3.245}{6} \text{ x } 2.675 - \frac{3.6441 - 6.0639}{2.675}$$

$= 8.826$ tf.m

$$S_{FA} = \frac{2 \text{ x } 3.245 + 7.2575}{6} \text{ x } 2.675 - \frac{6.0639 - 3.6441}{2.675}$$

$= 5.224$ tf.m

$$S = 0 \quad \rightarrow \quad 8.826 - 7.2575x - \frac{3.245 - 7.2575}{2 \text{ x } 2.675} x^2 = 0$$

$$-0.75x^2 - 7.2575x + 8.826 = 0$$

$$x^2 - 9.677x + 11.768 = 0$$

$$x = \frac{9.677 - \sqrt{9.677^2 - 4 \text{ x } 11.768}}{2}$$

$$x = 1.426 \text{ m}$$

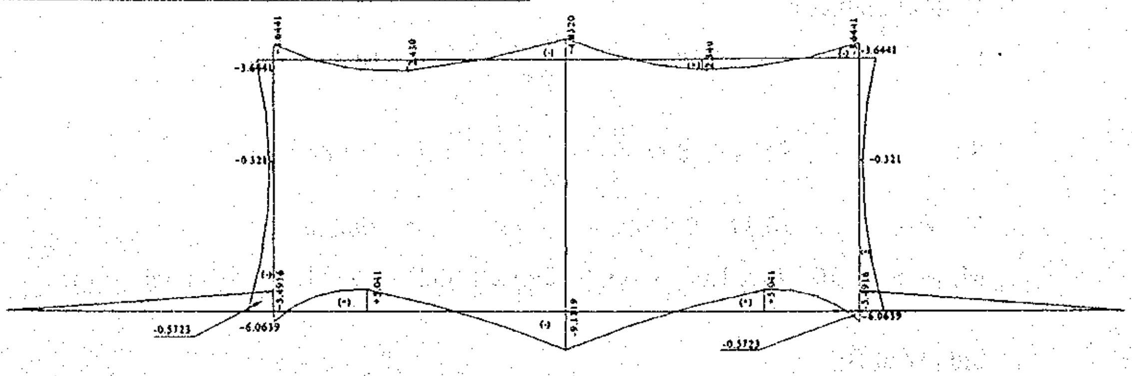
$$M_{max} = 8.826 \text{ x } 1.426 - \frac{7.2575}{2} \text{ x } 1.426^2 - \frac{3.245 - 7.2575}{6 \text{ x } 2.675} \text{ x } 1.426^2$$

$= -6.0639 \quad = -0.132$ tf.m

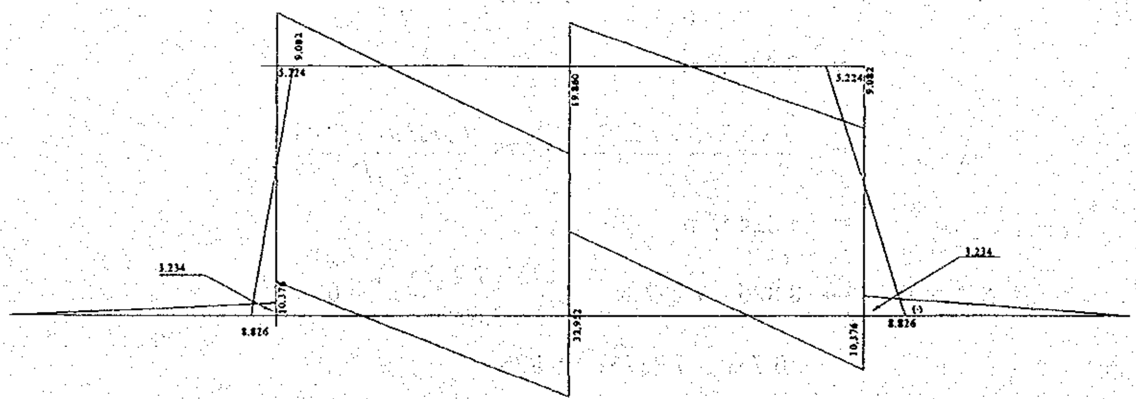
Bending Moment, Shear Force and Axial load

Location		M (t.m)	S (t)	N (t)
Slab BA	BA	-5.4916	3.234	-
Top Slab	F = H	-3.6441	9.082	5.264
	Center	+2.430	-	5.224
	G	-4.8320	9.9.0	5.224
Bottom Slab	B = D	-0.5725	0.376	8.826
	Center	+5.041	-	8.826
	C	-9.1119	16.476	8.826
Side Wall	B = D	-6.0639	8.826	10.376
	Center	-0.321	-	10.376
	F = H	-3.6441	5.224	9.082
Center Wall	C	-	-	16.476
	Center	-	-	16.476
	g	-	-	16.476

Bending Moment Diagram for Flood Condition



Shear Force Diagram for Flood Condition



Construction Case

Q	$= 1 \times 12.4$	= 12.400 t/m
Weight of soil I	$= 2.5 \times 12.4 \times 1.8$	= 55.800 t/m
Weight of soil II	$= (12.4-6.35) \times 2.5 \times 1.8$	= 27.225 t/m
Weight of top slab	$= 0.5 \times 6.35 \times 2.5$	= 7.938 t/m
Weight of side wall	$= 2 \times 0.75 \times 2 \times 2.5$	= 7.500 t/m
Weight of center wall	$= 0.85 \times 2 \times 2.5$	= 4.250 t/m
Weight of other concrete	$= \dfrac{0.15 \times 0.15}{2} \times 10 \times 2.5$	= 0.281 t/m
		= 115.394 t/m

Sub grade reaction $q_R = \dfrac{115.394}{12.4} = 9.5899\ t/m^2$

$q_1 = 1+(2.5 \times 1.8)+(0.5 \times 2.5) = 6.750\ t/m^2$

$q_2 = 1+(5 \times 1.8) = 10\ t/m^2$

$M_{BA} = \frac{1}{2} \times (10 - 9.301) \times 3.4^2 = 4.0402\ t.m$

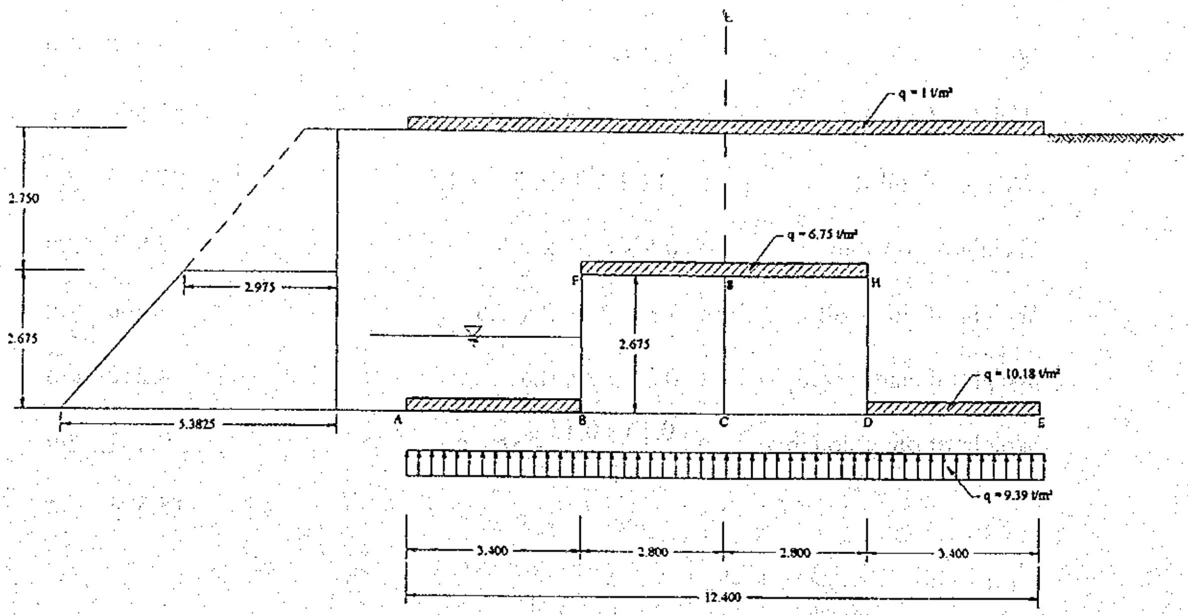
$M_{GF} = -M_{FG} = \frac{1}{12} \times 6.75 \times 2.8^2 = 4.4100\ t.m$

$M_{BC} = -M_{CB} = \frac{1}{12} \times 9.301 \times 2.8^2 = 6.0767\ t.m$

$$M_{BF} = \frac{-2.675^2 \times (2 \times 2.975 + 3 \times 5.3825)}{60} = -2.6355$$

$$M_{FB} = \frac{-2.675^2 \times (2 \times 5.3825 + 3 \times 2.975)}{60} = +2.3842$$

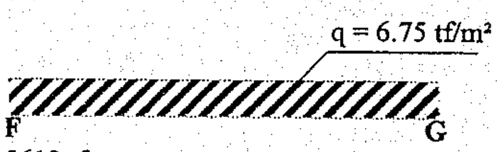
Load Diagram for Normal Case



Moment Distribution by Cross Method

C	B			F		G
CB	BC	BA	BF	FB	FG	GF
-	0.5818	-	0.4182	0.7794	0.2206	-
-6.0767	+6.0767	+4.0462	-2.6355	+2.3484	-4.4100	+4.4100
-2.1763	-4.3527		-3.1290	-1.5644		
			+1.4131	+2.8261	-0.7999	+0.3999
-0.4111	-0.8221		-0.5909	-0.2955		
			+0.1151	+0.2303	-0.0652	+0.0326
-0.0335	-0.0670		-0.0481	-0.0241		
			+0.0094	+0.0188	-0.0053	+0.0027
-0.0027	-0.0055		-0.0039	-0.0020		
			+0.0008	+0.0016	-0.0004	+0.0002
-0.0003	-0.0005		-0.0003	-0.0002		
				+0.0002	-0.0000	
-8.7006	0.8289	+4.0462	-4.8693	+3.5392	-3.5392	+4.8454

Top Slab FG



M = -3.5619 tf.m M = -4.834 tf.m

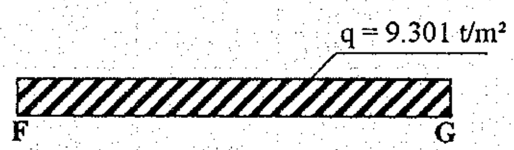
$$S_{FG} = {}^{2.8}\!/_{2} \times 6.75 - \frac{4.834 - 3.5619}{2.8} = 8.996 \text{ tf}$$

$S_{GF} \quad = \quad {}^{2.8}\!/_{2} \times 6.75 - \dfrac{3.5619 - 4.834}{2.8} \quad = \quad 9.904 \text{ tf}$

$S \;= 0 \quad \rightarrow \quad 8.996 - 6.75x \;=\; 0 \quad \rightarrow \quad x = 1.333 \text{ m}$

$M_{max} \quad = \quad 8.996 \times 1.333 - ½ \times 6.75 \times 1.333^2 - 3.5619 \quad = \quad 2.4327 \text{ tf.m}$

<u>Bottom Slab BC</u>



M = 0.7728 t.m M = -8.8196 t.m

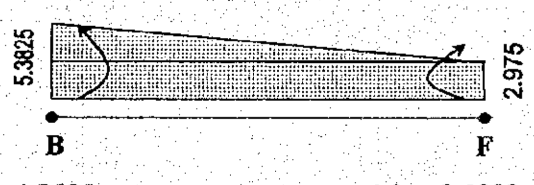
$S_{BC} \quad = \quad {}^{2.8}\!/_{2} \times 9.301 - \dfrac{8.8196 - 0.7728}{2.8} \quad = \quad 10.147 \text{ tf}$

$S_{CB} \quad = \quad {}^{2.8}\!/_{2} \times 9.301 - \dfrac{0.7728 - 8.8196}{2.8} \quad = \quad 15.895 \text{ tf}$

$D \;= 0 \quad \rightarrow \quad 10.147 - 9.301x = 0 \quad \rightarrow \quad x = 1.091 \text{ m}$

$M_{max} \quad = \quad 10.147 \times 1.091 - ½ \times 9.301 \times 1.091^2 - 0.7728 \quad = \quad 4.7622 \text{ tf.m}$

<u>Side Wall BF</u>



M = 4.8695 t.m M = -3.5392 t.m

$R_{BF} \quad = \quad \dfrac{2 \times 5.3825}{6} \times 2.675 - \dfrac{3.5393 - 4.8693}{2.675}$

$\quad = \quad 6.6229 \text{ tf.m}$

$R_{FB} \quad = \quad \dfrac{2 \times 2.975 + 5.3825}{6} \times 2.675 - \dfrac{4.8693 - 3.559}{2.675}$

$\quad = \quad 4.5552 \text{ tf.m}$

$S \;= 0 \rightarrow 0 = 6.6229 - 5.3825x - \dfrac{2.975 - 5.3825}{2 \times 2.675} x^3$

$-0.45x^2 - 5.3825x + 6.6229 = 0$

$x \;= \dfrac{-11.9611 + \sqrt{11.9611^2 - 4 \times 14.7179}}{2} = 1.3926$

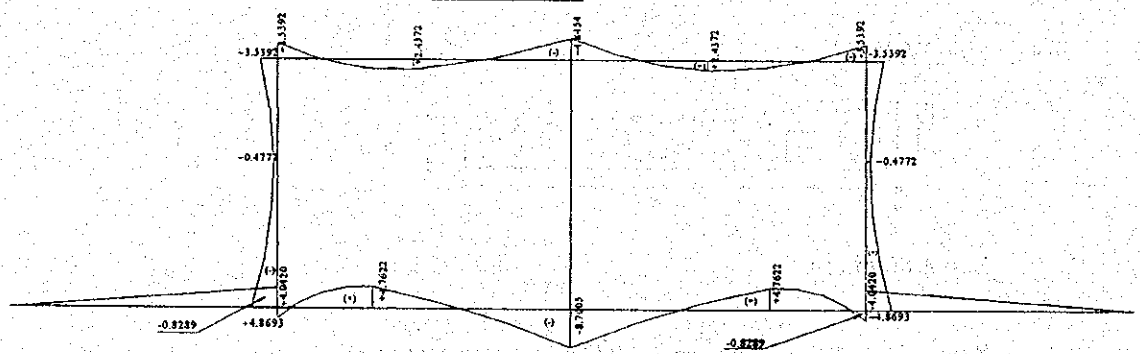
$$M_x = 6.6229 \times 1.3926 - \frac{5.3825}{2} \times 1.3926^2 - \frac{2 \times 2.975 - 5.285}{6 \times 2.675} \times 1.3926^3$$

$= 4.8693 \quad = -0.4772$ t.m

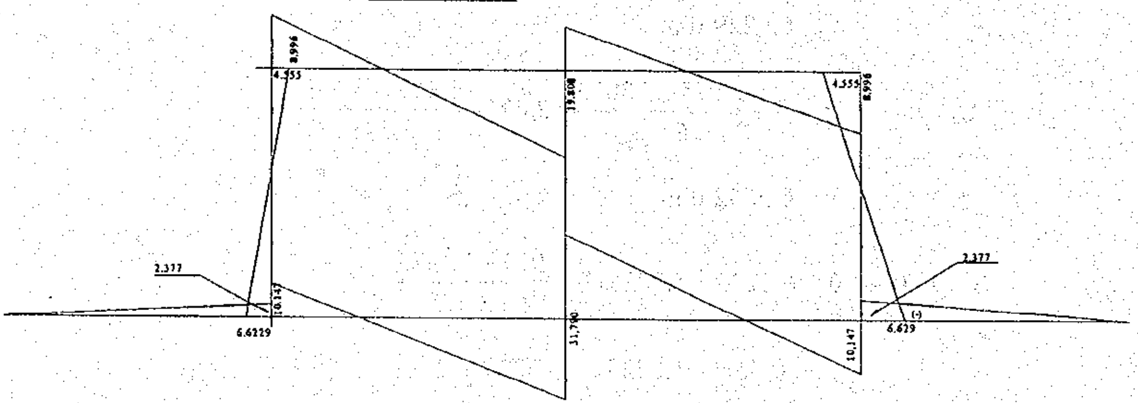
Bending Moment, Shear Force and Axial Load

Location		M (tf.m)	S (tf)	N (tf)
Slab BA	BA	+4.0402	2.377	-
Top Slab	F = H	-3.5392	8.996	4.5552
	Center	+2.4377	0	4.5552
	G	-4.854	9.904	4.5552
Bottom Slab	B = D	-8.289	10.236	6.6229
	Center	+4.7622	-	6.6229
	C	-8.7005	15.983	6.6229
Side Wall	B = D	-4.8693	6.6229	10.147
	Center	-0.4772	-	10.147
	F = H	-3.5392	4.5552	10.147
Center Wall	C	-	-	15.865
	Center	-	-	15.865
	G	-	-	15.865

Bending Moment Diagram for During Construction



Shear Force Diagram for During Construction



Shear Stress

Description	unit	Normal condition	Flood condition	During construction
I. Top Slab				
a. Joint F and H				
S	kg.f	8996	9082	8996
H	cm	41	41	41
$\tau = \dfrac{s}{7/8 \times 100 \times h}$	kgf/cm²	2.508	2.532	2.508
b. Joint G				
S	kg.f	9904	9930	9904
H	cm	41	41	41
$\tau = \dfrac{s}{7/8 \times 100 \times h}$	kgf/cm²	2.761	2.768	2.761
II. Bottom Slab				
a. Joint B and D				
S	kg.f	10236	10376	10146
H	Cm	68.5	68.5	68.5
$\tau = \dfrac{s}{7/8 \times 100 \times h}$	kgf/cm²	1.708	1.731	1.693
b. Joint C				
S	kgf	15983	16746	15865
H	cm	68.5	68.5	68.5
$\tau = \dfrac{s}{7/8 \times 100 \times h}$	kgf/cm²	2.667	2.794	2.647
III. Side Wall				
a. Joint B and D				
S	kg.f	7524	8826	6623
H	Cm	66	66	66
$\tau = \dfrac{s}{7/8 \times 100 \times h}$	kgf/cm²	1.303	1.528	1.147

Description	unit	Normal condition	Flood condition	During construction
b. Joint F and H				
S	kg.f	4658	5224	4555
H	cm	66	66	66
$\tau = \frac{s}{7/8 \times 100 \times h}$	kgf/cm²	0.807	0.905	0.789
c. Joint				
S	kg.f	2570	3234	2377
H	cm	76	76	76
$\tau = \frac{s}{7/8 \times 100 \times h}$	kgf/cm²	0.386	0.486	0.357

All shear stress $\tau <$ allowable shear stress $\bar{\tau}$ = **6.5** kg/cm² (**OK**).

Calculation of reinforcement bar caused by bending moment and axial load.

Top Slab (Joint F)

Description	unit	Normal condition	Flood condition	During construction
M =	t.m	3.5619	3.6441	3.5397
N =	tf	4.658	5.224	4.555
h_t =	m	0.50	0.50	0.50
h =	m	0.41	0.41	0.41
$\ell_{o1} = M/N$	m	0.765	0.698	0.777
$\ell_{o2} = 1/30\, h_t$	m	0.017	0.017	0.017
$\ell_o = \ell_{o1} + \ell_{o2}$	m	0.782	0.715	0.794
ℓ_o / h_t	m	1.564	1.430	1.588
C_1	-	1	1	1
C_2	-	7	7	7
ℓ_k	m	2.8	2.8	2.8
$\ell_1 = C_1 C_2 \left(\frac{l_k}{100 h_t} \right)^2 h_t$	m	0.011	0.011	0.011
$\ell_2 = 0.15\, h_t$	m	0.075	0.075	0.075
$\ell = \ell_o + \ell_1 + \ell_2$	m	0.868	0.801	0.880
$d = h_t - h$	m	0.090	0.090	0.090
$\ell_a = \ell + \frac{1}{2} h_t - d$	m	1.028	0.961	1.040
N_{ea}	tf.m	4.785	5.016	4.736
b=100; n=15; σ=1600 $C_a = \frac{h}{\sqrt{\frac{n.N_{ea}}{b.\bar{\sigma}_a}}}$	-	6.121	5.979	6.153
δ = 0	-	0	0	0
Ø	-	3.702	3.602	3.724
n.ω	-	0.0287	0.0302	0.0284
ζ	-	0.929	0.928	0.929
$i = \frac{1}{1 - \zeta h / ea}$	-	1.589	1.655	1.589
$iA = \frac{n\omega}{n} b.h$	cm²	7.845	8.255	7.763
$A = \frac{iA}{i}$	cm²	4.937	4.988	4.885

Used D 16-250 → A = 8.042 cm²

Top Slab (Joint G)

Description	unit	Normal condition	Flood condition	During construction
M =	t.m	4.834	4.8320	4.8454
N =	tf	4.658	5.224	4.555
h_t =	m	0.50	0.50	0.50
h =	m	0.41	0.41	0.41
$\ell_{o1} = M/N$	m	1.038	0.925	1.064
$\ell_{o2} = 1/30\, h_t$	m	0.017	0.017	0.017
$\ell_o = \ell_{o1} + \ell_{o2}$	m	1.055	0.942	1.081
ℓ_o / h_t	m	2.110	1.884	2.162
C_1	-	1	1	1
C_2	-	7	7	7
ℓ_k	m	2.8	2.8	2.8
$\ell_1 = C_1 C_2 \left(\frac{l_k}{100 h_t}\right)^2 h_t$	m	0.011	0.011	0.011
$\ell_2 = 0.15\ h_t$	m	0.075	0.075	0.075
$\ell = \ell_o + \ell_1 + \ell_2$	m	1.141	1.028	1.167
$d = h_t - h$	m	0.090	0.090	0.090
$\ell_a = \ell + \frac{1}{2} h_t - d$	m	1.301	1.188	1.327
N_{ea}	tf.m	4.785	5.016	4.736
b=100; n=15; σ=1600 $C_a = \frac{h}{\sqrt{\frac{n.N_{ea}}{b.\overline{\sigma}_a}}}$	-	5.441	5.394	5.448
δ = 0	-	0	0	0
∅	-	3.702	3.602	3.724
n.ω	-	0.0366	0.0373	0.0366
ζ	-	0.929	0.921	0.921
$i = \frac{1}{1 - \zeta h / ea}$	-	1.414	1.398	1.398
$iA = \frac{n\omega}{n} b.h$	cm²	10.004	10.195	10.004
$A = \frac{iA}{i}$	cm²	7.075	7.293	7.156

Used D 13-125 → A = 10.619 cm²

Top Slab (Positive Moment)

Description	unit	Normal condition	Flood condition	During construction
M =	t.m	2.431	2.430	2.437
N =	tf	4.658	5.224	4.555
h_t =	m	0.50	0.50	0.50
h =	m	0.41	0.41	0.41
$\ell_{o1} = M/N$	m	0.522	0.465	0.535
$\ell_{o2} = 1/30\, h_t$	m	0.017	0.017	0.017
$\ell_o = \ell_{o1} + \ell_{o2}$	m	0.539	0.482	0.552
ℓ_o / h_t	m	1.078	0.964	1.104
C_1	-	1	1	1
C_2	-	7	7	7
ℓ_k	m	2.8	2.8	2.8
$\ell_1 = C_1 C_2 \left(\frac{l_k}{100 h_t} \right)^2 h_t$	m	0.011	0.011	0.011
$\ell_2 = 0.15\, h_t$	m	0.075	0.075	0.075
$\ell = \ell_o + \ell_1 + \ell_2$	m	0.625	0.568	0.638
$d = h_t - h$	m	0.090	0.090	0.090
$\ell_a = \ell + ½ h_t - d$	m	0.785	0.728	0.798
N_{ea}	tf.m	4.785	5.016	4.736
b=100; n=15; σ=1600 $C_a = \frac{h}{\sqrt{\frac{n.N_{ea}}{b.\bar{\sigma}_a}}}$	-	7.005	6.867	7.051
δ = 0	-	0	0	0
Ø	-	3.702	3.602	3.724
n.ω	-	0.0217	0.0226	0.0214
ζ	-	0.937	0.936	0.938
$i = \frac{1}{1 - \zeta h / ea}$	-	1.958	1.930	1.930
$iA = \frac{n\omega}{n} b.h$	cm²	5.931	6.177	5.849
$A = \frac{iA}{i}$	cm²	3.029	3.201	3.031

Used D16-250 → A = 8.042 cm²

Bottom Slab (Joint C)

Description	unit	Normal condition	Flood condition	During construction
M =	t.m	8.816	9.1119	8.7005
N =	tf	7.574	8.826	6.6229
h_t =	m	0.85	0.85	0.85
h =	m	0.685	0.685	0.685
$\ell_{o1} = M/N$	m	1.164	1.032	1.314
$\ell_{o2} = \frac{1}{30} h_t$	m	0.028	0.028	0.028
$\ell_o = \ell_{o1} + \ell_{o2}$	m	1.192	1.06	1.342
ℓ_o / h_t	m	1.402	1.247	1.57882
C_1	-	1	1	1
C_2	-	7	7	7
ℓ_k	m	2.8	2.8	2.8
$\ell_1 = C_1 C_2 \left(\frac{l_k}{100 h_t} \right)^2 h_t$	m	0.006	0.006	0.006
$\ell_2 = 0.15\ h_t$	m	0.128	0.128	0.128
$\ell = \ell_o + \ell_1 + \ell_2$	m	1.326	1.194	1.476
$d = h_t - h$	m	0.165	0.165	0.165
$\ell_a = \ell + \frac{1}{2} h_t - d$	m	1.586	1.454	1.736
N_{ea}	tf.m	4.785	5.016	4.736
b=100; n=15; σ=1600 $C_a = \frac{h}{\sqrt{\frac{n.N_{ea}}{b.\overline{\sigma}_a}}}$	-	6.454	6.244	6.598
δ = 0	-	0	0	0
∅	-	3.702	3.602	3.724
n.ω	-	0.0257	0.0276	0.0246
ζ	-	0.932	0.920	0.934
$i = \frac{1}{1 - \zeta h / ea}$	-	1.674	1.584	1.584
$iA = \frac{n\omega}{n} b.h$	cm²	11.736	12.604	11.234
$A = \frac{iA}{i}$	cm²	7.011	7.957	7.092

Used D 19-250 → A = 11.340 cm²

Bottom Slab (Joint B)

Description	unit	Normal condition	Flood condition	During construction
M =	t.m	0.7228	0.5793	0.8289
N =	tf	7.574	8.826	6.6229
h_t =	m	0.85	0.85	0.85
h =	m	0.685	0.685	0.685
$\ell_{o1} = M/N$	m	0.095	0.066	0.125
$\ell_{o2} = 1/30\, h_t$	m	0.028	0.028	0.028
$\ell_o = \ell_{o1} + \ell_{o2}$	m	0.123	0.094	0.153
ℓ_o / h_t	m	0.145	0.111	0.180
C_1	-	1	1	1
C_2	-	7	7	7
ℓ_k	m	2.8	2.8	2.8
$\ell_1 = C_1 C_2 \left(\frac{l_k}{100 h_t} \right)^2 h_t$	m	0.006	0.006	0.006
$\ell_2 = 0.15\, h_t$	m	0.128	0.128	0.128
$\ell = \ell_o + \ell_1 + \ell_2$	m	0.257	0.228	0.287
$d = h_t - h$	m	0.165	0.165	0.165
$\ell_a = \ell + ½h_t - d$	m	0.517	0.488	0.547
N_{ea}	tf.m	4.785	5.016	4.736
b=100; n=15; σ=1600 $C_a = \frac{h}{\sqrt{\frac{n.N_{ea}}{b.\bar{\sigma}_a}}}$	-	11.302	10.796	11.754
δ = 0	-	0	0	0
∅	-	3.702	3.602	3.724
n.ω	-	0.0082	0.0089	0.0075
ζ	-	0.960	0.958	0.962
$i = \frac{1}{1 - \zeta h / ea}$	-	-3.677	-4.885	-4.885
$iA = \frac{n\omega}{n} b.h$	cm²	3.745	4.064	3.425
$A = \frac{iA}{i}$	cm²	-1.018	-0.832	-0.701

Used D 19-200 → A = 4.341 cm²

Bottom Slab (Positive Moment)

Description	unit	Normal condition	Flood condition	During construction
M =	t.m	4.822	5.041	4.762
N =	tf	7.574	8.826	6.623
h_t =	m	0.85	0.85	0.85
h =	m	0.76	0.76	0.76
$\ell_{o1} = M/N$	m	0.637	0.571	0.719
$\ell_{o2} = \frac{1}{30} h_t$	m	0.028	0.028	0.028
$\ell_o = \ell_{o1} + \ell_{o2}$	m	0.665	0.599	0.747
ℓ_o / h_t	m	0.782	0.705	0.87882
C_1	-	1	1	1
C_2	-	7	7	7
ℓ_k	m	2.8	2.8	2.8
$\ell_1 = C_1 C_2 \left(\frac{l_k}{100 h_t} \right)^2 h_t$	m	0.006	0.006	0.006
$\ell_2 = 0.15\ h_t$	m	0.128	0.128	0.128
$\ell = \ell_o + \ell_1 + \ell_2$	m	0.799	0.733	0.881
$d = h_t - h$	m	0.090	0.090	0.090
$\ell_a = \ell + \frac{1}{2} h_t - d$	m	1.134	1.068	1.216
N_{ea}	tf.m	4.785	5.016	4.736
b=100; n=15; σ=1600 $C_a = \frac{h}{\sqrt{\frac{n.N_{ea}}{b.\bar{\sigma}_a}}}$	-	8.470	8.083	8.746
δ = 0	-	0	0	0
Ø	-	3.702	3.602	3.724
n.ω	-	0.0147	0.0163	0.014
ζ	-	0.948	0.945	0.949
$i = \frac{1}{1 - \zeta h / ea}$	-	2.742	2.458	2.458
$iA = \frac{n\omega}{n} b.h$	cm²	7.448	8.259	7.093
$A = \frac{iA}{i}$	cm²	2.716	3.360	2.886

Used D 19-250 → A = 11.341 cm²

Side Wall (Joint A)

Description	unit	Normal condition	Flood condition	During construction
M =	t.m	5.3159	6.6039	4.8693
N =	tf	10.236	10.376	10.147
h_t =	m	0.75	0.75	0.75
h =	m	0.66	0.66	0.66
$\ell_{o1} = M/N$	m	0.519	0.636	0.480
$\ell_{o2} = \frac{1}{30} h_t$	m	0.025	0.025	0.025
$\ell_o = \ell_{o1} + \ell_{o2}$	m	0.544	0.661	0.505
ℓ_o / h_t	m	0.725	0.881	0.67333
C_1	-	1	1	1
C_2	-	7	7	7
ℓ_k	m	2.675	2.675	2.675
$\ell_1 = C_1 C_2 \left(\frac{l_k}{100 h_t}\right)^2 h_t$	m	0.007	0.007	0.007
$\ell_2 = 0.15\ h_t$	m	0.113	0.113	0.113
$\ell = \ell_o + \ell_1 + \ell_2$	m	0.664	0.781	0.625
$d = h_t - h$	m	0.090	0.090	0.090
$\ell_a = \ell + \frac{1}{2} h_t - d$	m	0.949	1.066	0.91
N_{ea}	tf.m	9.709	11.057	9.224
b=100; n=15; σ=1600 $C_a = \frac{h}{\sqrt{\frac{n.N_{ea}}{b.\overline{\sigma}_a}}}$	-	6.918	6.482	7.097
δ = 0	-	0	0	0
Ø	-	3.702	3.602	3.724
n.ω	-	0.0287	0.0302	0.0284
ζ	-	0.937	0.933	0.938
$i = \frac{1}{1 - \zeta h / ea}$	-	2.826	3.065	3.065
$iA = \frac{n\omega}{n} b.h$	cm²	12.628	13.288	12.496
$A = \frac{iA}{i}$	cm²	4.469	4.335	4.077

Used D 13-125 → A = 10.618 cm²

Side Wall (Joint F)

Description	unit	Normal condition	Flood condition	During construction
M =	t.m	3.5619	3.6441	3.5392
N =	tf	8.998	9.082	8.996
h_t =	m	0.75	0.75	0.75
h =	m	0.66	0.66	0.66
$\ell_{o1} = M/N$	m	0.396	0.401	0.393
$\ell_{o2} = 1/30\, h_t$	m	0.025	0.025	0.025
$\ell_o = \ell_{o1} + \ell_{o2}$	m	0.421	0.426	0.418
ℓ_o / h_t	m	0.561	0.568	0.55733
C_1	-	1	1	1
C_2	-	6.92	6.92	6.92
ℓ_k	m	2.675	2.675	2.675
$\ell_1 = C_1 C_2 \left(\frac{l_k}{100 h_t} \right)^2 h_t$	m	0.007	0.007	0.007
$\ell_2 = 0.15\, h_t$	m	0.113	0.113	0.113
$\ell = \ell_o + \ell_1 + \ell_2$	m	0.541	0.546	0.538
$d = h_t - h$	m	0.090	0.090	0.090
$\ell_a = \ell + ½h_t - d$	m	0.826	0.831	0.823
N_{ea}	tf.m	7.422	7.544	7.399
b=100; n=15; σ=1600 $C_a = \frac{h}{\sqrt{\frac{n.N_{ea}}{b.\bar{\sigma}_a}}}$	-	7.912	7.848	7.924
δ = 0	-	0	0	0
Ø	-	3.702	3.602	3.724
n.ω	-	0.017	0.0172	0.017
ζ	-	0.944	0.944	0.944
$i = \frac{1}{1 - \zeta h / ea}$	-	4.070	4.116	4.116
$iA = \frac{n\omega}{n} b.h$	cm²	7.480	7.568	7.480
$A = \frac{iA}{i}$	cm²	1.838	1.839	1.817

Used D 13-125 → A = 10.618 cm²