

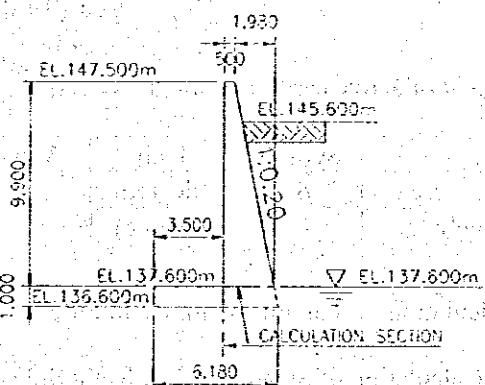
Chute

(1) Right Side of joint J5, Upper Section

Structural calculations of standing wall and toe slab are carried out.

(a) Basic design condition

Typical cross section and dimension are shown in the following figure.



J5 RIGHT SIDE, UPPER SECTION

Design conditions, such as material properties, are shown in the following tables.

Item	Symbol	Unit	Value	Description
Unit weight of concrete	γ_c	(tf/m ³)	2.50	Thick structure
Unit weight of wetted pervious material (Dam)	γ_t	(tf/m ³)	1.94	Wet density
Unit weight of submerged pervious material (Dam)	γ_s	(tf/m ³)	1.16	Submerged density
Horizontal seismic coefficient	K_h	-	0.16	100%

< Coefficient of earth pressure >

$$K_a = \frac{\cos^2(\phi - \theta)}{\cos^2 \theta \cdot \cos(\theta + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha)}{\cos(\theta + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

Ka : Coefficient of active earth pressure under normal condition

Item	Symbol	Unit	Value	Description
Angle between wall backside surface and vertical plane	θ	(degree)	11.3	V:H=1:0.20
Angle between ground surface and horizontal plane	α	(degree)	0.0	100%
Internal friction angle of soil	ϕ	(degree)	45.0	Pervious material of Dam
Friction angle of soil to concrete	δ	(degree)	30.0	$\delta = 2/3 \phi$

$$Kea = \frac{\cos^2(\phi - \theta_0 - \alpha)}{\cos\theta_0 \cdot \cos^2\theta \cdot \cos(\theta + \theta_0 + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

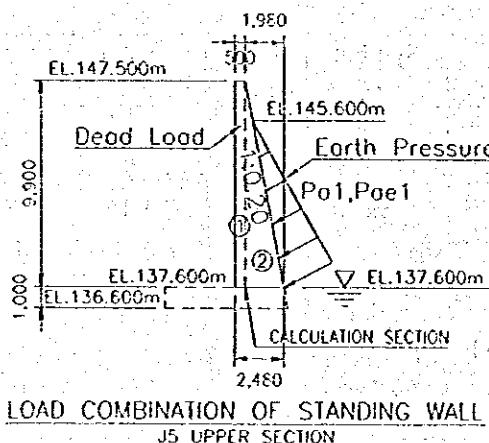
Kea : Coefficient of active earth pressure under seismic condition

Item	Symbol	Unit	Value	Description
Friction angle of soil to concrete	δ_e	(degree)	22.5	$\delta_e = 1/2 \phi$
Seismic composite angle	θ_0	(degree)	9.1	$\tan\theta_0 = Kh$

(b) Structural Calculation of Standing Wall, Right Side of J5 Upper Section

(i) Loading Calculation of Standing Wall, Right Side of J5 Upper Section

Structural model and load combinations are shown in the following figure.



Each load is calculated hereinafter.

Dead Load

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	4.95	12.38	-0.99	-12.25	-1.98	4.95	-9.80
2(concrete)	9.80	24.50	-0.08	-1.96	-3.92	3.30	-12.94
Total	14.75	36.88		-14.21	-5.90		-22.74

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.249$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	10.19	0.71	7.20	-11.60	2.67	-30.93
Total	-	10.19		7.20	-11.60		-30.93

Earth Pressure with Earthquake

Seismic composite angle : $\theta_0=9.1$ (degree) ($\tan\theta_0=Kh=0.16$)

Coefficient of active earth pressure : $K_{ea}=0.340$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	11.76	0.71	8.31	-17.56	2.67	-46.83
Total	-	11.76		8.31	-17.56		-46.83

(ii) Structural Calculation of Standing Wall, Right Side of J5 Upper Section

Case 1 : Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	36.88	0.00	-14.21	0.00
Earth Pressure	10.19	-11.60	7.20	-30.93
Total	47.07	-11.60	-7.01	-30.93

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -0.806 \text{ m} > 0.413 \text{ m} = b/6 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 5.60 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -1.80 \text{ (kgf/m}^2\text{)} < -3 \text{ OK}$$

Case 2 : Seismic condition (with Earthquake), Kh=0.16(100%)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	36.9	-5.9	-14.2	-22.7
Earth Pressure	11.8	-17.6	8.3	-46.8
Total	48.64	-23.46	-5.90	-69.57

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -1.552 \text{ m} > 0.827 \text{ m} = b/3 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

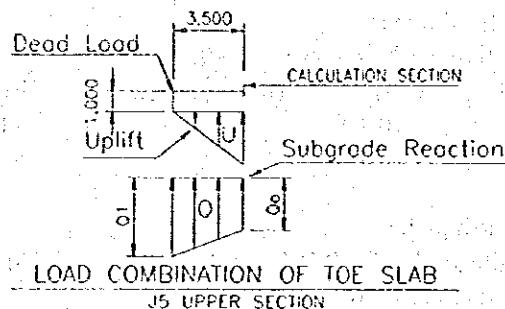
$$\text{Compressive stress } \sigma_c = 9.32 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -5.40 \text{ (kgf/m}^2\text{)} > -4.5 \quad \boxed{\text{NG}}$$

(c) Structural Calculation of Toe Slab, Right Side of J5 Upper Section

(i) Loading Calculation of Toe Slab, Right Side of J5 Upper Section

Structural model and load combinations are shown in the following figure.



Each load is calculated hereinafter.

Dead Load

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
I(concrete)	3.50	8.75	1.75	15.31	-	-	-
Total	3.50	8.75		15.31	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 5.190 \text{ (tf/m}^2\text{)}, \quad Q_0 = 10.661 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-27.74	1.55	-42.96	-	-	-
Total	-	-27.74		-42.96	-	-	-

Subgrade Reaction with Earthquake

$$Q_1 = 12.981 \text{ (tf/m}^2\text{)}, \quad Q_0 = 9.989 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-40.20	1.83	-73.40	-	-	-
Total	-	-40.20		-73.40	-	-	-

Uplift

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-0.99	1.17	-1.16	-	-	-
Total	-	-0.99		-1.16	-	-	-

(ii) Structural Calculation of Toe Slab, Right Side of J5 Upper Section

Case 1 : Normal condition (without Earthquake)

Total Load	V(-S)(tf)	H(-N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	8.75	0.00	15.31	0.00
Subgrade Reaction	-27.74	0.00	-42.96	0.00
Uplift	-0.99	0.00	-1.16	0.00
Total	-19.98	0.00	-28.80	0.00

Here; S : shearing forth, N : axial forth, M : moment

Stress calculation of concrete

Shear stress $\tau_c = 2.00 \text{ (kgf/m}^2\text{)} < 5.5 \text{ OK}$

Compressive stress $\sigma_c = 17.28 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$

Tensile stress $\sigma_t = -17.28 \text{ (kgf/m}^2\text{)} > -3 \text{ NG}$

Case 2 : Seismic condition (with Earthquake), $K_h=0.16(100\%)$

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	8.75	0.00	15.31	0.00
Subgrade Reaction	-40.20	0.00	-73.40	0.00
Uplift	-0.99	0.00	-1.16	0.00
Total	-32.44	0.00	-59.24	0.00

Here; S : shearing forth, N : axial forth, M : moment

Stress calculation of concrete

Shear stress	$\tau_c =$	3.24 (kgf/m ²)	<	8.25	OK
Compressive stress	$\sigma_c =$	35.55 (kgf/m ²)	<	90	OK
Tensile stress	$\sigma_t =$	-35.55 (kgf/m ²)	>	-4.5	NG

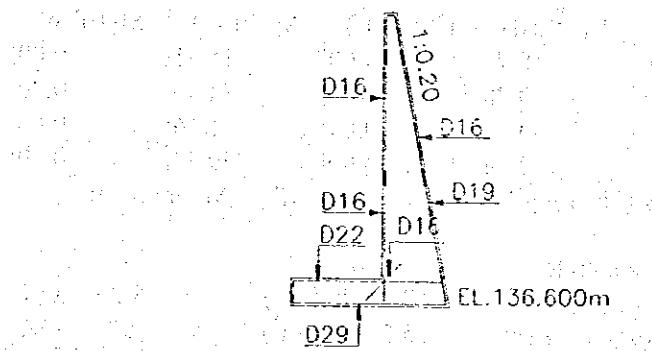
(d) Calculation of reinforcing bar arrangement for Right Side of J5 Upper Section

Results of calculation of reinforcement bar arrangement on each member are shown as follows.

[Calculation of reinforcing bar arrangement for Right Side of J5 Upper Section]

Member		Standing Wall		Toe Slab	
Calculation condition		Normal	Seismic	Normal	Seismic
Shape of member		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	37.94	75.47	28.8	59.24
N	tf	47.07	48.64	0	0
S	tf	11.6	23.46	19.98	32.44
B	cm	100	100	100	100
D	cm	238	238	90	90
A _c	cm ²	23800	23800	9000	9000
A _s	cm ²	D19@200 =14.20	D19@200 =14.20	D29@200 =33.05	D29@200 =33.05
P=A _s (B×D)		0.0006	0.0006	0.00367	0.00367
N=E _s /E _c		15	15	15	15
X ₀	cm	131.1	60.6	25.3	25.3
K=X ₀ /D		0.551	0.255	0.281	0.281
M/(B×D ²)	kgf/cm ²	0.67	1.332	3.556	7.314
S/(B×D)	kgf/cm ²	0.487	0.986	2.22	3.604
(C)		11.015	15.161	7.844	7.844
(S)		8.987	44.359	20.033	20.033
(Z)		2.219	1.547	1.103	1.103
σ_c	kgf/cm ²	7.4	20.2	27.9	57.4
σ_s	kgf/cm ²	90	887	1068	2198
τ	kgf/cm ²	0.49	0.99	2.22	3.6
σ_{ca}	kgf/cm ²	60	90	60	90
σ_{sa}	kgf/cm ²	1,800	2,700	1,800	2,700
τ_a	kgf/cm ²	5.5	8.25	5.5	8.25

Figure of main reinforcing bar arrangement is shown as follow.

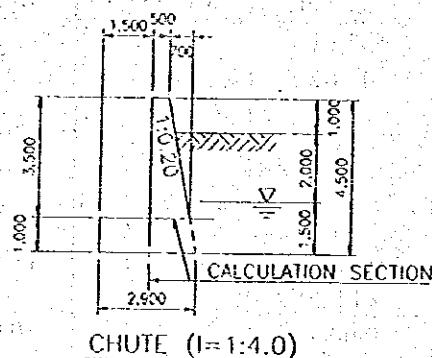


J5 RIGHT SIDE, UPPER SECTION

(2) Upstream Portion of Chute ($i=1:4.0$)

(a) Basic design condition

Typical cross section and dimension are shown in the following figure.



Design conditions, such as material properties, are shown in the following tables.

Item	Symbol	Unit	Value	Description
Unit weight of concrete	γ_c	(tf/m ³)	2.50	Thin structure
Unit weight of wetted backfill soil	γ_t	(tf/m ³)	1.90	Wet density
Unit weight of submerged backfill soil	γ_s	(tf/m ³)	0.90	Submerged density
Horizontal seismic coefficient	K_h	-	0.16	100%

< Coefficient of earth pressure >

$$K_a = \frac{\cos^2(\phi - \theta)}{\cos^2\theta \cdot \cos(\theta + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha)}{\cos(\theta + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

K_a : Coefficient of active earth pressure under normal condition

Item	Symbol	Unit	Value	Description
Angle between wall backside surface and vertical plane	θ	(degree)	11.3	V:H=1:0.20
Angle between ground surface and horizontal plane	α	(degree)	0.0	
Internal friction angle of soil	ϕ	(degree)	35.0	Sandy soil
Friction angle of soil to concrete	δ	(degree)	23.3	$\delta = 2/3 \phi$

$$K_{ea} = \frac{\cos^2(\phi - \theta_0 - \theta)}{\cos\theta_0 \cdot \cos^2\theta \cdot \cos(\theta + \theta_0 + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

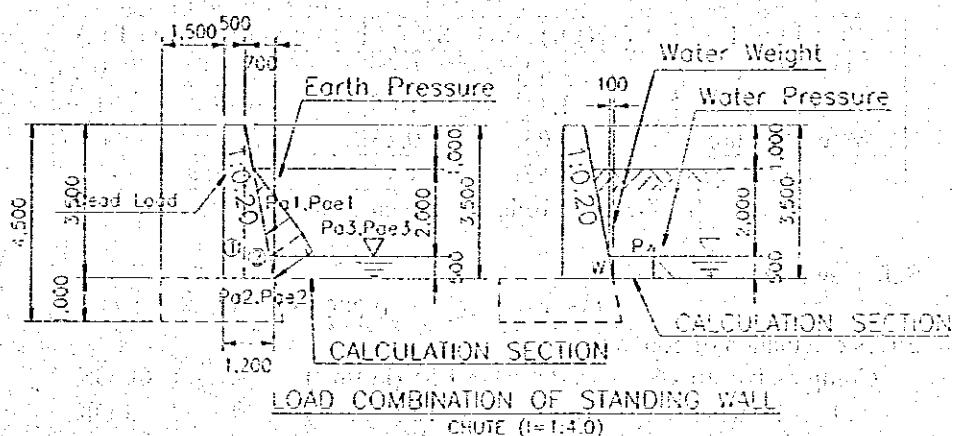
K_{ea} : Coefficient of active earth pressure under seismic condition

Item	Symbol	Unit	Value	Description
Friction angle of soil to concrete	δ_e	(degree)	17.5	$\delta_e = 1/2 \phi$
Seismic composite angle	θ_0	(degree)	9.1	$\tan\theta_0 = K_h$

(b) Structural Calculation of Standing Wall, Upstream Portion of Chute ($i=1:4.0$)

(i) Loading Calculation of Standing Wall, Upstream Portion of Chute ($i=1:4.0$)

Structural model and load combinations are shown in the following figure.



Each load is calculated hereinafter.

Dead Load

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	1.75	4.38	-0.35	-1.53	-0.70	1.75	-1.23
2(concrete)	1.23	3.06	0.13	0.41	-0.49	1.17	-0.57
Total	2.98	7.44		-1.12	-1.19		-1.80

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.335$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	0.72	0.37	0.27	-1.05	1.17	-1.22
Pa2	-	0.36	0.55	0.20	-0.52	0.25	-0.13
Pa3	-	0.02	0.57	0.01	-0.03	0.17	-0.01
Total	-	1.11		0.48	-1.60		-1.36

Earth Pressure with Earthquake

Seismic composite angle : $\theta_0=9.1$ (degree) ($\tan\theta_0=Kh=0.16$)

Coefficient of active earth pressure : $K_{ea}=0.449$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	0.82	0.37	0.30	-1.49	1.17	-1.74
Pae2	-	0.41	0.55	0.23	-0.75	0.25	-0.19
Pae3	-	0.02	0.57	0.01	-0.04	0.17	-0.01
Total	-	1.26		0.54	-2.28		-1.94

Water Pressure

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	0.03	0.03	0.57	0.01	-0.13	0.17	-0.02
Total	-	0.03		0.01	-0.13		-0.02

(ii) Structural Calculation of Standing Wall,

Upstream Portion of Chute ($i=1:4.0$)

Case 1 : Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	7.44	0.00	-1.12	0.00
Earth Pressure	1.11	-1.60	0.48	-1.36
Water Pressure	0.03	-0.13	0.01	-0.02
Total	8.57	-1.73	-0.63	-1.38

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -0.235 \text{ m} > 0.200 \text{ m} = b/6 \quad \text{NG}$$

Stress calculation of concrete

Compressive stress $\sigma_c = 1.55 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$

Tensile stress $\sigma_t = -0.12 \text{ (kgf/m}^2\text{)} < -3 \text{ OK}$

Case 2 : Seismic condition (with Earthquake), $Kh=0.16(100\%)$

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	7.4	-1.2	-1.1	-1.8
Earth Pressure	1.3	-2.3	0.5	-1.9
Water Pressure	0.0	-0.1	0.0	-0.0
Total	8.7	-3.6	-0.6	-3.8

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -0.496 \text{ m} > 0.400 \text{ m} = b/3 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

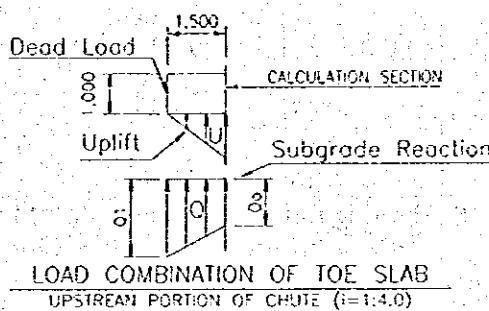
$$\text{Compressive stress } \sigma_c = 2.53 \text{ (kgf/m}^2\text{)} < 90 \quad \text{OK}$$

$$\text{Tensile stress } \sigma_t = -1.07 \text{ (kgf/m}^2\text{)} < -4.5 \quad \text{OK}$$

(c) Structural Calculation of Toe Slab, Upstream Portion of Chute ($i=1:4.0$)

(i) Loading Calculation of Toe Slab, Upstream Portion of Chute ($i=1:4.0$)

Structural model and load combinations are shown in the following figure.



Each load is calculated hereinafter.

Dead Load

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	1.50	3.75	0.75	2.81	-	-	-
Total	1.50	3.75		2.81	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 4.373 \text{ (tf/m}^2\text{)}, \quad Q_0 = 5.019 \text{ (tf/m}^2\text{)}$$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-7.04	0.73	-5.16	-	-	-
Total	-	-7.04		-5.16	-	-	-

Subgrade Reaction with Earthquake

$$Q_1 = 7.849 \text{ (tf/m}^2\text{)}, \quad Q_0 = 4.994 \text{ (tf/m}^2\text{)}$$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-9.63	0.81	-7.76	-	-	-
Total	-	-9.63		-7.76	-	-	-

Uplift

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-0.58	0.50	-0.29	-	-	-
Total	-	-0.58		-0.29	-	-	-

(ii) Structural Calculation of Toe Slab, Upstream Portion of Chute ($i=1:4.0$)

Case 1 : Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	3.75	0.00	2.81	0.00
Subgrade Reaction	-7.04	0.00	-5.16	0.00
Uplift	-0.58	0.00	-0.29	0.00
Total	-3.88	0.00	-2.64	0.00

Here; S : shearing forth, N : axial forth, M : moment

Stress calculation of concrete

Shear stress	$\tau_c = 0.39 \text{ (kgf/m}^2\text{)}$	<	5.5	OK
Compressive stress	$\sigma_c = 1.58 \text{ (kgf/m}^2\text{)}$	<	60	OK
Tensile stress	$\sigma_t = -1.58 \text{ (kgf/m}^2\text{)}$	<	-3	OK

Case 2 : Seismic condition (with Earthquake), Kh=0.16(100%)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	3.75	0.00	2.81	0.00
Subgrade Reaction	-9.63	0.00	-7.76	0.00
Uplift	-0.58	0.00	-0.29	0.00
Total	-6.46	0.00	-5.24	0.00

Here; S : shearing forth, N : axial forth, M : moment

Stress calculation of concrete

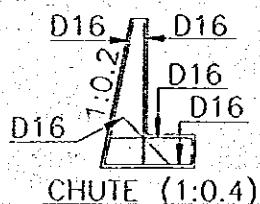
Shear stress	$\tau_c = 0.65 \text{ (kgf/m}^2\text{)}$	<	8.25	OK
Compressive stress	$\sigma_c = 3.14 \text{ (kgf/m}^2\text{)}$	<	90	OK
Tensile stress	$\sigma_t = -3.14 \text{ (kgf/m}^2\text{)}$	>	-4.5	OK

(d) Calculation of reinforcing bar arrangement for Upstream Portion of Chute (i=1:4.0)

All calculated stresses of concrete are smaller than allowable stresses.

But, since thickness of standing wall and toe slab is comparatively thin, steel bar of D16 mm is used as the reinforcing bar for standing wall and toe slab of Upstream Portion of Chute. And reinforcing bar arrangement of Downstream Portion of Chute (i=1:2.0) is same as this arrangement.

Figure of main reinforcing bar arrangement is shown as follow.

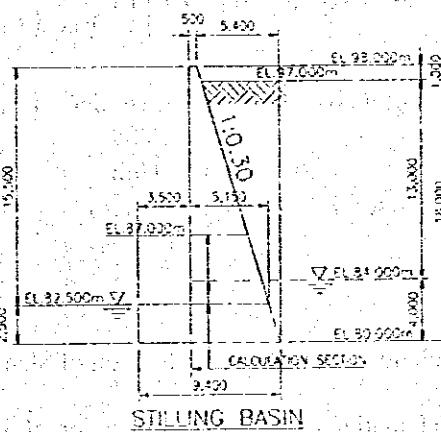


Stilling Basin

(a) Basic design condition

Structural calculations of standing wall and toe slab are carried out for the sidewall of Stilling Basin.

Typical cross section and dimension are shown in the following figure.



Design conditions, such as material properties, are shown in the following tables.

Item	Symbol	Unit	Value	Description
Unit weight of concrete	γ_c	(tf/m ³)	2.35	Thick structure
Unit weight of wetted backfill soil	γ_t	(tf/m ³)	1.90	Wet density
Unit weight of submerged backfill soil	γ_s	(tf/m ³)	0.90	Submerged density
Horizontal seismic coefficient	K_h	-	0.16	100%

< Coefficient of earth pressure >

$$K_a = \frac{\cos^2(\phi - \theta)}{\cos^2 \theta \cdot \cos(0 + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha)}{\cos(0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

Ka : Coefficient of active earth pressure under normal condition

Item	Symbol	Unit	Value	Description
Angle between wall backside surface and vertical plane	θ	(degree)	16.7	V:H=1:0.30
Angle between ground surface and horizontal plane	α	(degree)	0.0	
Internal friction angle of soil	ϕ	(degree)	35.0	Sandy soil
Friction angle of soil to concrete	δ	(degree)	23.3	$\delta = 2/3 \phi$

$$Kea = \frac{\cos^2(\phi - \theta_0 - \alpha)}{\cos \theta_0 \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0 + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

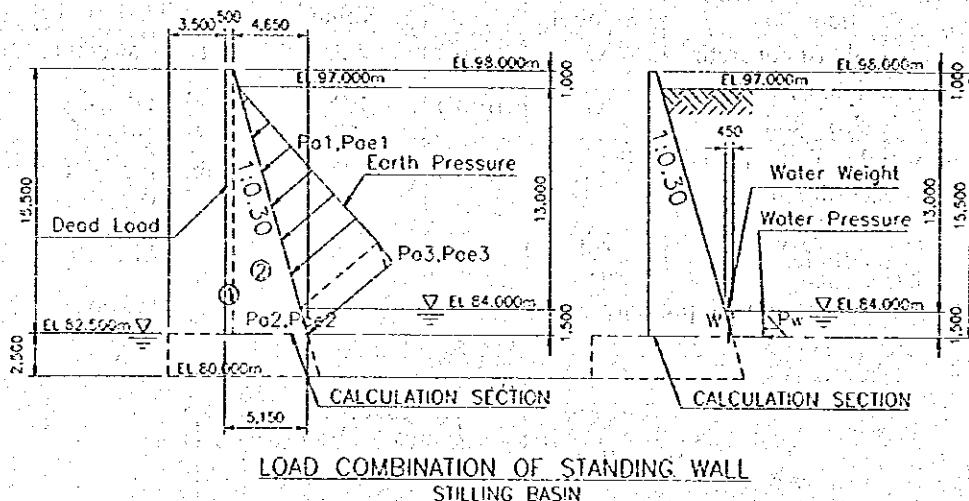
Kea : Coefficient of active earth pressure under seismic condition

Item	Symbol	Unit	Value	Description
Friction angle of soil to concrete	δ_e	(degree)	17.5	$\delta_e = 1/2 \phi$
Seismic composite angle	θ_0	(degree)	9.1	$\tan \theta_0 = K_h$

(b) Structural Calculation of EL.82.500m Section of Standing Wall, Stilling Basin

(i) Loading Calculation of EL.82.500m Section of Standing Wall, Stilling Basin

Structural model and load combinations are shown in the following figure.



Each load is calculated hereinafter.

Dead Load

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	7.75	19.38	-2.33	-45.05	-3.10	7.75	-24.03
2(concrete)	36.04	90.09	-0.53	-47.30	-14.42	5.17	-74.48
Total	43.79	109.47		-92.35	-17.52		-98.50

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.389$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	40.19	0.83	33.16	-47.84	5.83	-279.06
Pa2	-	9.27	2.35	21.79	-11.04	0.75	-8.28
Pa3	-	0.25	2.43	0.61	-0.30	0.50	-0.15
Total	-	49.72		55.56	-59.18		-287.49

Earth Pressure with Earthquake

Seismic composite angle : $\theta_0=9.1$ (degree) ($\tan\theta_0=Kh=0.16$)

Coefficient of active earth pressure : $K_{ae}=0.508$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	45.86	0.83	37.84	-67.49	5.83	-393.67
Pae2	-	10.58	2.35	24.87	-15.57	0.75	-11.68
Pae3	-	0.29	2.43	0.70	-0.43	0.50	-0.21
Total	-	56.74		63.41	-83.49		-405.56

Water Pressure

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	0.34	0.34	2.43	0.82	-1.13	0.50	-0.56
Total		0.34		0.82	-1.13		-0.56

(ii) Structural Calculation of EL.82.500m Section of Standing Wall, Stilling Basin

Case 1 : Nominal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	109.5	0.0	-92.3	0.0
Earth Pressure	49.7	-59.2	55.6	-287.5
Water Pressure	0.3	-1.1	0.8	-0.6
Total	159.52	-60.31	-35.96	-288.05

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -2.031 \text{ m} > 0.858 \text{ m} = b/6 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 10.43 \text{ (kgf/m}^2\text{)} < 60 \quad \text{OK}$$

$$\text{Tensile stress } \sigma_t = -4.23 \text{ (kgf/m}^2\text{)} > -3 \quad \boxed{\text{NG}}$$

Seismic condition (with Earthquake), Kh=0.16(100%)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	109.5	-17.5	-92.3	-98.5
Earth Pressure	56.7	-83.5	63.4	-405.6
Water Pressure	0.3	-1.1	0.8	-0.6
Total	166.54	-102.13	-28.12	-504.63

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -3.199 \text{ m} > 1.717 \text{ m} = b/3 \quad \text{NG}$$

Stress calculation of concrete

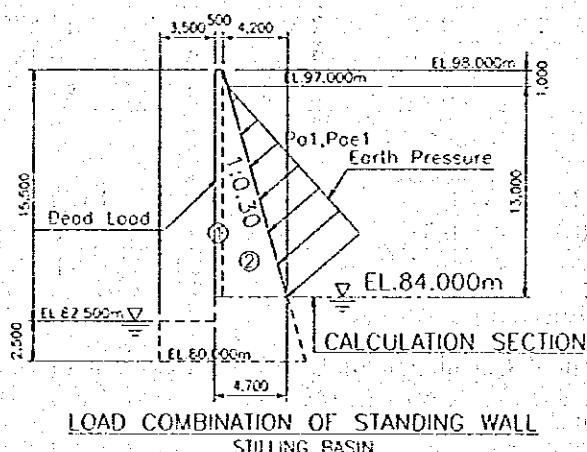
$$\text{Compressive stress } \sigma_c = 15.29 \text{ (kgf/m}^2\text{)} < 90 \quad \text{OK}$$

$$\text{Tensile stress } \sigma_t = -8.82 \text{ (kgf/m}^2\text{)} > -4.5 \quad \text{NG}$$

(c) Structural Calculation of EL.84.000m Section of Standing Wall, Stilling Basin

(i) Loading Calculation of EL.84.000m Section of Standing Wall, Stilling Basin

Structural model and load combinations are shown in the following figure.



Each load is calculated hereinafter.

Dead Load

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	7.00	17.50	-2.10	-36.75	-2.80	7.00	-19.60
2(concrete)	29.40	73.50	-0.45	-33.08	-11.76	4.67	-54.88
Total	36.40	91.00		-69.83	-14.56		-74.48

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.389$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
P _{a1}	-	40.19	1.05	42.20	-47.84	4.33	-207.30
Total	-	40.19		42.20	-47.84		-207.30

Earth Pressure with Earthquake

Seismic composite angle : $\theta_0=9.1(\text{degree})$ ($\tan\theta_0=Kh=0.16$)

Coefficient of active earth pressure : $K_{ae}=0.508$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
P _{ae1}	-	45.86	1.05	48.16	-67.49	4.33	-292.44
Total	-	45.86		48.16	-67.49		-292.44

(ii) Structural Calculation of EL.84.000m Section of Standing Wall, Stilling Basin

Case 1 : Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=-S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	91.0	0.0	-69.8	0.0
Earth Pressure	40.2	-47.8	42.2	-207.3
Total	131.19	-47.84	-27.63	-207.30

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -1.791 \text{ m} > 0.783 \text{ m} = b/6 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 9.17 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -3.59 \text{ (kgf/m}^2\text{)} > -3 \quad \boxed{\text{NG}}$$

Seismic condition (with Earthquake), Kh=0.16(100%)

Total Load	V(=N)(tf)	H(=-S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	91.0	-14.6	-69.8	-74.5
Earth Pressure	45.9	-67.5	48.2	-292.4
Total	136.86	-82.05	-21.67	-366.92

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -2.839 \text{ m} > 1.567 \text{ m} = b/3 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

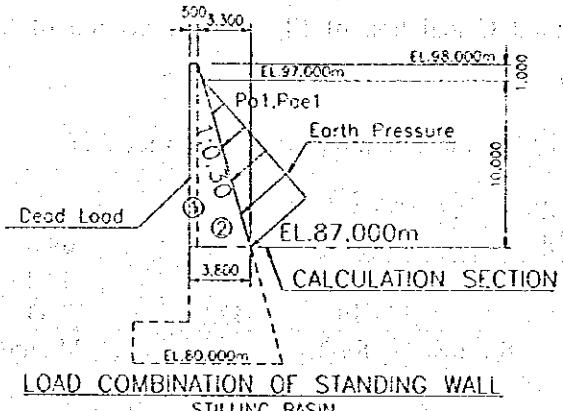
$$\text{Compressive stress } \sigma_c = 13.47 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -7.64 \text{ (kgf/m}^2\text{)} > -4.5 \quad \boxed{\text{NG}}$$

(d) Structural Calculation of EL.87.000m Section of Standing Wall, Stilling Basin

(i) Loading Calculation of EL.87.000m Section of Standing Wall, Stilling Basin

Structural model and load combinations are shown in the following figure.



Each load is calculated hereinafter.

Dead Load

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	5.50	13.75	-1.65	-22.69	-2.20	5.50	-12.10
2(concrete)	18.15	45.38	-0.30	-13.61	-7.26	3.67	-26.62
Total	23.65	59.13		-36.30	-9.46		-38.72

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.389$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
P _{a1}	-	23.78	0.90	21.40	-28.31	3.33	-94.36
Total	-	23.78		21.40	-28.31		-94.36

Earth Pressure with Earthquake

Seismic composite angle : $\theta_0=9.1$ (degree) ($\tan\theta_0=Kh=0.16$)

Coefficient of active earth pressure : $K_{ea}=0.508$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
P _{a1}	-	27.14	0.90	24.42	-39.93	3.33	-133.11
Total	-	27.14		24.42	-39.93		-133.11

(ii) Structural Calculation of EL.87.000m Section of Standing Wall, Stilling Basin

Case 1 : Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	59.1	0.0	-36.3	0.0
Earth Pressure	23.8	-28.3	21.4	-94.4
Total	82.90	-28.31	-14.90	-94.36

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -1.318 \text{ m} > 0.633 \text{ m} = b/6 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 6.72 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -2.36 \text{ (kgf/m}^2\text{)} > -3 \text{ OK}$$

Seismic condition (with Earthquake), Kh=0.16(100%)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	59.1	-9.5	-36.3	-38.7
Earth Pressure	27.1	-39.9	24.4	-133.1
Total	86.26	-49.39	-11.88	-171.83

Here; S : shearing forth, N : axial forth, M : moment

Safety against overturning

$$e = -2.130 \text{ m} > -1.267 \text{ m} = b/3 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

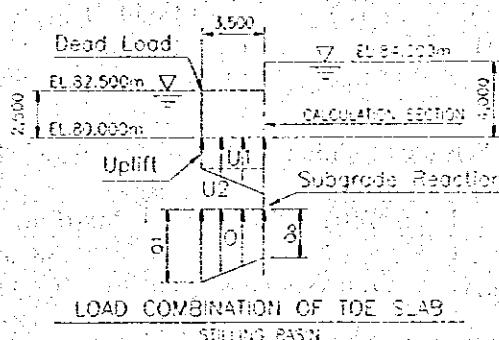
$$\text{Compressive stress } \sigma_c = 9.90 \text{ (kgf/m}^2\text{)} < 90 \quad \text{OK}$$

$$\text{Tensile stress } \sigma_t = -5.36 \text{ (kgf/m}^2\text{)} > -4.5 \quad \boxed{\text{NG}}$$

(e) Structural Calculation of Toe Slab, Stilling Basin

(i) Loading Calculation of Toe Slab, Stilling Basin

Structural model and load combinations are shown in the following figure.



Each load is calculated hereinafter.

Dead Load

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
I(concrete)	8.75	21.88	1.75	38.28	-	-	-
Total	8.75	21.88		38.28			

Subgrade Reaction without Earthquake

$$Q_1 = 37.129 \text{ (tf/m}^2\text{)}, \quad Q_0 = 25.676 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q		-109.91	1.86	-204.03	-	-	-
Total	-	-109.91		-204.03	-		-

Subgrade Reaction with Earthquake

$$Q_1 = 59.494 \text{ (tf/m}^2\text{)}, \quad Q_0 = 32.133 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-160.35	1.92	-308.54	-	-	-
Total	-	-160.35		-308.54	-	-	-

Uplift

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U1	-	-8.75	1.75	-15.31	-	-	-
U2	-	-0.98	1.17	-1.14	-	-	-
Total	-	-9.73		-16.45	-	-	-

(ii) Structural Calculation of Toe Slab, Stilling Basin

Case 1 : Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	21.88	0.00	38.28	0.00
Subgrade Reaction	-109.91	0.00	-204.03	0.00
Uplift	-9.73	0.00	-16.45	0.00
Total	-97.76	0.00	-182.20	0.00

Here; S : shearing forth, N : axial forth, M : moment

Stress calculation of concrete

Shear stress	$\tau_c = 3.91 \text{ (kgf/m}^2\text{)}$	<	5.5	OK
Compressive stress	$\sigma_c = 17.49 \text{ (kgf/m}^2\text{)}$	<	60	OK
Tensile stress	$\sigma_t = -17.49 \text{ (kgf/m}^2\text{)}$	>	-3	NG

Case 2 : Seismic condition (with Earthquake), Kh=0.16(100%)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	21.88	0.00	38.28	0.00
Subgrade Reaction	-160.35	0.00	-308.54	0.00
Uplift	-9.73	0.00	-16.45	0.00
Total	-148.20	0.00	-286.71	0.00

Here; S : shearing forth, N : axial forth, M : moment

Stress calculation of concrete

Shear stress	$\tau_c = 5.93 \text{ (kgf/m}^2\text{)}$	<	8.25	OK
Compressive stress	$\sigma_c = 27.52 \text{ (kgf/m}^2\text{)}$	<	90	OK
Tensile stress	$\sigma_t = -27.52 \text{ (kgf/m}^2\text{)}$	>	-4.5	NG

(i) Calculation of reinforcing bar arrangement, Stilling Basin

Results of calculation of reinforcement bar arrangement on each member are shown as follows.

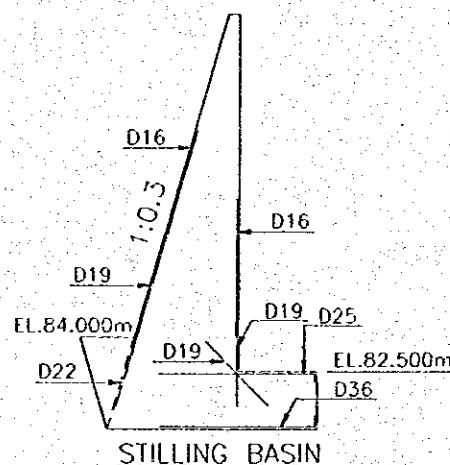
[Calculation of reinforcing bar Arrangement, Stilling Basin (1/2)]

Member		Standing Wall, EL.82.500m		Toe Slab	
Calculation condition		Normal	Seismic	Normal	Seismic
Shape of member		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	324.01	532.75	182.2	286.71
N	tf	159.52	166.54	0	0
S	tf	60.31	102.13	97.76	148.2
B	cm	100	100	100	100
D	cm	505	505	240	240
A _c	cm ²	50500	50500	24000	24000
A _s	cm ²	D22@200 =19.00	D22@200 =19.00	D36@200 =51.00	D36@200 =51.00
P=A _s /(B × D)		0.00038	0.00038	0.00213	0.00213
N=E _s /E _c		15	15	15	15
X ₀	cm	204.3	111	53.4	53.4
K=X ₀ /D		0.405	0.22	0.223	0.223
M/(B × D ²)	kgf/cm ²	1.271	2.089	3.163	4.978
S/(B × D)	kgf/cm ²	1.194	2.022	4.073	6.175
(C)		12.818	17.572	9.704	9.704
(S)		18.868	62.39	33.887	33.887
(Z)		2.509	1.666	1.08	1.08
σ _c	kgf/cm ²	16.3	36.7	30.7	48.3
σ _s	kgf/cm ²	360	1955	1608	2530
τ	kgf/cm ²	1.19	2.02	4.07	6.17
σ _{ca}	kgf/cm ²	60	90	60	90
σ _{sa}	kgf/cm ²	1,800	2,700	1,800	2,700
τ _a	kgf/cm ²	5.5	8.25	5.5	8.25

[Calculation of reinforcing bar Arrangement, Stilling Basin (2/2)]

Member		Standing Wall, EL.84.000m		Standing Wall, EL.87.000m	
Calculation condition		Normal	Seismic	Normal	Seismic
Shape of member		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	234.93	388.59	109.26	183.71
N	tf	131.19	136.86	82.9	86.26
S	tf	47.84	82.05	28.31	49.39
B	cm	100	100	100	100
D	cm	460	460	370	370
A _c	cm ²	46000	46000	37000	37000
A _s	cm ²	D19@200 =14.20	D19@200 =14.20	D16@200 =10.05	D16@200 =10.05
P=As/(B × D)		0.00031	0.00031	0.00027	0.00027
N=Es/Ec		15	15	15	15
X ₀	cm	191.2	96.2	177.2	79.9
K=X ₀ /D		0.416	0.209	0.479	0.216
M/(B × D ²)	kgf/cm ²	1.11	1.836	0.798	1.342
S/(B × D)	kgf/cm ²	1.04	1.784	0.765	1.335
(C)		12.759	18.602	11.945	18.658
(S)		17.936	70.323	12.996	67.791
(Z)		2.645	1.748	2.626	1.922
σ _c	kgf/cm ²	14.2	34.2	9.5	25
σ _s	kgf/cm ²	299	1937	156	1365
τ	kgf/cm ²	1.04	1.78	0.77	1.33
σ _{ca}	kgf/cm ²	60	90	60	90
σ _{sa}	kgf/cm ²	1,800	2,700	1,800	2,700
τ _a	kgf/cm ²	5.5	8.25	5.5	8.25

Figure of main reinforcing bar arrangement is shown as follows.



2.5 Diversion Tunnel

2.5.1 Structural Calculation of Upstream Portal Facility

Inlet structure of diversion tunnel consists of U shape channel and box culvert.

In structural calculation, each structure that is estimated at independent is calculated.

(1) General Condition

Basic Condition

Seismic Coefficient $k = 0.16$

Rock Foundation

Elastic Modulus = $9,000 \text{ kgf/cm}^2$

Poisson's Ratio = 0.3

Reinforced Concrete

Elastic Modulus = $210,000 \text{ kgf/cm}^2$

Poisson's Ratio = 0.2

Unit Weight = 2.50 tf/m^3

Weight of water

$W = 1.00 \text{ tf/m}^3$

Allowable compressive strength of concrete is 175 kgf/cm^2 .

Allowable tension strength of reinforcing bar is $1,800 \text{ kgf/cm}^2$ at Normal case.

Minimum diameter of main reinforcing bar is D16 mm above.

Required additional rate

Case	Rate
Normal	1.0
Seismic	1.5

Cases to be Studied

(a) Section Type A (section of U shape channel)

Case 1 - No water pressure with earthquake

Case 2 - Water Surface EL. 103.000 m with earthquake

Case 3 - Water Surface EL. 113.000 m without earthquake

(b) Section Type B (section of box culvert)

Case 1 - Water Surface EL. 136.000 m without earthquake

(2) U shape channel

Standard cross section is shown as follows.

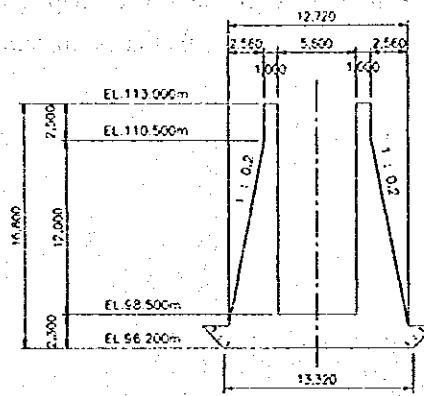
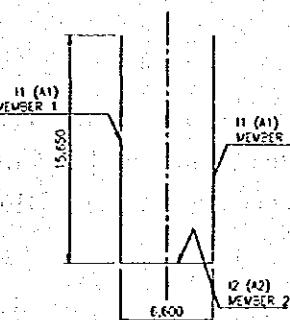


Figure of frame dimension is shown as follows.



Geometrical moment of inertia

Member	Calculation	Geometrical Moment of inertia (m^4)
1	$y_1 = \frac{3.40 + 2 \times 1.00}{3.40 + 1.00} \times \frac{12.00}{3} = 4.909 m$ $Y = 12.00 - y_1 = 7.091 m$ $H = Y \times 0.20 + 1.00 = 2.418 m$ $I_1 = \frac{(1.00 \times H^3)}{12}$	1.178115
2	$\frac{1}{12} \times 1.00 \times 2.30^3$	1.013917

Section area

Member	Calculation	Area (m^2)
1	$\frac{1}{2} \times (1.00 + 3.40) \times 12.00 + 1.00 \times 2.50$	28.900
2	$\frac{1}{2} \times (12.40 + 13.32) \times 2.30$	29.578

Case-1

Load calculation

1) **Weight of wall**

$$A1 = 1/2 \times (1.00 + 3.40) \times 12.00 = 26.400 \text{ m}^2$$

$$A2 = 1.00 \times 2.50 = 2.500 \text{ m}^2$$

$$N = (A1+A2) \times 2.50 \text{ tf/m}^3 = 72.250 \text{ tf/m}$$

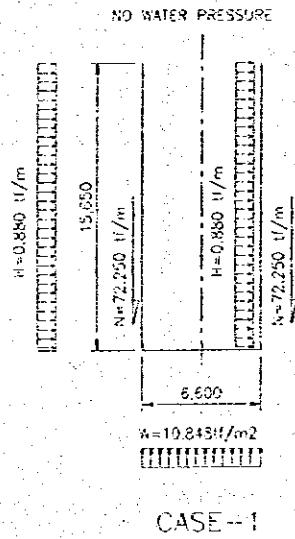
2) **Weight of wall in seismic case**

$$H = 1/2 \times (1.00 + 3.40) \times 1.00 \times 2.50 \text{ tf/m}^3 \times 0.16 = 0.880 \text{ tf/m}$$

3) **Subgrade reaction**

$$W = 2 \times N/B_0 = 2 \times 72.250 / 13.320 = 10.848 \text{ tf/m}^2$$

Figure of acting load is shown as follows.



Case-2

Load calculation

1) **Weight of wall**

$$N = 72.250 \text{ tf/m}$$

2) **Weight of wall in seismic case**

$$H = 0.880 \text{ tf/m}$$

3) **Weight of water**

$$W_1 = (EL+103.00 \text{ m} - EL+98.50 \text{ m}) \times 1.00 \text{ tf/m}^3 = 4.50 \text{ tf/m}^2$$

4) **Hydrodynamic force due to earthquake**

$$P_d = \frac{7}{12} K \times W \times B \times H^2 , \quad h_g = 2/5 H$$

Where,

- Pd: Hydrodynamic force caused by earthquake (tf)
- K: Coefficient of horizontal earthquake factor
- W: Unit weight of water (tf/m³)
- B: Width of wall structure (m)
- H: Water depth (m)
- hg: Hydrodynamic force acting depth from the bottom (m)

$$P_d = \frac{7}{12} \times 0.16 \times 1.00 \times 1.00 \times 5.65^2 = 2.979 \text{ tf/m}$$

$$h_g = 2/5 \times 5.65 = 2.260 \text{ m}$$

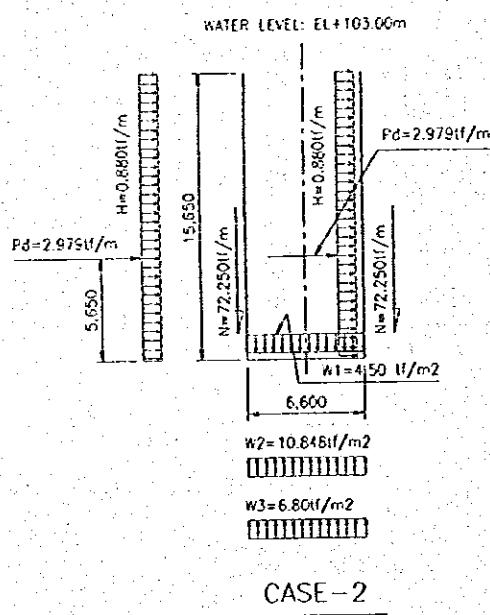
5) Subgrade reaction

$$W_2 = 10.848 \text{ tf/m}^2$$

6) Uplift

$$W_3 = (EL+103.00 \text{ m} - EL+96.20 \text{ m}) \times 1.00 \text{ tf/m}^3 = 6.80 \text{ tf/m}^2$$

Figure of acting load is shown as follows.



Case-3

Load calculation

1) Weight of wall

$$N = 72.250 \text{ tf/m}$$

2) Weight of water

$$W_1 = (EL+113.00 \text{ m} - EL+98.50 \text{ m}) \times 1.00 \text{ tf/m}^3 = 14.50 \text{ tf/m}^2$$

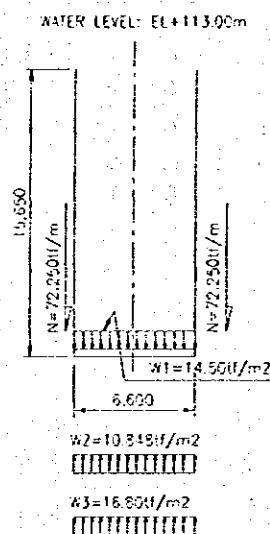
3) Subgrade reaction

$$W_2 = 10.848 \text{ tf/m}^2$$

4) Uplift

$$W_3 = (EL+113.00 \text{ m} - EL+96.20 \text{ m}) \times 1.00 \text{ t/m}^3 = 16.80 \text{ t/m}^2$$

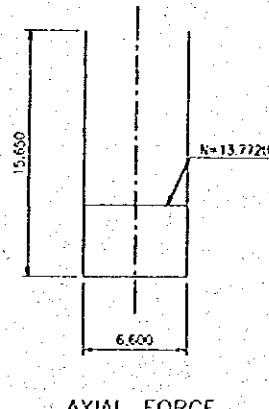
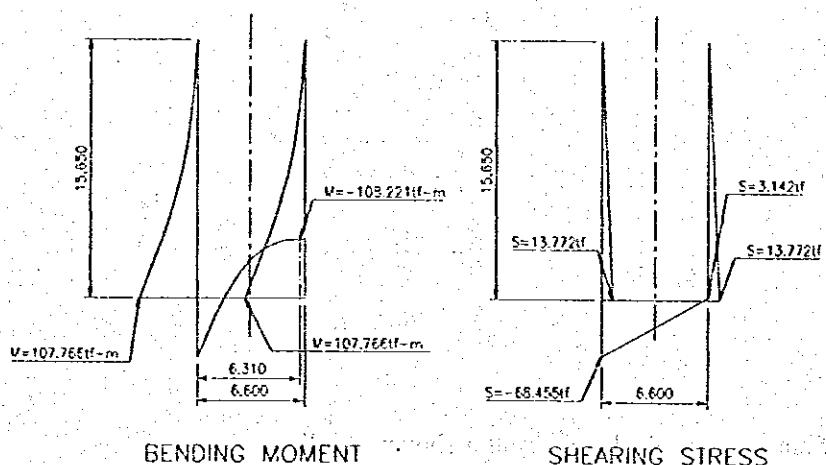
Figure of acting load is shown as follows.



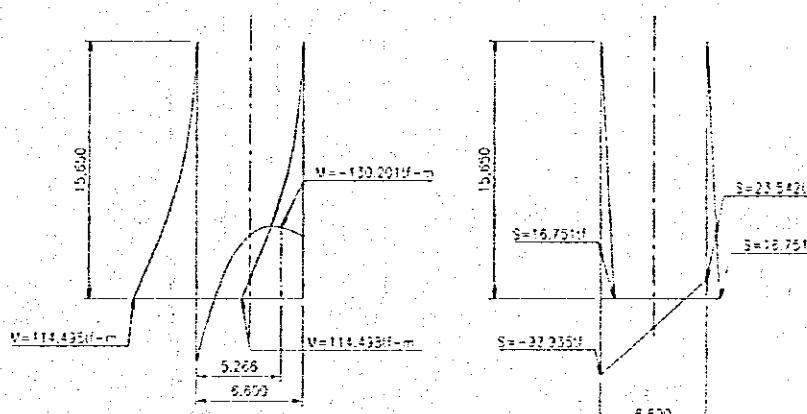
CASE-3

Summary of calculation result is shown as follows.

	Member	Condition	Distance (m)	Bending moment M (tf-m)	Shearing stress S (tf)	Axial Force N (tf)
Case-1	M1	Maximum	15.650	107.766	13.772	0.000
		Minimum	0.000	0.000	0.000	0.000
	M2	Maximum	0.000	107.766	-68.455	13.772
		Minimum	6.310	-108.221	0.000	13.772
	M3	Maximum	15.650	107.766	13.772	0.000
		Minimum	0.000	0.000	0.000	0.000

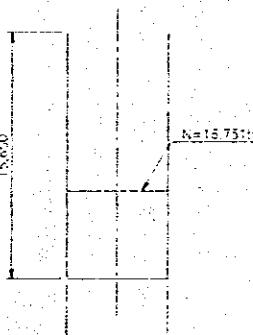


	Member	Condition	Distance (m)	Bending moment M (tf-m)	Shearing stress S (tf)	Axial Force N (tf)
Case-2	M1	Maximum	15.650	114.498	16.751	0.000
		Minimum	0.000	0.000	0.000	0.000
	M2	Maximum	0.000	114.498	-92.935	16.751
		Minimum	5.266	-130.201	0.000	16.751
	M3	Maximum	15.650	114.498	16.751	0.000
		Minimum	0.000	0.000	0.000	0.000



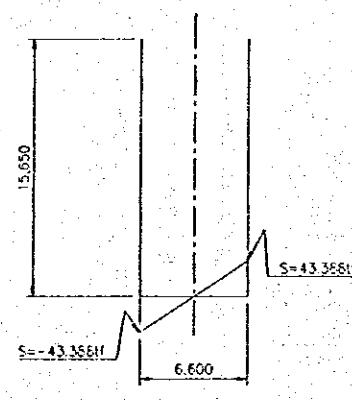
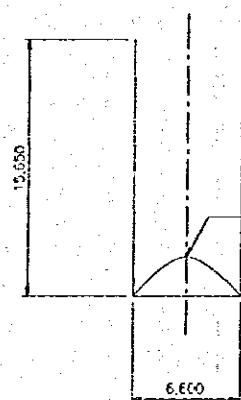
BENDING MOMENT

SHEARING STRESS



AXIAL FORCE

	Member	Condition	Distance (m)	Bending moment M (tf-m)	Shearing stress S (tf)	Axial Force N (tf)
Case-3	M1	Maximum	0.000	0.000	0.000	0.000
		Minimum	15.650	0.000	0.000	0.000
	M2	Maximum	0.000	0.000	-43.388	0.000
		Minimum	3.300	-71.591	0.000	0.000
	M3	Maximum	0.000	0.000	0.000	0.000
		Minimum	15.650	0.000	0.000	0.000



Results of Strength calculation on each member are shown as follows.

[Case-1]

	Member of shape	Wall Section		Slab Section	
		Bottom side	Middle side	Top side	Bottom side
M	tf-m	107.766	26.942	-108.221	107.766
N	tf	0.000	0.000	13.772	13.772
S	tf	13.772	6.886	0.000	68.455
B	cm	100.0	100.0	100.0	100.0
D	cm	330.0	196.5	220.0	220.0
A _c	cm ²	33000	19650	22000	22000
A _s	cm ²	D19@200 =14.20	D16@200 =10.05	D25@200 =24.55	D22@200 =19.00
P=A _s (B×D)		0.00043	0.00051	0.00112	0.00086
N=E _s /E _c		15	15	15	15
X ₀	cm	35.4	22.9	41.3	36.9
K=X ₀ /D		0.107	0.116	0.188	0.168
M/(B×D ²)	kgf/cm ²	0.990	0.698	2.236	2.227
S/(B×D)	kgf/cm ²	0.417	0.350	0.000	3.112
(C)		19.323	17.871	12.943	14.412
(S)		160.679	135.611	55.930	71.553
(Z)		1.037	1.040	1.071	1.066
σ _c	kgf/cm ²	19.10	12.50	28.90	32.10
σ _s	kgf/cm ²	2385.00	1419.00	1876.00	2390.00
τ	kgf/cm ²	0.42	0.35	0.00	3.11
σ _{ca}	kgf/cm ²	90.00	90.00	90.00	90.00
σ _{sa}	kgf/cm ²	2700.00	2700.00	2700.00	2700.00
τ _a	kgf/cm ²	8.25	8.25	8.25	8.25

[Case-2]

Member of shape		Wall Section		Slab Section	
		Bottom side	Middle side	Top side	Bottom side
M	tf-m	114.498	26.942	-130.201	114.498
N	tf	0.000	0.000	16.751	16.751
S	tf	16.751	6.886	0.000	92.935
B	cm	100.0	100.0	100.0	100.0
D	cm	330.0	196.5	220.0	220.0
Ac	cm ²	33000	19650	22000	22000
As	cm ²	D19@200 =14.20	D16@200 =10.05	D25@200 =24.55	D22@200 =19.00
P=As/(B×D)		0.00043	0.00051	0.00112	0.00086
N=Es/Ec		15	15	15	15
X0	cm	35.4	22.9	41.4	37.5
K=X0/D		0.107	0.116	0.188	0.171
M/(B×D ²)	kgf/cm ²	1.051	0.698	2.690	2.366
S/(B×D)	kgf/cm ²	0.508	0.350	0.000	4.224
(C)		19.323	17.871	12.945	14.432
(S)		160.679	135.611	55.851	70.173
(Z)		1.037	1.040	1.072	1.070
σ_c	kgf/cm ²	20.30	12.50	34.80	34.10
σ_s	kgf/cm ²	2534.00	1419.00	2254.00	2490.00
τ	kgf/cm ²	0.51	0.35	0.00	4.22
σ_{ca}	kgf/cm ²	90.00	90.00	90.00	90.00
σ_{sa}	kgf/cm ²	2700.00	2700.00	2700.00	2700.00
τ_a	kgf/cm ²	8.25	8.25	8.25	8.25

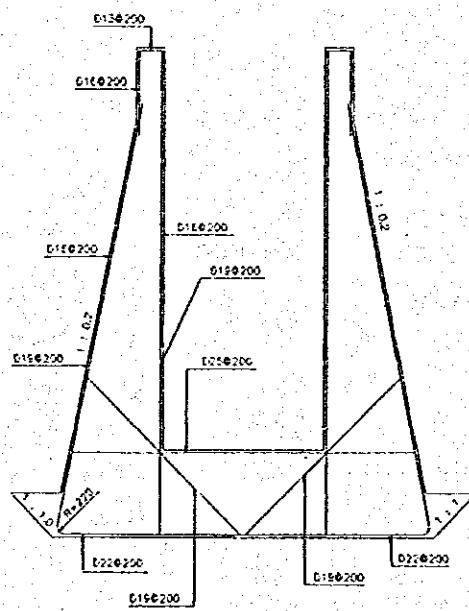
[Case-3]

Member of shape	Wall Section		Slab Section	
	Bottom side	Middle side	Top side	Bottom side
Rectangle	Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m		-71.591	
N	tf		0.000	
S	tf		0.000	
B	cm		100.0	
D	cm		220.0	
Ac	cm ²		22000	
As	cm ²		D25@200 =24.55	
P=As/(B×D)			0.00112	
N=Es/Ec			15	
X0	cm		36.7	
K=X0/D			0.167	
M/(B×D ²)	kgf/cm ²		1.479	
S/(B×D)	kgf/cm ²		0.000	
(C)			12.683	
(S)			63.263	
(Z)			1.059	
σ c	kgf/cm ²		18.80	
σ s	kgf/cm ²		1404.00	
τ	kgf/cm ²		0.00	
σ ca	kgf/cm ²		60.00	
σ sa	kgf/cm ²		2700.00	
τ a	kgf/cm ²		8.25	

[Case-2]: Blockout Section

Member of shape	Wall Section		Slab Section		
	Bottom side	Middle side	Top side	Bottom side	
M	(f-m)	114.498	26.942	-130.201	114.498
N	tf	0.000	0.000	16.751	16.751
S	tf	16.751	6.886	0.000	92.935
B	cm	100.0	100.0	100.0	100.0
D	cm	270.0	136.5	180.0	180.0
A _c	cm ²	27000	13650	18000	18000
A _s	cm ²	D22@200 =19.00	D16@200 =10.05	D29@200 =33.05	D25@200 =24.55
P=A _s /(B×D)		0.0007	0.00074	0.00184	0.00136
N=E _s /E _c		15	15	15	15
X ₀	cm	36.5	18.8	41.3	36.7
K=X ₀ /D		0.135	0.138	0.229	0.204
M/(B×D ²)	kgf/cm ²	1.571	1.446	4.019	3.534
S/(B×D)	kgf/cm ²	0.620	0.504	0.000	5.163
(C)		15.499	15.193	10.542	11.907
(S)		99.205	94.913	35.456	46.478
(Z)		1.047	1.048	1.083	1.075
σ _c	kgf/cm ²	24.30	22.00	42.40	42.10
σ _s	kgf/cm ²	2337.00	2059.00	2137.00	2464.00
τ	kgf/cm ²	0.62	0.50	0.00	5.16
σ _{ca}	kgf/cm ²	90.00	90.00	90.00	90.00
Σsa	kgf/cm ²	2700.00	2700.00	2700.00	2700.00
T _a	kgf/cm ²	8.25	8.25	8.25	8.25

Figure of main reinforcing bar is shown as follows.



(3) Box culvert

Standard cross section is shown as follows.

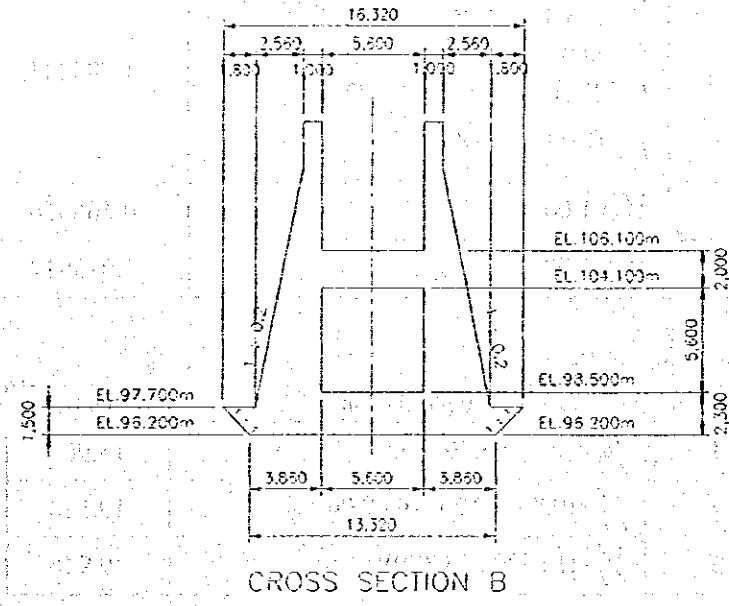
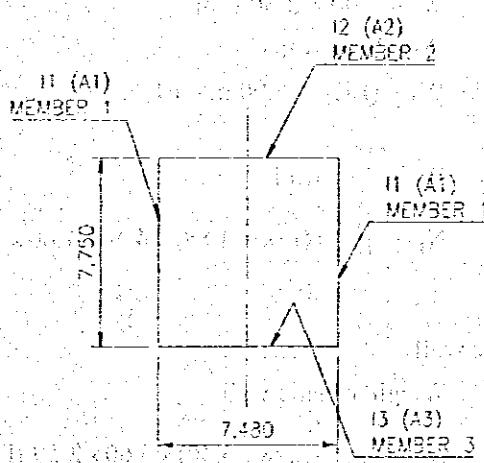


Figure of frame dimension is shown as follows.



Geometrical moment of inertia

Member	Calculation	Geometrical Moment of inertia (m^4)
1	$y_1 = \frac{3.40 + 2 \times 2.28}{3.40 + 2.28} \times \frac{5.60}{3} = 2.616 m$ $Y = 5.60 - y_1 = 2.984 m$ $H = Y \times 0.20 + 2.28 = 2.877 m$ $I_1 = \frac{(1.00 \times H^3)}{12}$	1.984444
2	$\frac{1}{12} \times 1.00 \times 2.00^3$	0.666666
3	$\frac{1}{12} \times 1.00 \times 2.30^3$	1.013917

Section area

Member	Calculation	Area (m^2)
1	$\frac{1}{2} \times (2.28 + 3.40) \times 5.60$	15.904
2	$\frac{1}{2} \times (9.360 + 10.160) \times 2.00$	19.520
3	$\frac{1}{2} \times (12.720 + 13.320) \times 2.30$	29.946

Case-1

Load calculation

1) Top slab

a) Weight of top slab

$$W_1 = 2.00 \times 2.50 \text{ tf/m}^3 = 5.00 \text{ tf/m}^2$$

b) Weight of water

$$W_2 = (EL+136.00 \text{ m} - EL+106.10 \text{ m}) \times 1.00 \text{ tf/m}^3 = 29.90 \text{ tf/m}^2$$

c) Weight of wall

$$N_1 = \left\{ \frac{1}{2} \times (1.00 + 1.88) \times 4.40 + 1.00 \times 2.50 \right\} \times 2.50 \text{ tf/m}^3 = 22.09 \text{ tf/m}^2$$

2) Side wall

a) Weight of side wall

$$N_2 = \frac{1}{2} \times (2.28 + 3.40) \times 5.60 \times 2.50 \text{ tf/m}^3 = 39.76 \text{ tf/m}^2$$

b) Water pressure

$$H_1 = (EL+136.00 \text{ m} - EL+105.10 \text{ m}) \times 1.00 \text{ tf/m}^3 = 30.90 \text{ tf/m}^2$$

$$H_2 = (EL+136.00 \text{ m} - EL+97.35 \text{ m}) \times 1.00 \text{ tf/m}^3 = 39.76 \text{ tf/m}^2$$

3) Bottom slab

a) Subgrade reaction

$$W_1 = 5.00 \text{ tf/m}^2$$

$$W_2 = 30.00 \text{ tf/m}^2$$

$$P_1 = 2 \times N_1 / B_0 = 2 \times 22.09 / 13.32 = 3.317 \text{ tf/m}^2$$

$$P_2 = 2 \times N_2 / B_0 = 2 \times 39.76 / 13.32 = 5.970 \text{ tf/m}^2$$

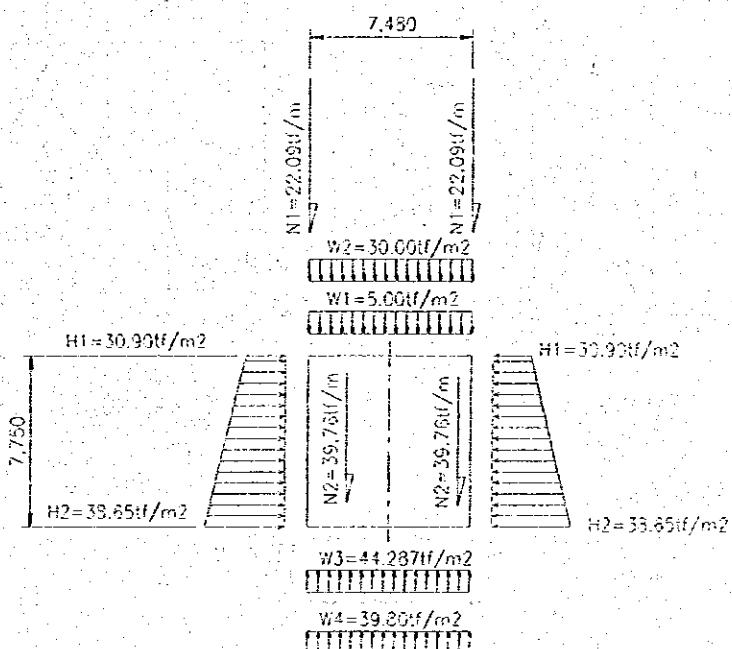
$$W_3 = W_1 + W_2 + P_1 + P_2 = 44.287 \text{ tf/m}^2$$

b) Uplift

$$W_4 = (EL+136.00 \text{ m} - EL+96.20 \text{ m}) \times 1.00 \text{ tf/m}^3$$

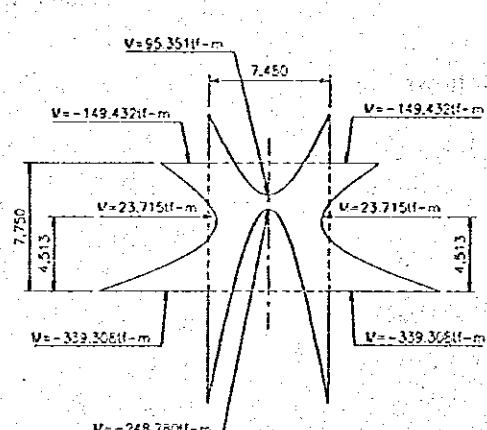
$$= 39.80 \text{ tf/m}^2$$

Figure of acting load is shown as follows.

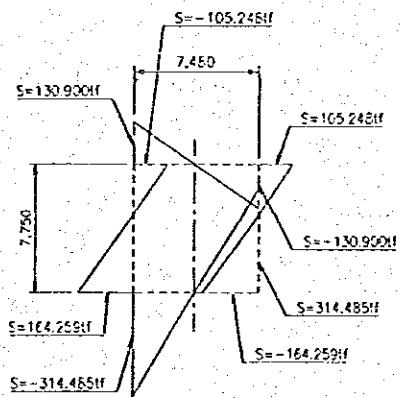


Summary of calculation result is shown as follows.

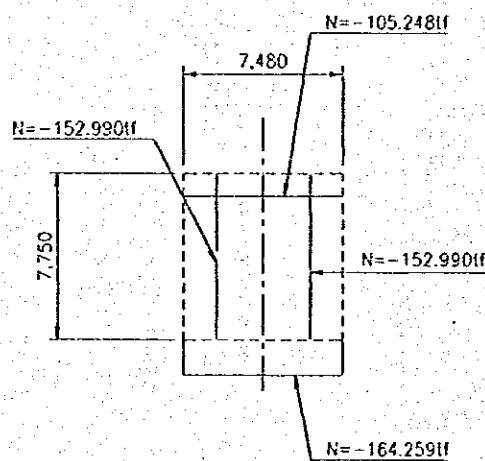
	Member	Condition	Distance (m)	Bending moment M (tf-m)	Shearing stress S (tf)	Axial Force N (tf)
Case-1	M1	Maximum	4.513	23.715	0.000	-152.990
		Minimum	0.000	-339.308	164.258	-152.990
M2	Maximum	3.740	95.351	0.000	-105.248	
		Minimum	7.480	-149.432	-130.900	-105.248
M3	Maximum	0.000	339.308	-314.485	-164.258	
		Minimum	3.740	-248.780	0.000	-164.258



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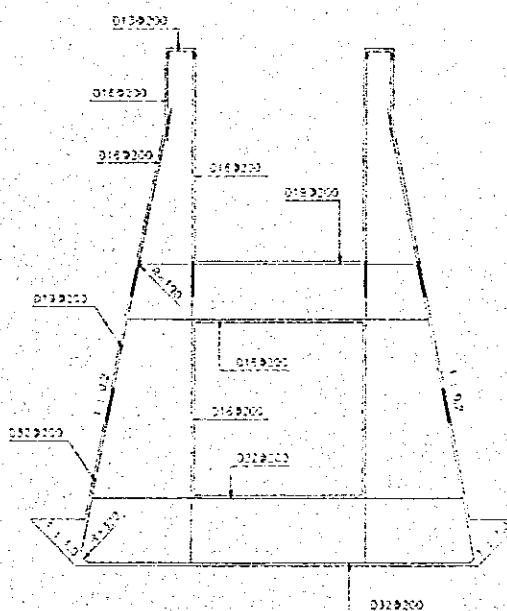


AXIAL FORCE

Results of Strength calculation on each member are shown as follows.

[Case-1]		Top Section		Side Section		Bottom Section	
		Outside	Inside	Outside	Inside	Outside	Inside
Member of shape		Rectangle	Rectangle	Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	-339.308	23.715	-149.432	95.351	339.308	-248.780
N	tf	152.990	0.000	105.248	105.248	164.258	164.258
S	tf	164.258	0.000	130.900	0.000	314.485	0.000
B	cm	100.0	100.0	100.0	100.0	100.0	100.0
D	cm	330.0	269.9	190.0	190.0	220.0	220.0
A _c	cm ²	33000	26990	19000	19000	22000	22000
A _s	cm ²	D22@200 =19.00	D16@200 =10.05	D19@200 =14.20	D16@200 =10.05	D32@200 =40.20	D22@200 =19.00
P=A _s (B×D)		0.00058	0.00037	0.00075	0.00053	0.00183	0.00086
N=E _s /E _c		15	15	15	15	15	15
X ₀	cm	81	27.1	47.8	64.3	69.3	61.7
K=X ₀ /D		0.245	0.100	0.251	0.338	0.315	0.280
M/(B×D ²)	kgf/cm ²	3.116	0.326	4.139	2.641	7.010	5.140
S/(B×D)	kgf/cm ²	4.978	0.000	6.889	0.000	14.295	0.000
(C)		15.484	20.639	14.490	13.649	10.868	13.584
(S)		47.630	185.228	43.137	26.694	23.619	34.867
(Z)		1.518	1.035	1.393	2.062	1.233	1.440
σ_c	kgf/cm ²	48.20	6.70	60.00	36.10	76.20	69.80
σ_s	kgf/cm ²	2226.00	905.00	2678.00	1058.00	2484.00	2688.00
τ	kgf/cm ²	4.98	0.00	6.89	0.00	14.29	0.00
σ_{ca}	kgf/cm ²	90.00	90.00	90.00	90.00	90.00	90.00
σ_{sa}	kgf/cm ²	2700.00	2700.00	2700.00	2700.00	2700.00	2700.00
τ_a	kgf/cm ²	8.25	8.25	8.25	8.25	8.25	8.25

Figure of main reinforcing bar is shown as follows.



2.6 Intake Structure

2.6.1 Structural Calculation of Inclined Intake Structure

Inclined intake structure consists of box culvert type channel, U shape type channel and operation deck.

In structural calculation, each structure that is estimated at independent is calculated.

(1) General Condition

Basic Condition

- (i) Allowable compressive strength of concrete is 225 kgf/cm^2
- (ii) Allowable tension strength of reinforcing bar is $1,800 \text{ kgf/m}^2$ at Normal case.
- (iii) Minimum diameter of main reinforcing bar is D16 mm above.
- (iv) Weight of water is 1.00 tf/m^3 .
- (v) Weight of concrete with reinforcing bar is 2.50 tf/m^3 .
- (vi) Live load is 0.30 tf/m^2 .
- (vii) Required additional rate

Case	Rate
Normal	1.0
Seismic	1.5

Cases to be Studied

- (i) Box culvert type channel

Water Surface EL+130.00 m without earthquake in box culvert vacantly

- (ii) U shape type channel

No water pressure with earthquake

- (iii) Operation deck

Case - 1 Normal case with hoisting load

Case - 2 Seismic case without hoisting load

(2) Box culvert type channel

Standard cross section is shown as follows.

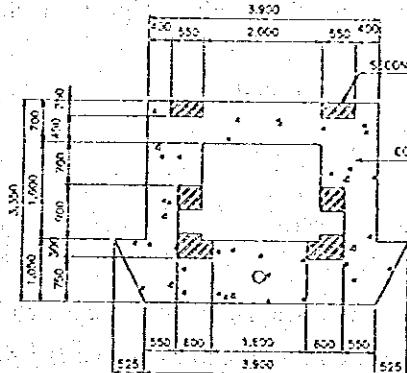
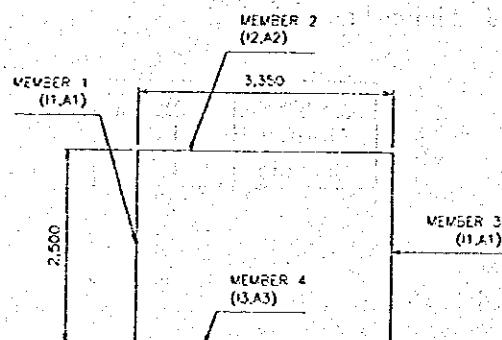


Figure of frame dimension is shown as follows.



Geometrical moment of inertia

Member	Calculation	Geometrical Moment of inertia (m^4)
1	$\frac{1}{12} \times 1.00 \times 0.55^3$	0.03865
2	$\frac{1}{12} \times 1.00 \times 0.45^3$	0.007594
3	$\frac{1}{12} \times 1.00 \times 0.75^3$	0.035156

Section area

Member	Calculation	Area (m^2)
1	1.00×0.55	0.550
2	1.00×0.45	0.450
3	1.00×0.75	0.750

Load calculation

(i) Top slab

a) Weight of top slab
 $W_1 = 0.70 \times 2.50 \text{ tf/m}^3 = 1.75 \text{ tf/m}^2$

b) Weight of water
 $W_2 = (EL+130.00 - EL+115.00) \times 1.00 \text{ tf/m}^3 = 15.00 \text{ tf/m}^2$

(ii) Side wall

a) Weight of side wall
 $N_1 = 0.95 \times 1.60 \times 2.50 \text{ tf/m}^3 = 3.80 \text{ tf/m}$

b) Hydrostatic pressure
 $P_1 = (EL+130.00 - EL+114.525) \times 1.00 \text{ tf/m}^3 = 15.48 \text{ tf/m}^2$
 $P_2 = (EL+130.00 - EL+112.025) \times 1.00 \text{ tf/m}^3 = 17.98 \text{ tf/m}^2$

(iii) Bottom slab

a) Subgrade reaction

$W_1 = 1.75 \text{ tf/m}^2$

$W_2 = 15.00 \text{ tf/m}^2$

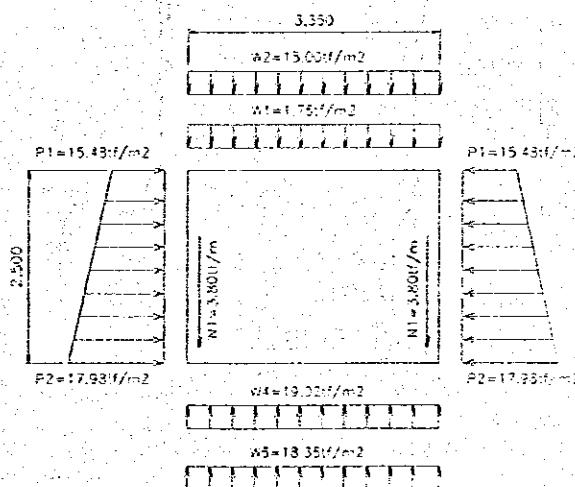
$W_3 = 2 \times N_1 / B_0 = 2 \times 3.80 / 3.35 = 2.27 \text{ tf/m}^2$

$W_4 = W_1 + W_2 + W_3 = 19.02 \text{ tf/m}^2$

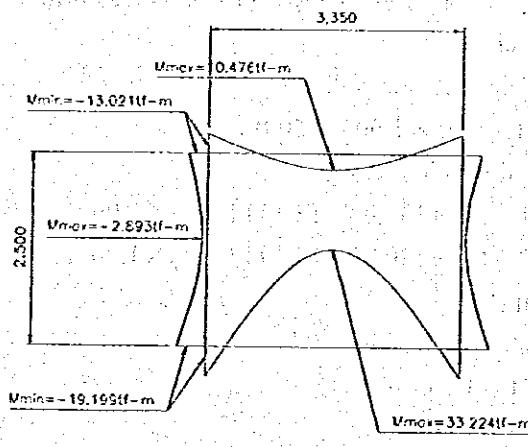
b) Uplift

$W_5 = (EL+130.00 - EL+111.65) \times 1.00 \text{ tf/m}^3 = 18.35 \text{ tf/m}^2$

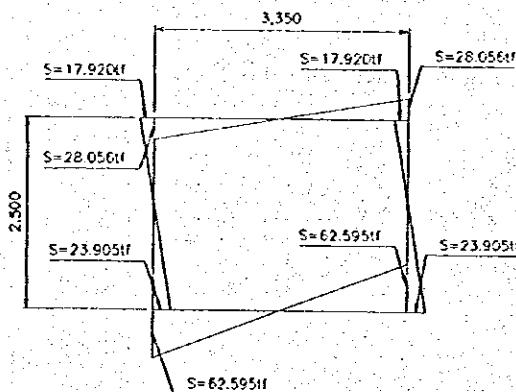
Figure of acting load is shown as follows.



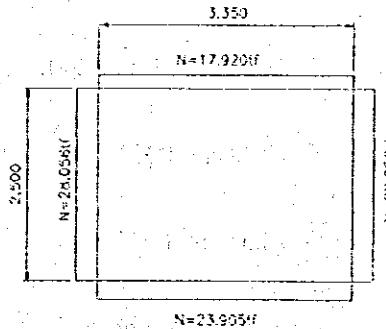
Member	Condition	Distance (m)	Bending moment M (tf-m)	Shearing stress S (tf)	Axial Force N (tf)
M1	Maximum	1.383	-2.893	0.000	28.056
	Minimum	0.000	-19.199	23.905	28.056
M2	Maximum	1.675	10.476	0.000	17.920
	Minimum	3.350	-13.021	28.056	17.920
M3	Maximum	1.117	-2.893	0.000	28.056
	Minimum	2.500	-19.199	-23.905	28.056
M4	Maximum	1.675	33.224	0.000	23.905
	Minimum	3.350	-19.199	62.595	23.905



BENDING MOMENT



SHEARING STRESS



AXIAL FORCE

Results of Strength calculation on each member are shown as follows.

Member of shape	Top slab		Side wall		Bottom slab	
	Inside	Outside	Inside	Outside	Inside	Outside
Rectangle	Rectangle	Rectangle	Rectangle	Rectangle	Rectangle	Rectangle
M tf-m	10.476	-13.021		-19.199	33.224	-19.199
N tf	17.920	17.920		28.056	23.905	23.905
S tf	0.000	28.056		23.905	0.000	62.595
B cm	100.0	100.0		100.0	100.0	100.0
D cm	35.0	35.0		45.0	65.0	65.0
A _c cm ²	3500	3500		4500	6500	6500
A _s cm ²	10.70	14.30		14.97	19.30	8.93
P=A _s (B×D)	0.00306	0.00408		0.00333	0.00297	0.00137
N=E _s /E _c	15	15		15	15	15
X ₀ cm	11.4	12.2		15.4	19.9	16.6
K=X ₀ /D	0.324	0.349		0.342	0.306	0.255
M/(B×D ²) kgf/cm ²	8.552	10.629		9.481	7.864	4.544
S/(B×D) kgf/cm ²	0.000	8.016		5.312	0.000	9.630
(C)	8.983	8.055		8.771	8.977	12.045
(S)	18.709	15.053		16.876	20.347	35.210
(Z)	1.139	1.134		1.150	1.121	1.168
σ _c kgf/cm ²	76.80	85.60		83.20	70.60	54.70
σ _s kgf/cm ²	2400.00	2400.00		2400.00	2400.00	2400.00
τ kgf/cm ²	0.00	8.02		5.31	0.00	9.63
σ _{ca} kgf/cm ²	112.50	112.50		112.50	112.50	112.50
σ _{sa} kgf/cm ²	2400.00	2400.00		2400.00	2400.00	2400.00
τ _a kgf/cm ²	9.75	9.75		9.75	9.75	9.75

Area of reinforcement

(i) Inside of top slab

$As = 10.70 \text{ cm}^2 \leq 14.20 \text{ cm}^2 (\text{D19@200}) \dots \text{O.K}$

(ii) Out side of top slab

$As = 14.30 \text{ cm}^2 \leq 19.00 \text{ cm}^2 (\text{D22@200}) \dots \text{O.K}$

(iii) Outside of side wall

$As = 14.97 \text{ cm}^2 \leq 19.00 \text{ cm}^2 (\text{D22@200}) \dots \text{O.K}$

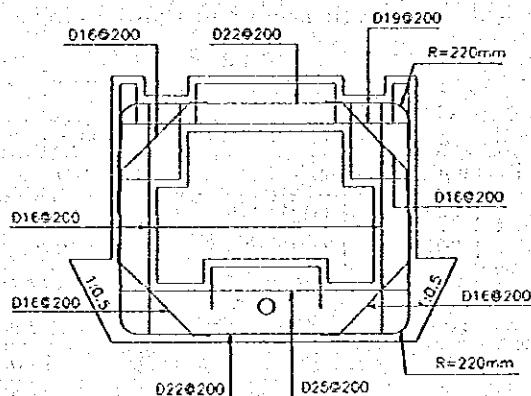
(iv) Inside of bottom slab

$As = 19.30 \text{ cm}^2 \leq 24.55 \text{ cm}^2 (\text{D25@200}) \dots \text{O.K}$

(v) Outside of bottom slab

$As = 8.93 \text{ cm}^2 \leq 19.00 \text{ cm}^2 (\text{D22@200}) \dots \text{O.K}$

Figure of main reinforcing bar is shown as follows.



(3) U shape type channel

Standard cross section is shown as follows.

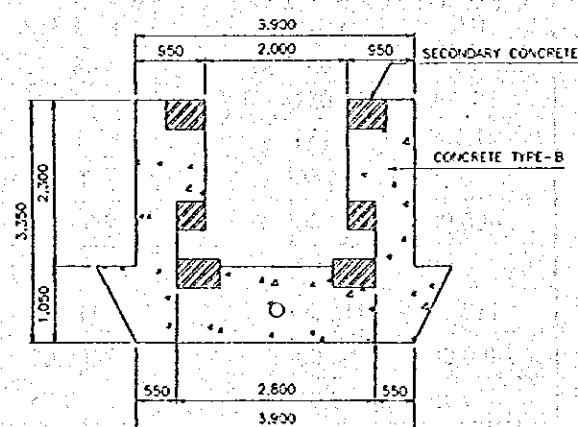
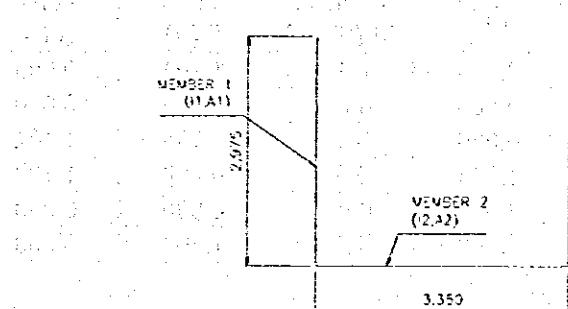


Figure of frame dimension is shown as follows.



Geometrical moment of inertia

Member	Calculation	Geometrical Moment of inertia (m ⁴)
1	$\frac{1}{12} \times 1.00 \times 0.55^3$	0.03865
2	$\frac{1}{12} \times 1.00 \times 0.75^3$	0.03516

Section area

Member	Calculation	Area (m ²)
1	1.00×0.55	0.550
2	1.00×0.75	0.750

Load calculation

(i) Side wall

a) Weight of side wall

$$N1 = 2.60 \times 0.95 \times 2.50 \text{ t/m}^3 = 6.18 \text{ t/m}$$

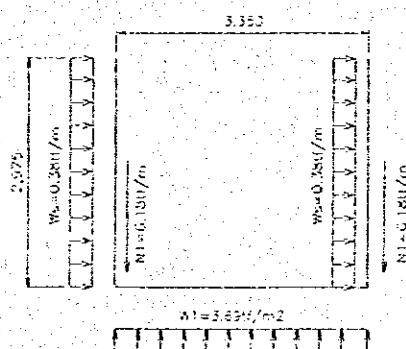
b) Seismic load

$$W_s = 0.95 \times 1.00 \times 2.50 \text{ t/m}^3 \times 0.16 = 0.38 \text{ t/m}^2$$

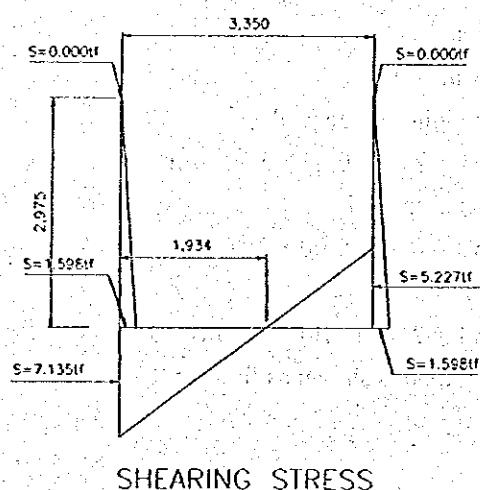
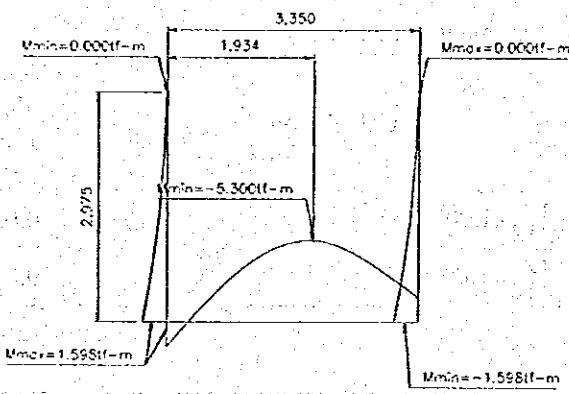
(ii) Bottom slab

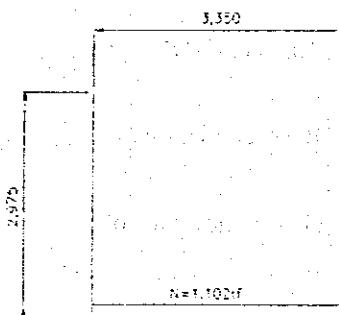
$$W1 = 2 \times N1 / B0 = 2 \times 6.18 / 3.35 = 3.69 \text{ t/m}^2$$

Figure of acting load is shown as follows.



Member	Condition	Distance (m)	Bending moment M (tf-m)	Shearing stress S (tf)	Axial Force N (tf)
M1	Maximum	2.975	1.598	1.102	0.000
	Minimum	0.000	0.000	0.000	0.000
M2	Maximum	0.000	1.598	7.135	1.102
	Minimum	1.934	-5.300	0.000	1.102
M3	Maximum	2.975	0.000	0.000	0.000
	Minimum	0.000	-1.598	1.102	0.000





AXIAL FORCE

Results of Strength calculation on each member are shown as follows.

Member of shape	Side wall		Bottom slab		
		Outside Rectangle	Inside Rectangle	Outside Rectangle	
M	tf-m		1.598	-5.300	1.598
N	tf		0.000	1.102	1.102
S	tf		1.102	0.000	7.135
B	cm		100.0	100.0	100.0
D	cm		45.0	65.0	65.0
A _c	cm ²		4500	6500	6500
A _s	cm ²		1.36	2.95	0.73
P=As/(B×D)			0.0003	0.00045	0.00011
N=Es/Ec			15	15	15
X ₀	cm		4.10	7.60	4.50
K=X ₀ /D			0.091	0.117	0.070
M/(B×D ²)	kgf/cm ²		0.789	1.254	0.378
S/(B×D)	kgf/cm ²		0.245	0.000	1.098
(C)			22.745	19.000	35.817
(S)			228.098	143.491	475.907
(Z)			1.031	1.042	1.065
σ _c	kgf/cm ²		17.90	23.80	13.50
σ _s	kgf/cm ²		2700.00	2700.00	2700.00
τ	kgf/cm ²		0.24	0.00	1.10
σ _{ca}	kgf/cm ²		112.50	112.50	112.50
σ _{sa}	kgf/cm ²		2700.00	2700.00	2700.00
τ _a	kgf/cm ²		9.75	9.75	9.75

Area of reinforcement

(i) Out side of side wall

$$As = 1.36 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K}$$

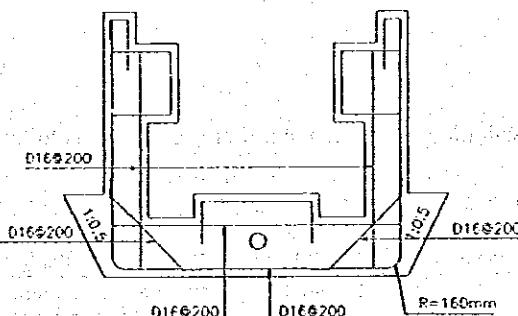
(ii) Inside of bottom slab

$As = 2.95 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K.}$

(iii) Outside of bottom slab

$As = 0.73 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K.}$

Figure of main reinforcing bar is shown as follows.



(4) Operation deck

Operation deck consists of standard section (rigid frame structure) and opening section installed inspection steps.

In structural calculation, each structure that is estimated at independent is calculated.

(a) Standard section

Standard section is shown as follows.

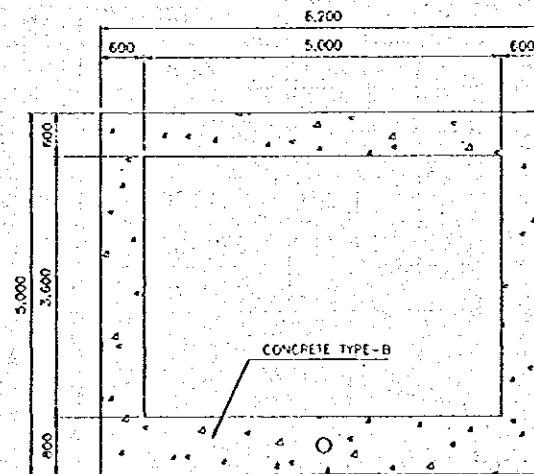
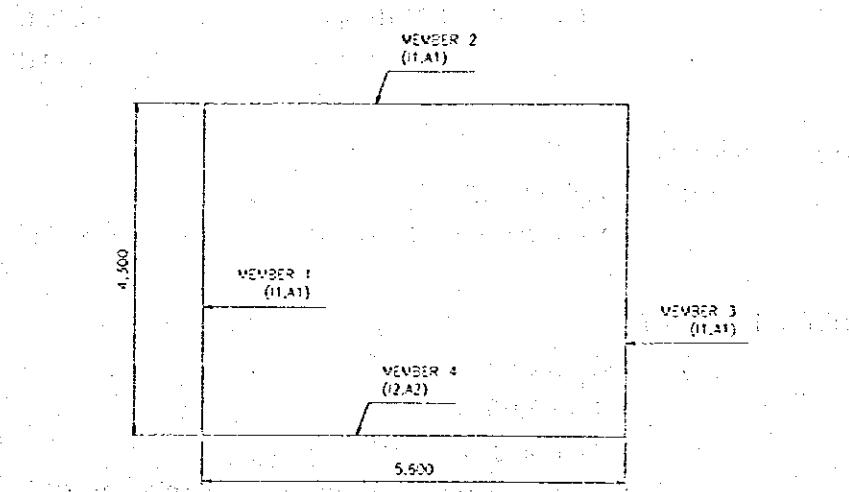


Figure of frame dimension is shown as follows.



Geometrical moment of inertia

Member	Calculation	Geometrical Moment of inertia (m^4)
1	$\frac{1}{12} \times 1.00 \times 0.60^3$	0.01800
2	$\frac{1}{12} \times 1.00 \times 0.80^3$	0.04267

Section area

Member	Calculation	Area (m^2)
1	1.00×0.60	0.600
2	1.00×0.80	0.800

Load calculation (Normal case)

(i) Top slab

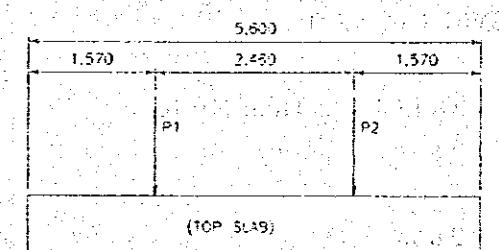
a) Weight of slab

$$W_1 = 0.60 \times 2.50 \text{ tf/m}^3 = 1.50 \text{ tf/m}^2$$

b) Live load

$$W_2 = 0.30 \text{ tf/m}^2$$

c) Hoisting load for low water outlet gate



$$\begin{aligned}
 P1 &= \text{Hoist weight} + \text{Hoisting load} \\
 &= 5.00 \text{ tf/unit} + 1.30 \text{ tf/rope} \\
 P2 &= 6.30 \text{ tf} \\
 &= 6.30 \text{ tf}
 \end{aligned}$$

(ii) Side wall

$$\begin{aligned}
 \text{a)} \quad &\text{Weight of side wall} \\
 N1 &= 3.60 \times 0.60 \times 2.50 \text{ tf/m}^3 \\
 &= 5.40 \text{ tf/m}
 \end{aligned}$$

(iii) Bottom slab

$$\begin{aligned}
 \text{a)} \quad &\text{Subgrade reaction} \\
 W1 &= 1.50 \text{ tf/m}^2 \\
 W2 &= 0.30 \text{ tf/m}^2 \\
 W3 &= (P1 + P2) / B0 = (6.30 + 6.30) / 5.60 = 2.25 \text{ tf/m}^2 \\
 W4 &= 2 \times N1 / B0 = 2 \times 5.40 / 5.60 = 1.93 \text{ tf/m}^2 \\
 W5 &= W1 + W2 + W3 + W4 \\
 &= 5.98 \text{ tf/m}^2
 \end{aligned}$$

Load calculation (Seismic case)

(i) Top slab

$$\begin{aligned}
 \text{a)} \quad &\text{Weight of slab} \\
 W1 &= 0.60 \times 2.50 \text{ tf/m}^3 \\
 &= 1.50 \text{ tf/m}^2 \\
 \text{b)} \quad &\text{Hoist weight} \\
 P1 &= 5.00 \text{ tf} \\
 P2 &= 5.00 \text{ tf} \\
 \text{c)} \quad &\text{Seismic load} \\
 \text{(a)} \quad &\text{Weight of slab} \\
 H1 &= 6.20 \times 0.60 \times 2.50 \text{ tf/m}^3 \times 0.16 \\
 &= 1.49 \text{ tf} \\
 \text{(b)} \quad &\text{Hoist weight} \\
 H2 &= (5.00 + 5.00) \times 0.16 \\
 &= 1.60 \text{ tf}
 \end{aligned}$$

$$\begin{aligned}
 \Sigma H &= H1 + H2 \\
 &= 3.09 \text{ tf} \\
 M_e &= 1.60 \text{ tf} \times 1.30 \text{ m} \\
 &= 2.08 \text{ tf-m}
 \end{aligned}$$

(ii) Side wall

$$\begin{aligned}
 \text{a)} \quad &\text{Weight of side wall} \\
 N1 &= 3.60 \times 0.60 \times 2.50 \text{ tf/m}^3 \\
 &= 5.40 \text{ tf/m} \\
 \text{b)} \quad &\text{Seismic load} \\
 W_s &= 0.60 \times 1.00 \times 2.50 \text{ tf/m}^3 \times 0.16 \\
 &= 0.24 \text{ tf/m}
 \end{aligned}$$

(iii) Bottom slab

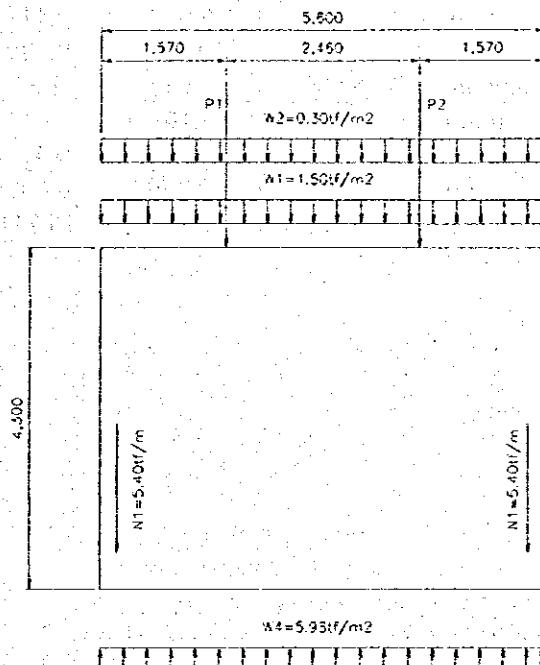
$$\begin{aligned}
 \text{a)} \quad &\text{Subgrade reaction} \\
 W1 &= 1.50 \text{ tf/m}^2 \\
 W2 &= (P1 + P2) / B0 = (5.00 + 5.00) / 5.60 \\
 &= 1.79 \text{ tf/m}^2 \\
 W3 &= 2 \times N1 / B0 = 2 \times 5.40 / 5.60 \\
 &= 1.93 \text{ tf/m}^2
 \end{aligned}$$

$$W_4 = W_1 + W_2 + W_3$$

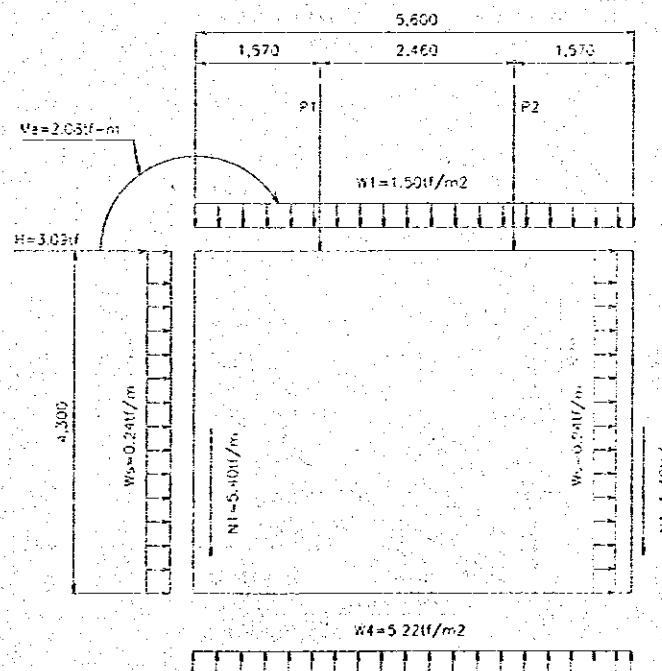
$$= 5.22 \text{ tf/m}^2$$

Figure of frame dimension is shown as follows.

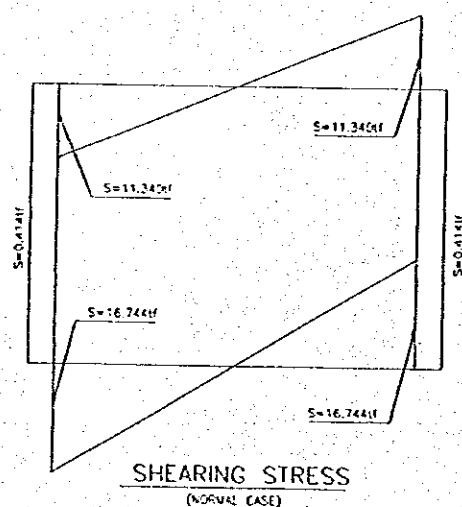
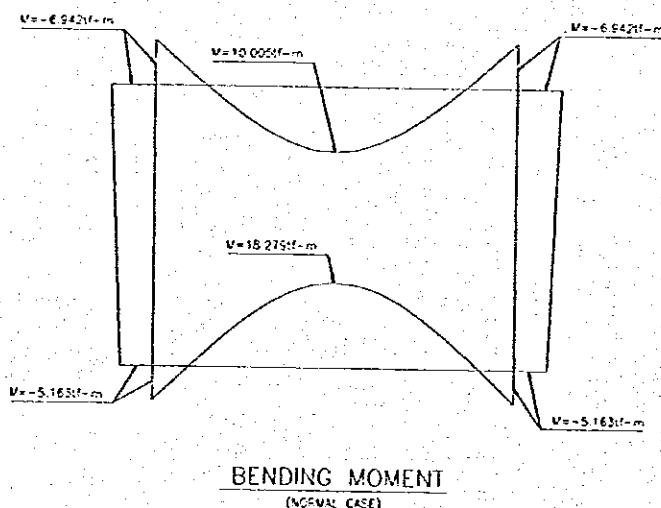
(Normal case)



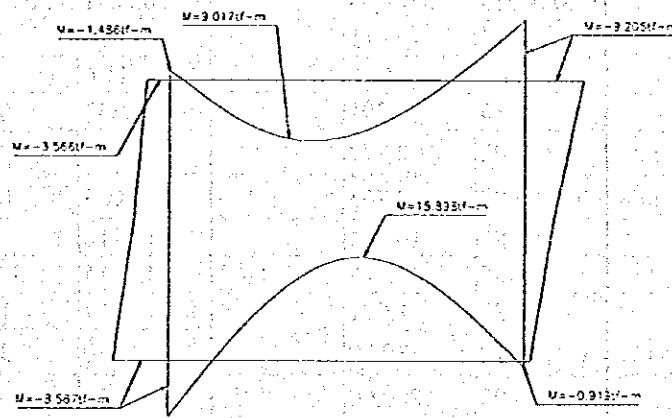
(Seismic case)



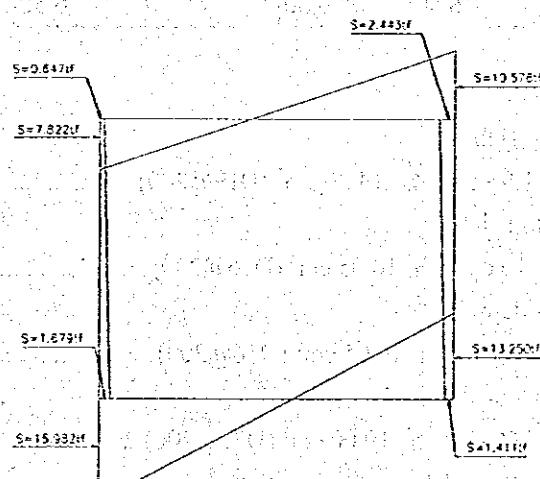
	Member	Condition	Distance (m)	Bending moment M (tf-m)	Shearing stress S (tf)	Axial Force N (tf)
Normal case	M1	Maximum	0.000	-5.163	0.414	11.340
		Minimum	4.300	-6.942	0.414	11.340
	M2	Maximum	2.800	10.005	0.000	0.414
		Minimum	5.600	-6.942	11.340	0.414
	M3	Maximum	4.300	-5.163	0.414	11.340
		Minimum	0.000	-6.942	0.414	11.340
	M4	Maximum	2.800	18.279	0.000	0.414
		Minimum	0.000	-5.163	16.744	0.414



	Member	Condition	Distance (m)	Bending moment M (tf-m)	Shearing stress S (tf)	Axial Force N (tf)
Seismic case	M1	Maximum	4.300	-3.566	0.647	7.822
		Minimum	0.000	-8.567	1.679	7.822
M2	M2	Maximum	1.881	9.017	0.000	2.443
		Minimum	5.600	-9.205	10.578	2.443
M3	M3	Maximum	4.300	-0.919	1.411	10.578
		Minimum	0.000	-9.205	2.443	10.578
M4	M4	Maximum	2.538	15.898	0.000	1.411
		Minimum	5.600	-8.567	15.982	1.411



BENDING MOMENT
(SEISMIC CASE)



SHEARING STRESS
(SEISMIC CASE)

Results of Strength calculation on each member are shown as follows.

(Normal case)

	Member of shape	Top slab		Side wall		Bottom slab	
		Inside Rectangle	Outside Rectangle	Inside Rectangle	Outside Rectangle	Inside Rectangle	Outside Rectangle
M	lf-m	10.005	-6.942		-6.942	18.279	-5.163
N	lf	0.414	0.414		11.340	0.414	0.414
S	tf	0.000	11.340		0.414	0.000	16.744
B	cm	100.0	100.0		100.0	100.0	100.0
D	cm	50.0	50.0		50.0	70.0	70.0
A _c	cm ²	5000	5000		5000	7000	7000
A _s	cm ²	11.96	8.16		5.48	15.60	4.17
P=A _s /(B×D)		0.00239	0.00163		0.0011	0.00223	0.0006
N=Es/Ec		15	15		15	15	15
X ₀	cm	11.8	10.0		11.6	16.0	9.0
K=X ₀ /D		0.236	0.201		0.233	0.229	0.128
M/(B×D ²)	kgf/cm ²	4.002	2.777		2.777	3.730	1.054
S/(B×D)	kgf/cm ²	0.000	2.268		0.083	0.000	2.392
(C)		9.281	10.844		13.116	9.54	16.751
(S)		29.985	43.215		43.215	32.168	113.887
(Z)		1.085	1.071		1.17	1.082	1.043
σ _c	kgf/cm ²	37.10	30.10		36.40	35.60	17.70
σ _s	kgf/cm ²	1800.00	1800.00		1800.00	1800.00	1800.00
τ	kgf/cm ²	0.00	2.27		0.08	0.00	2.39
σ _{ca}	kgf/cm ²	75.00	75.00		75.00	75.00	75.00
σ _{sa}	kgf/cm ²	1800.00	1800.00		1800.00	1800.00	1800.00
τ _a	kgf/cm ²	6.50	6.50		6.50	6.50	6.50

Area of reinforcement

(i) Inside of top slab

$$As = 11.96 \text{ cm}^2 \leq 14.20 \text{ cm}^2 (\text{D19@200}) \dots \text{O.K}$$

(ii) Outside of top slab

$$As = 8.16 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K}$$

(iii) Outside of side wall

$$As = 5.48 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K}$$

(iv) Inside of bottom slab

$$As = 15.60 \text{ cm}^2 \leq 19.00 \text{ cm}^2 (\text{D22@200}) \dots \text{O.K}$$

(v) Outside of bottom slab

$$As = 4.17 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K}$$

(Seismic case)

		Top slab		Side wall		Bottom slab	
Member of shape		Inside	Outside	Inside	Outside	Inside	Outside
		Rectangle	Rectangle	Rectangle	Rectangle	Rectangle	Rectangle
M	tf-ni	9.017	-9.205		-9.205	15.898	-8.567
N	tf	2.443	2.443		10.578	1.411	1.411
S	tf	0.000	10.578		2.443	0.000	15.982
B	cm	100.0	100.0		100.0	100.0	100.0
D	cm	50.0	50.0		50.0	70.0	70.0
Ac	cm ²	5000	5000		5000	7000	7000
As	cm ²	6.71	6.87		5.52	8.70	4.50
P=As/(B×D)		0.00134	0.00137		0.0011	0.00124	0.00064
N=Es/Ec		15	15		15	15	15
X0	cm	9.6	9.7		10.6	12.6	9.5
K=X0/D		0.192	0.194		0.211	0.180	0.136
M/(B×D ²)	kgf/cm ²	3.607	3.682		3.682	3.244	1.748
S/(B×D)	kgf/cm ²	0.000	2.116		0.489	0.000	2.283
(C)		11.872	11.759		13.103	12.184	16.253
(S)		49.906	48.886		48.886	55.479	102.953
(Z)		1.067	1.068		1.114	1.062	1.047
σ_c	kgf/cm ²	42.80	43.30		48.20	39.50	28.40
σ_s	kgf/cm ²	2700.00	2700.00		2700.00	2700.00	2700.00
τ	kgf/cm ²	0.00	2.12		0.49	0.00	2.28
σ_{ca}	kgf/cm ²	112.50	112.50		112.50	112.50	112.50
σ_{sa}	kgf/cm ²	2700.00	2700.00		2700.00	2700.00	2700.00
τ_a	kgf/cm ²	9.75	9.75		9.75	9.75	9.75

Area of reinforcement**(i) Inside of top slab**

$$As = 6.71 \text{ cm}^2 \leq 14.20 \text{ cm}^2 (\text{D19@200}) \dots \text{O.K}$$

(ii) Outside of top slab

$$As = 6.87 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K}$$

(iii) Outside of side wall

$$As = 5.52 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K}$$

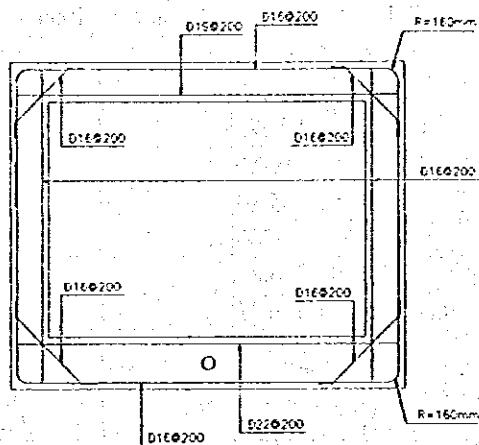
(iv) Inside of bottom slab

$$As = 8.70 \text{ cm}^2 \leq 19.00 \text{ cm}^2 (\text{D22@200}) \dots \text{O.K}$$

(v) Outside of bottom slab

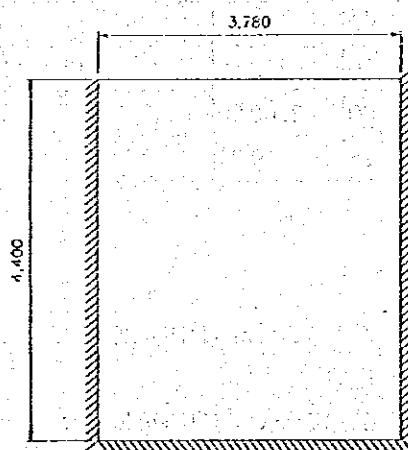
$$As = 4.50 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K}$$

Figure of main reinforcing bar is shown as follows.



(b) Opening section

Opening section is regarded as slab fixed in 3 sides.



$$\text{Slenderness ratio : } \frac{\ell_y}{\ell_x} = 4.40 / 3.78 = 1.16$$

Load calculation

a) Hoisting load

$$W_1 = (10.00 \text{ tf} + 3.50 \text{ tf} \times 0.581) / (2.00 \times 3.00) = 2.01 \text{ tf/m}^2$$

b) Live load

$$W_2 = 0.30 \text{ tf/m}^2$$

c) Weight of slab

$$W_3 = 0.60 \times 2.50 \text{ tf/m}^3 = 1.50 \text{ tf/m}^2$$

$$W = W_1 + W_2 + W_3 = 3.81 \text{ tf/m}^2$$

Bending moment

$$M_{x1} = -0.085 \times 3.81 \text{ tf/m}^2 \times 3.78^2 = -4.63 \text{ tf-m}$$

$$M_{x2} = 0.052 \times 3.81 \text{ tf/m}^2 \times 3.78^2 = 2.78 \text{ tf-m}$$

$$M_{y1} = -0.058 \times 3.81 \text{ tf/m}^2 \times 3.78^2 = -3.16 \text{ tf-m}$$

Shearing stress

$$S_x = 0.51 \times 3.81 \text{ tf/m}^2 \times 3.78 = 7.34 \text{ tf}$$

$$S_y = 0.40 \times 3.81 \text{ tf/m}^2 \times 3.78 = 5.76 \text{ tf}$$

Combination of load

For short side section ($L = 3.78 \text{ m}$)

(Outside)

$$M_x = -4.63 \text{ tf-m} \quad S_x = 7.34 \text{ tf}$$

(Inside)

$$M_x = 2.78 \text{ tf-m} \quad S_x = 0.00 \text{ tf}$$

For long side section ($L = 4.40 \text{ m}$)

$$M_y = -3.16 \text{ tf-m} \quad S_y = 5.76 \text{ tf}$$

Results of Strength calculation on each member are shown as follows.

Member of shape	L=3.78 m		L=4.40 m		Bottom slab	
	Inside Rectangle	Outside Rectangle	Inside Rectangle	Outside Rectangle	Inside Rectangle	Outside Rectangle
M	tf-m	2.780	-4.630		-3.160	
N	tf	0.000	0.000		0.000	
S	tf	0.000	7.340		5.760	
B	cm	100.0	100.0		100.0	
D	cm	50.0	50.0		50.0	
Ac	cm ²	5000	5000		5000	
As	cm ²	3.23	5.44		3.68	
P=As/(B × D)		0.00065	0.00109		0.00074	
N=Es/Ec		15	15		15	
X0	cm	6.5	8.3		6.9	
K=X0/D		0.130	0.165		0.138	
M/(B × D ²)	kgf/cm ²	1.112	1.852		1.264	
S/(B × D)	kgf/cm ²	0.000	1.468		1.152	
(C)		16.101	12.817		15.195	
(S)		107.914	64.795		94.937	
(Z)		1.045	1.058		1.048	
σ c	kgf/cm ²	17.90	23.70		19.20	
σ s	kgf/cm ²	1800.00	1800.00		1800.00	
τ	kgf/cm ²	0.00	1.47		1.15	
σ ca	kgf/cm ²	75.00	75.00		75.00	
σ sa	kgf/cm ²	1800.00	1800.00		1800.00	
τ a	kgf/cm ²	6.50	6.50		6.50	

Area of reinforcement

(i) Inside of short side

$$As = 3.23 \text{ cm}^2 \leq 6.633 \text{ cm}^2 (\text{D16@300}) \dots \text{O.K}$$

(ii) Outside of short side

$$As = 5.44 \text{ cm}^2 \leq 6.633 \text{ cm}^2 (\text{D16@300}) \dots \text{O.K}$$

(iii) Outside of long side

$$As = 3.68 \text{ cm}^2 \leq 10.05 \text{ cm}^2 (\text{D16@200}) \dots \text{O.K}$$