

Control Portion

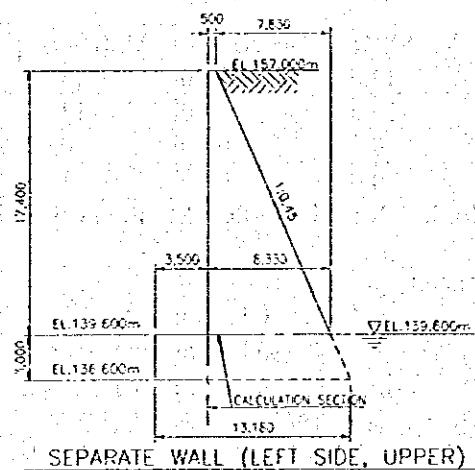
In the control portion, five (5) shapes of separate walls are analyzed.

(1) Left Side Upper Separate Wall of Control Portion

Structural calculations of standing wall and toe slab are carried out for the Left Side Upper Separate Wall.

(a) Basic design condition

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



Design conditions 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 >

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

Ka : Coefficient of active earth pressure under normal condition

Item	Symbol	Unit	Value	Description
Angle between wall backside surface and vertical plane	θ	(degree)	24.2	V:H=1:0.45
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	$\delta = 2/3 \phi$

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

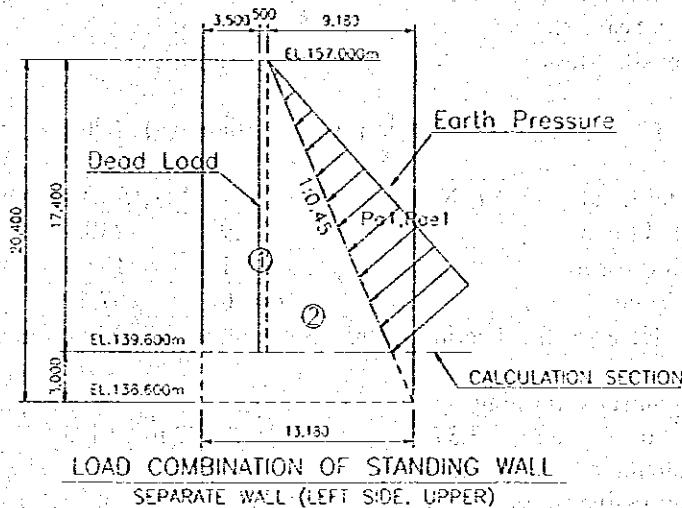
Kea : Coefficient of active earth pressure under seismic condition

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 Standing Wall, Left Side Upper Separate Wall

(i) Loading Calculation of Standing Wall, Left Side Upper Separate Wall

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(l)	Y(m)	My(tf-m)
1(concrete)	8.70	20.45	-3.92	-80.04	-3.27	8.70	-28.46
2(concrete)	68.12	160.08	-1.06	-168.89	-25.61	5.80	-148.56
Total	76.82	180.53		-248.93	-28.88		-177.02

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.481$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pal	-	102.12	1.56	158.79	-93.37	5.80	-541.57
Total	-	102.12		158.79	-93.37		-541.57

Earth Pressure with Earthquake

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

Coefficient of active earth pressure : $K_{ea}=0.611$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	116.93	1.56	181.83	-131.11	5.80	-760.45
Total	-	116.93		181.83	-131.11		-760.45

(ii) Structural Calculation of Standing Wall, Left Side Upper Separate Wall

Case 1 : Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	180.5	0.0	-248.9	0.0
Earth Pressure	102.1	-93.4	158.8	-541.6
Total	282.65	-93.37	-90.14	-541.57

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

Safety against overturning

$$e = -2.235 \text{ m} < 1.388 \text{ m} = b/6 \quad \text{OK}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 8.86 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -2.07 \text{ (kgf/m}^2\text{)} < -3 \text{ OK}$$

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	180.5	-28.9	-248.9	-177.0
Earth Pressure	116.9	-131.1	181.8	-760.4
Total	297.46	-160.00	-67.10	-937.46

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

Safety against overturning

$$e = -3.377 \text{ m} > 2.777 \text{ m} = b/3 \quad \text{NG}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 12.26 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$$

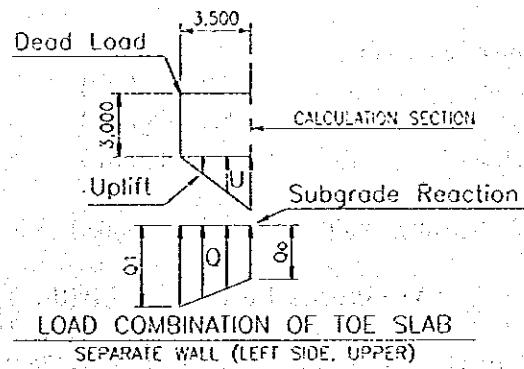
$$\text{Tensile stress } \sigma_t = -5.12 \text{ (kgf/m}^2\text{)} > -4.5 \quad \boxed{\text{NG}}$$

Calculated tensile stress of concrete under seismic condition is bigger than allowable stresses. Therefore, the reinforcing bar arrangement is necessary for standing wall of the Left Side Upper Separate Wall.

(c) Structural Calculation of Toe Slab, Left Side Upper Separate Wall

(i) Loading Calculation of Toe Slab, Left Side Upper Separate Wall

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)	10.50	24.68	1.75	43.18	-	-	-
Total	10.50	24.68		43.18	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 47.018 \text{ (tf/m}^2\text{)} , Q_0 = 37.750 \text{ (tf/m}^2\text{)}$$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-148.34	1.81	-269.06	-	-	-
Total	-	-148.34		-269.06	-	-	-

Subgrade Reaction with Earthquake

$$Q_1 = 68.100 \text{ (tf/m}^2\text{)} , Q_0 = 48.447 \text{ (tf/m}^2\text{)}$$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-203.96	1.85	-376.98	-	-	-
Total	-	-203.96		-376.98	-	-	-

Uplift

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-1.39	1.17	-1.63	-	-	-
Total	-	-1.39		-1.63	-	-	-

(ii) Structural Calculation of Toe Slab, Left Side Upper Separate Wall

Case 1 : Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-148.34	0.00	-269.06	0.00
Uplift	-1.39	0.00	-1.63	0.00
Total	-125.06	0.00	-227.51	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c =$	4.17 (kgf/m ²)	<	5.5	OK
Compressive stress	$\sigma_c =$	15.17 (kgf/m ²)	<	60	OK
Tensile stress	$\sigma_t =$	-15.17 (kgf/m ²)	>	-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	24.68	0.00	43.18	0.00
Subgrade Reaction	-203.96	0.00	-376.98	0.00
Uplift	-1.39	0.00	-1.63	0.00
Total	-180.67	0.00	-335.43	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c =$	6.02 (kgf/m ²)	<	8.25	OK
Compressive stress	$\sigma_c =$	22.36 (kgf/m ²)	<	90	OK
Tensile stress	$\sigma_t =$	-22.36 (kgf/m ²)	>	-4.5	NG

Calculated tensile stresses of concrete under normal and seismic condition are bigger than allowable stresses. Therefore, the reinforcing bar arrangement is necessary for toe slab of the Left Side Upper Separate Wall.

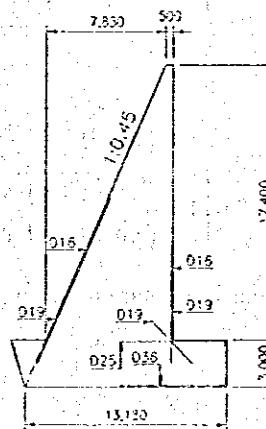
(d) Calculation of reinforcing bar arrangement for Left Side Upper Separate Wall

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

[Calculation of reinforcing bar arrangement for Left Side Upper Separate Wall]

Member		Standing Wall		Toe Slab	
Calculation condition		Normal	Seismic	Normal	Seismic
Shape of member		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	631.71	1004.56	227.51	335.43
N	tf	282.65	297.46	0	0
S	tf	93.37	160	125.06	180.67
B	cm	100	100	100	100
D	cm	823	823	290	290
Ac	cm ²	82300	82300	29000	29000
As	cm ²	D19@200 =14.20	D19@200 =14.20	D36@200 =51.00	D36@200 =51.00
P=As/(B × D)		0.00017	0.00017	0.00176	0.00176
N=Es/Ec		15	15	15	15
X0	cm	570.3	284.9	59.4	59.4
K=X0/D		0.693	0.346	0.205	0.205
M/(B × D ²)	kgf/cm ²	0.933	1.483	2.705	3.988
S/(B × D)	kgf/cm ²	1.135	1.944	4.312	6.23
(C)		10.663	14.491	10.48	10.48
(S)		4.724	27.375	40.686	40.686
(Z)		2.104	3.077	1.073	1.073
σ_c	kgf/cm ²	9.9	21.5	28.4	41.8
σ_s	kgf/cm ²	66	609	1651	2434
τ	kgf/cm ²	1.13	1.94	4.31	6.23
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.



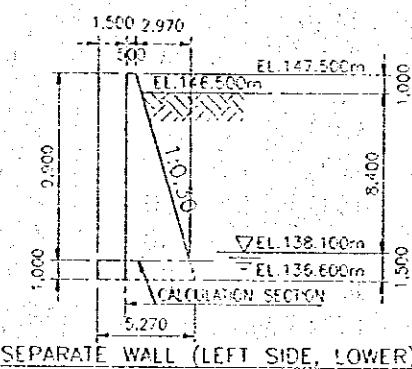
SEPARATE WALL (LEFT SIDE, UPPER)

(2) Left Side Lower Separate Wall of Control Portion

Structural calculations of standing wall and toe slab are carried out for the Left Side Upper Separate Wall.

(a) Basic design condition

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



Design conditions 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 >

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

Ka : Coefficient of active earth pressure under normal condition

Item	Symbol	Unit	Value	Description
Angle between wall backside surface and vertical plane	θ	(degree)	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	$\delta = 2/3 \phi$

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

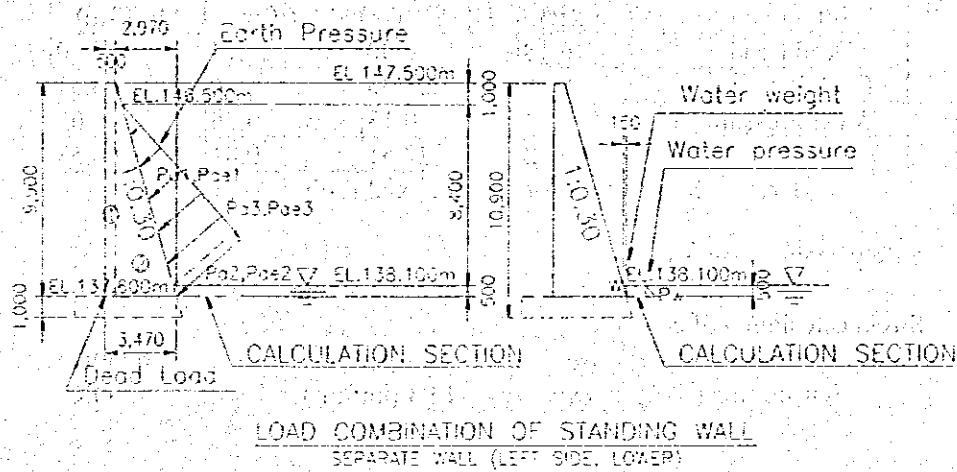
Kea : Coefficient of active earth pressure under seismic condition

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	$\tan \theta_0 = Kh$

(b) Structural Calculation of Standing Wall, Left Side Lower Separate Wall

(i) Loading Calculation of Standing Wall, Left Side Lower Separate Wall

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	11.63	-1.49	-17.27	-1.86	4.95	-9.21
2(concrete)	14.70	34.55	-0.25	-8.46	-5.53	3.30	-18.24
Total	19.65	46.18		-25.74	-7.39		-27.45

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	-	16.78	0.75	12.50	-19.97	3.30	-65.91
Pa2	-	2.00	1.66	3.32	-2.38	0.25	-0.59
Pa3	-	0.03	1.69	0.05	-0.03	0.17	-0.01
Total	-	18.80		15.86	-22.38		-66.51

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	-	19.15	0.75	14.27	-28.18	3.30	-92.98
Pae2	-	2.28	1.66	3.78	-3.35	0.25	-0.84
Pae3	-	0.03	1.69	0.05	-0.05	0.17	-0.01
Total	-	21.46		18.10	-31.58		-93.83

Water Pressure

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	0.04	0.04	1.69	0.06	-0.13	0.17	-0.02
Total		0.04		0.06	-0.13		-0.02

(ii) Structural Calculation of Standing Wall, Left Side Lower Separate Wall

Case 1 : Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	46.18	0.00	-25.74	0.00
Earth Pressure	18.80	-22.38	15.86	-66.51
Water Pressure	0.04	-0.13	0.06	-0.02
Total	65.02	-22.51	-9.81	-66.53

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

Safety against overturning

$$e = -1.174 \text{ m} > 0.578 \text{ m} = b/6 \quad \text{NG}$$

Stress calculation of concrete

Compressive stress $\sigma_c = 5.68 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$

Tensile stress $\sigma_t = -1.93 \text{ (kgf/m}^2\text{)} < -3 \text{ OK}$

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	46.2	-7.4	-25.7	-27.5
Earth Pressure	21.5	-31.6	18.1	-93.8
Water Pressure	0.0	-0.1	0.1	-0.0
Total	67.7	-39.1	-7.6	-121.3

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

Safety against overturning

$$e = -1.904 \text{ m} > 1.157 \text{ m} = b/3 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 8.4 \text{ (kgf/m}^2\text{)} < 90 \quad \text{OK}$$

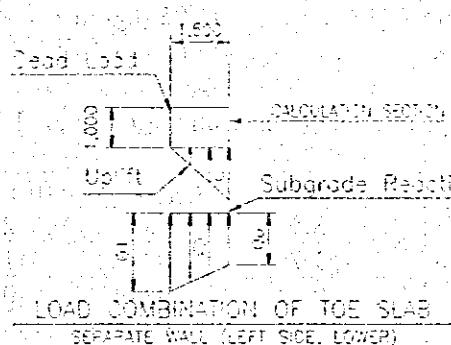
$$\text{Tensile stress } \sigma_t = -4.5 \text{ (kgf/m}^2\text{)} > -4.5 \quad \boxed{\text{NG}}$$

Calculated tensile stress of concrete under seismic condition is not smaller than allowable stresses. Therefore, the reinforcing bar arrangement is necessary for standing wall of the Left Side Lower Separate Wall.

(c) Structural Calculation of Toe Slab, Left Side Lower Separate Wall

(i) Loading Calculation of Toe Slab, Left Side Lower Separate Wall

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	3.53	0.75	2.64	-	-	-
Total	1.50	3.53		2.64	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 26.798 \text{ (tf/m}^2\text{)} \quad Q_0 = 19.928 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q		-35.04	0.79	-27.57	-	-	-
Total		-35.04		-27.57	-	-	-

Subgrade Reaction with Earthquake

$$Q_1 = 42.109 \text{ (tf/m}^2\text{)} \quad Q_0 = 26.874 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q		-51.74	0.81	-41.66	-	-	-
Total		-51.74		-41.66	-	-	-

Uplift

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-0.32	0.50	-0.16	-	-	-
Total	-	-0.32	-	-0.16	-	-	-

(ii) Structural Calculation of Toe Slab, Left Side Lower Separate Wall

Case 1 : Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	3.53	0.00	2.64	0.00
Subgrade Reaction	-35.04	0.00	-27.57	0.00
Uplift	-0.32	0.00	-0.16	0.00
Total	-31.84	0.00	-25.09	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c =$	3.18 (kgf/m^2)	<	5.5	OK
Compressive stress	$\sigma_c =$	15.05 (kgf/m^2)	<	60	OK
Tensile stress	$\sigma_t =$	-15.05 (kgf/m^2)	>	-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	3.53	0.00	2.64	0.00
Subgrade Reaction	-51.74	0.00	-41.66	0.00
Uplift	-0.32	0.00	-0.16	0.00
Total	-48.53	0.00	-39.18	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c =$	4.85 (kgf/m^2)	<	8.25	OK
Compressive stress	$\sigma_c =$	23.51 (kgf/m^2)	<	90	OK
Tensile stress	$\sigma_t =$	-23.51 (kgf/m^2)	>	-4.5	NG

Calculated tensile stresses of concrete under normal and seismic condition are bigger than allowable stresses. Therefore, the reinforcing bar arrangement is necessary for toe slab of the Left Side Lower Separate Wall.

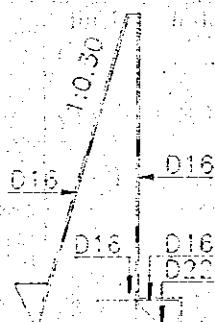
(d) Calculation of reinforcing bar arrangement, Left Side Lower Separate Wall

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

[Calculation of reinforcing bar Arrangement]

Member		Standing Wall		Toe Slab	
Calculation condition		Normal	Seismic	Normal	Seismic
Shape of member		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	76.34	128.9	25.09	39.18
N	tf	65.02	67.7	0	0
S	tf	22.51	39.1	31.84	48.53
B	cm	100	100	100	100
D	cm	337	337	90	90
Ac	cm ²	33700	33700	9000	9000
As	cm ²	D16@200 =10.05	D16@200 =10.05	D22@200 =19.00	D22@200 =19.00
P=As/(B × D)		0.0003	0.0003	0.00211	0.00211
N=Es/Ec		15	15	15	15
X0	cm	168.6	76.9	20	20
K=X0/D		0.5	0.228	0.222	0.222
M/(B × D ²)	kgf/cm ²	0.672	1.135	3.098	4.837
S/(B × D)	kgf/cm ²	0.668	1.16	3.538	5.392
(C)		11.684	17.874	9.73	9.73
(S)		11.671	60.419	34.102	34.102
(Z)		2.546	1.935	1.08	1.08
σ_c	kgf/cm ²	7.9	20.3	30.1	47.1
σ_s	kgf/cm ²	118	1029	1584	2474
τ	kgf/cm ²	0.67	1.16	3.54	5.39
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.



SEPARATE WALL (LEFT SIDE, UPPER)

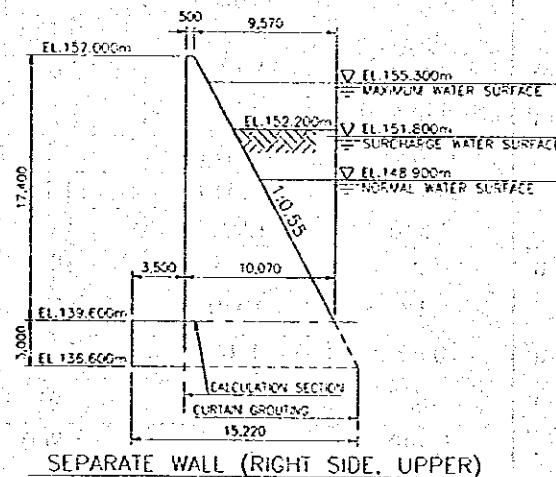
(3) Right Side Upper Separate Wall of Control Portion

Structural calculations of standing wall and toe slab are carried out for the Right Side Upper Separate Wall.

Since Right Side Upper Separate Wall faces to reservoir water, four (4) cases are studied accordingly conditions of reservoir water surface.

(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)	2.35	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)	28.8	V:H=1:0.55
Angle between ground surface and horizontal plane	α	(degree)	0.0	
Internal friction angle of soil	ϕ	(degree)	45.0	Pervious material of Dam
Friction angle of soil to concrete	δ	(degree)	30.0	$\delta = 2/3 \phi$

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

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)	-	$\tan\theta_0 = Kh$

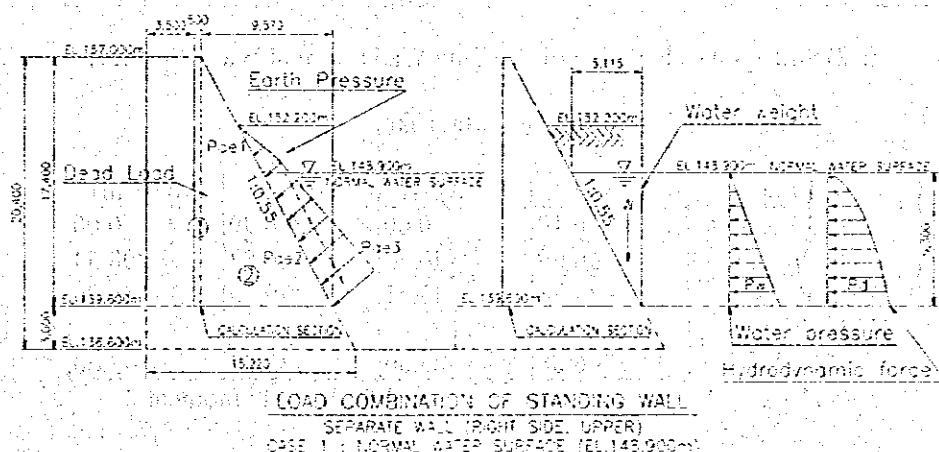
(b) Case 1 : Right Side Upper Separate Wall, Normal Water Surface : EL.148.900m

Horizontal seismic coefficient : $Kh=0.16$ (100%)

(i) Standing Wall of Right Side Upper Separate Wall (Normal Water Surface)

(i-1) Loading Calculation of Standing Wall (Normal Water Surface)

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)	8.70	20.45	-4.79	-97.83	-3.27	8.70	-28.46
2(concrete)	83.26	195.66	-1.35	-263.16	-31.31	5.80	-181.57
Total	91.96	216.10		-360.99	-34.58		-210.03

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.468$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	10.10	-1.02	-10.25	-6.11	11.00	-67.23
Pa2		36.82	2.48	91.22	-22.29	4.65	-103.65
Pa3		20.07	3.33	66.84	-12.15	3.10	-37.67
Total	-	66.99		147.82	-40.55		-208.54

Earth Pressure with Earthquake

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

Coefficient of active earth pressure : $K_{ea}=0.586$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	11.53	-1.02	-11.71	-9.24	11.00	-101.61
Pae2		42.07	2.48	104.22	-33.69	4.65	-156.65
Pae3		22.93	3.33	76.37	-18.37	3.10	-56.94
Total	-	76.53		168.88	-61.29		-315.20

Water Pressure

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	23.78	23.78	3.33	79.20	-43.25	3.10	-134.06
Total	23.78			79.20	-43.25		-134.06

Hydrodynamic Force (due to Earthquake)

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pd	-	-	-	-	-8.07	3.72	-30.03
Total	-	-	-	-	-8.07		-30.03

(i-2) Structural Calculation of Standing Wall (Normal Water Surface)

Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	216.10	0.00	-360.99	0.00
Earth Pressure	66.99	-40.55	147.82	-208.54
Water Pressure	23.78	-43.25	79.20	-134.06
Hydrodynamic	-	-	-	-
Total	306.88	-83.80	-133.97	-342.60

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

Safety against overturning

$$e = -1.553 \text{ m} < 1.678 \text{ m} = b/6 \quad \text{OK}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 5.87 \text{ (kgf/m}^2\text{)} < 60 \quad \text{OK}$$

$$\text{Tensile stress } \sigma_t = 0.23 \text{ (kgf/m}^2\text{)} < -3 \quad \text{OK}$$

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

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	216.1	-34.6	-361.0	-210.0
Earth Pressure	76.5	-61.3	168.9	-315.2
Water Pressure	23.8	-43.2	79.2	-134.1
Hydrodynamic	0.0	-8.1	0.0	-30.0
Total	316.4	-147.2	-112.9	-689.3

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

Safety against overturning

$$e = -2.535 \text{ m} < 3.357 \text{ m} = b/3 \quad \text{OK}$$

Stress calculation of concrete

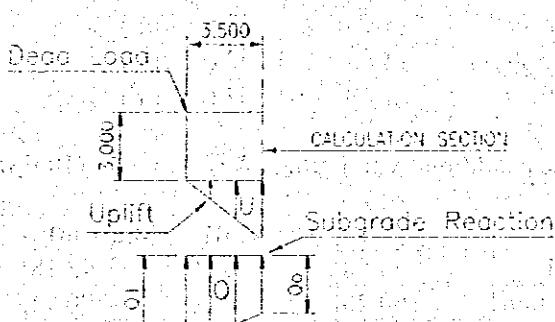
$$\text{Compressive stress } \sigma_c = 7.89 \text{ (kgf/m}^2\text{)} < 90 \quad \text{OK}$$

$$\text{Tensile stress } \sigma_t = -1.60 \text{ (kgf/m}^2\text{)} < -4.5 \quad \text{OK}$$

(ii) Toe Slab of Right Side Upper Separate Wall (Normal Water Surface)

(ii-1) Loading Calculation of Toe Slab (Normal Water Surface)

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



LOAD COMBINATION OF TOE SLAB

SEPARATE WALL (RIGHT SIDE, UPPER)
CASE 1 : NORMAL WATER SURFACE (EL.148.900m)

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)	10.50	24.68	1.75	43.18	-	-	-
Total	10.50	24.68		43.18			

Subgrade Reaction without Earthquake

$$Q_1 = 36.259 \text{ (tf/m}^2\text{)}, Q_0 = 32.332 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-120.03	1.78	-214.07	-	-	-
Total	-	-120.03		-214.07			

Subgrade Reaction with Earthquake

$$Q_1 = 50.922 \text{ (tf/m}^2\text{)}, \quad Q_0 = 40.655 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-160.26	1.82	-290.94	-	-	-
Total	-	-160.26		-290.94	-	-	-

Uplift

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-1.65	1.17	-1.92	-	-	-
Total	-	-1.65		-1.92	-	-	-

(ii-2) Structural Calculation of Toe Slab (Normal Water Surface)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-120.03	0.00	-214.07	0.00
Uplift	-1.65	0.00	-1.92	0.00
Total	-97.01	0.00	-172.81	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c = 3.23 \text{ (kgf/m}^2\text{)}$	<	5.5	OK
Compressive stress	$\sigma_c = 11.52 \text{ (kgf/m}^2\text{)}$	<	60	OK
Tensile stress	$\sigma_t = -11.52 \text{ (kgf/m}^2\text{)}$	>	-3	NG

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

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-160.26	0.00	-290.94	0.00
Uplift	-1.65	0.00	-1.92	0.00
Total	-137.24	0.00	-249.68	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c = 4.57 \text{ (kgf/m}^2\text{)}$	<	8.25	OK
Compressive stress	$\sigma_c = 16.65 \text{ (kgf/m}^2\text{)}$	<	90	OK
Tensile stress	$\sigma_t = -16.65 \text{ (kgf/m}^2\text{)}$	>	-4.5	NG

(c) Case 2 : Right Side Upper Separate Wall, Surcharge Water Surface :

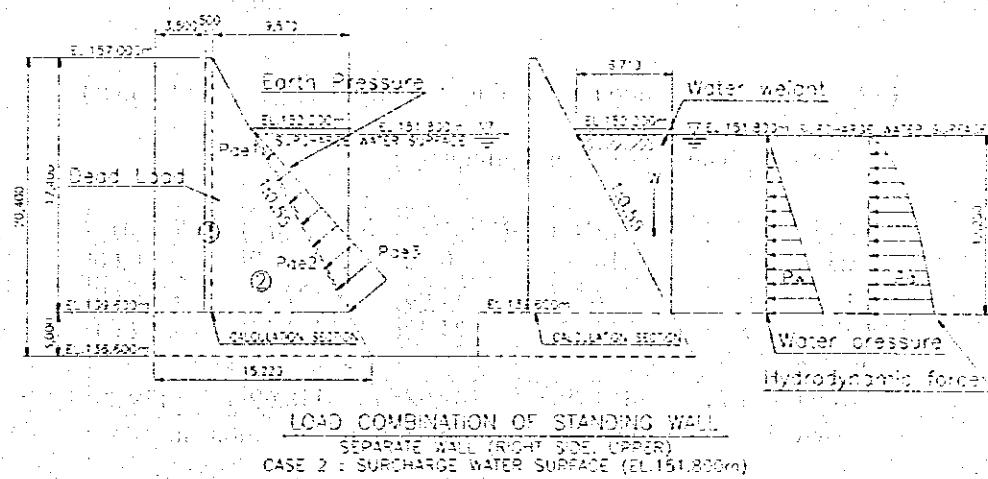
EL.151.800m

Horizontal seismic coefficient : Kh=0.08 (50%)

**(i) Standing Wall of Right Side Upper Separate Wall
(Surcharge Water Surface)**

(i-1) Loading Calculation of Standing Wall (Surcharge Water Surface)

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)	8.70	20.45	-4.79	-97.83	-1.64	8.70	-14.23
2(concrete)	83.26	195.66	-1.35	-263.16	-15.65	5.80	-90.79
Total	91.96	216.10		-360.99	-17.29		-105.02

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.468$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1		1.88	-2.08	-3.90	-1.14	12.93	-14.71
Pa2		20.84	1.68	35.00	-12.61	6.10	-76.94
Pa3		34.54	2.80	96.67	-20.91	4.07	-85.04
Total		57.26		127.77	-34.66		-176.69

Earth Pressure with Earthquake

Seismic composite angle : $\theta_0=4.6(\text{degree})$ ($\tan\theta_0=Kh=0.08$)

Coefficient of active earth pressure : $K_{ae}=0.505$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1		1.85	-2.08	-3.85	-1.48	12.93	-19.16
Pae2		20.52	1.68	34.47	-16.43	6.10	-100.24
Pae3		34.02	2.80	95.20	-27.25	4.07	-110.80
Total		56.39		125.83	-45.16		-230.20

Water Pressure

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw		40.93	2.80	114.54	-74.42	4.07	-302.64
Total		40.93		114.54	-74.42		-302.64

Hydrodynamic Force (due to Earthquake)

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pd	-	-	-	-	-6.95	4.88	-33.90
Total		-	-	-	-6.95		-33.90

(i-2) Structural Calculation of Standing Wall (Surcharge Water Surface)

Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	216.10	0.00	-360.99	0.00
Earth Pressure	57.26	-34.66	127.77	-176.69
Water Pressure	40.93	-74.42	114.54	-302.64
Hydrodynamic				
Total	314.29	-109.08	-118.69	-479.33

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

Safety against overturning

$$e = -1.903 \text{ m} > 1.678 \text{ m} = b/6 \quad \text{NG}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 6.66 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -0.42 \text{ (kgf/m}^2\text{)} < -3 \text{ OK}$$

Seismic condition (with Earthquake); Kh=0.08(50%)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	216.1	-17.3	-361.0	-105.0
Earth Pressure	56.4	-45.2	125.8	-230.2
Water Pressure	40.9	-74.4	114.5	-302.6
Hydrodynamic	0.0	-6.9	0.0	-33.9
Total	313.4	-143.8	-120.6	-671.8

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

Safety against overturning

$$e = -2.528 \text{ m} < 3.357 \text{ m} = b/3 \quad \text{OK}$$

Stress calculation of concrete

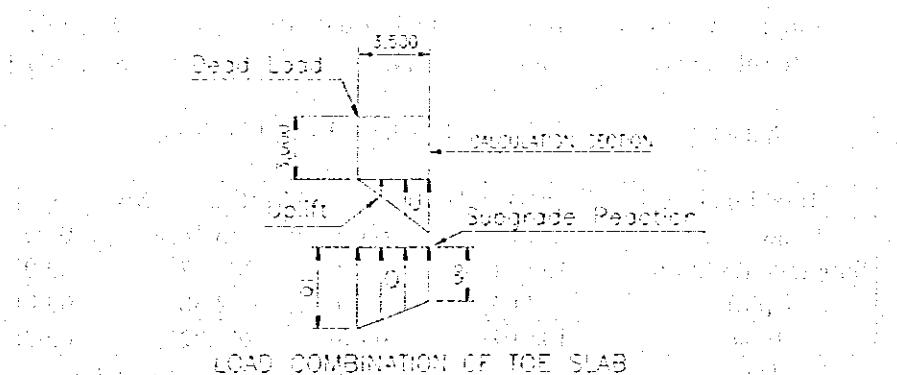
$$\text{Compressive stress } \sigma_c = 7.80 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -1.58 \text{ (kgf/m}^2\text{)} < -4.5 \text{ OK}$$

(ii) Toe Slab of Right Side Upper Separate Wall (Surcharge Water Surface)

(ii-1) Loading Calculation of Toe Slab (Surcharge Water Surface)

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)	10.50	24.68	1.75	43.18	-	-	-
Total	10.50	24.68		43.18	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 41.725 \text{ (tf/m}^2\text{)}, Q_0 = 35.348 \text{ (tf/m}^2\text{)}$$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-134.88	1.80	-242.55	-	-	-
Total	-	-134.88		-242.55	-	-	-

Subgrade Reaction with Earthquake

$$Q_1 = 50.220 \text{ (tf/m}^2\text{)}, Q_0 = 39.899 \text{ (tf/m}^2\text{)}$$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-157.71	1.82	-286.52	-	-	-
Total	-	-157.71		-286.52	-	-	-

Uplift

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-2.04	1.17	-2.38	-	-	-
Total	-	-2.04		-2.38	-	-	-

(ii-2) Structural Calculation of Toe Slab (Surcharge Water Surface)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-134.88	0.00	-242.55	0.00
Uplift	-2.04	0.00	-2.38	0.00
Total	-112.24	0.00	-201.75	0.00

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

Stress calculation of concrete

Shear stress $\tau_c = 3.74 \text{ (kgf/m}^2\text{)} < 5.5 \text{ OK}$

Compressive stress	$\sigma_c =$	13.45 (kgf/m ²)	<	60	OK
Tensile stress	$\sigma_t =$	-13.45 (kgf/m ²)	>	-3	NG

Seismic condition (with Earthquake), $K_h=0.08(50\%)$

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-157.71	0.00	-286.52	0.00
Uplift	-2.04	0.00	-2.38	0.00
Total	-135.07	0.00	-245.72	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c =$	4.50 (kgf/m ²)	<	8.25	OK
Compressive stress	$\sigma_c =$	16.38 (kgf/m ²)	<	90	OK
Tensile stress	$\sigma_t =$	-16.38 (kgf/m ²)	>	-4.5	NG

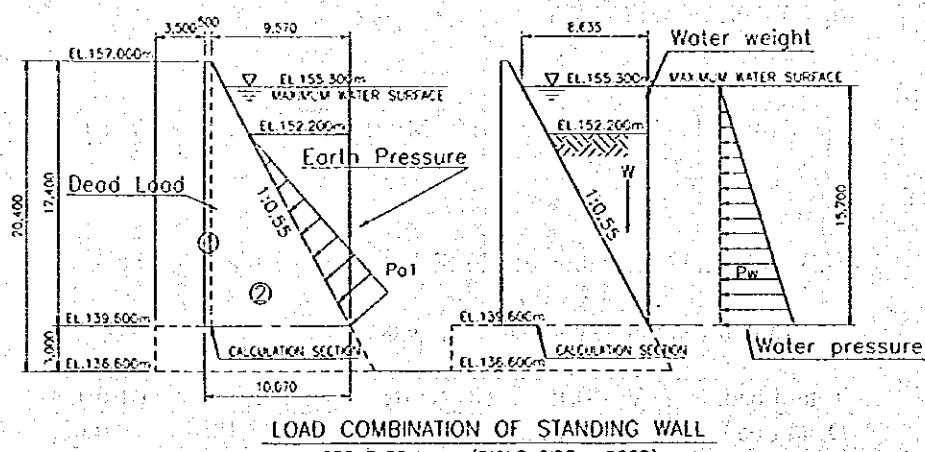
(d) Case 3 : Right Side Upper Separate Wall, Maximum Water Surface : EL.155.300m

Horizontal seismic coefficient : $K_h=0.0 (0\%)$

(i) Standing Wall of Right Side Upper Separate Wall (Maximum Water Surface)

(i-1) Loading Calculation of Standing Wall (Maximum Water Surface)

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)	8.70	20.45	-4.79	-97.83	0.00	8.70	0.00
2(concrete)	83.26	195.66	-1.35	-263.16	0.00	5.80	0.00
Total	91.96	216.10		-360.99	0.00		0.00

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.468$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
P _{a1}	-	48.13	2.40	115.26	-29.13	4.80	-139.84
Total	-	48.13		115.26	-29.13		-139.84

Water Pressure

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, P _w	-	67.78	2.16	146.19	-123.25	5.23	-644.98
Total		67.78		146.19	-123.25		-644.98

(i-2) Structural Calculation of Standing Wall (Maximum Water Surface)

Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	216.10	0.00	-360.99	0.00
Earth Pressure	48.13	-29.13	115.26	-139.84
Water Pressure	67.78	-123.25	146.19	-644.98
Total	332.01	-152.38	-99.54	-784.82

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

Safety against overturning

$$e = -2.664 \text{ m} > -1.678 \text{ m} = b/6 \quad \text{NG}$$

Stress calculation of concrete

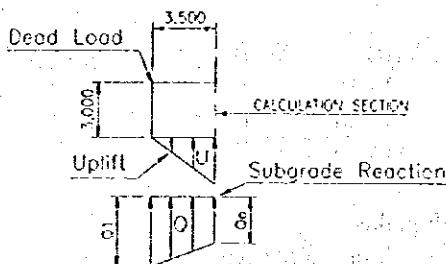
$$\text{Compressive stress } \sigma_c = 8.53 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -1.94 \text{ (kgf/m}^2\text{)} < -4.5 \text{ OK}$$

(ii) Toe Slab of Right Side Upper Separate Wall (Maximum Water Surface)

(ii-1) Loading Calculation of Toe Slab (Maximum Water Surface)

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



LOAD COMBINATION OF TOE SLAB

SEPARATE WALL (RIGHT SIDE, UPPER)
CASE 2 : MAXIMUM WATER SURFACE (EL.155.300m)

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)	10.50	24.68	1.75	43.18	-	-	-
Total	10.50	24.68		43.18			

Subgrade Reaction without Earthquake

$$Q_1 = 53.197 \text{ (tf/m}^2\text{)}, \quad Q_0 = 41.923 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-166.46	1.82	-302.81	-	-	-
Total	-	-166.46		-302.81			

Uplift

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-2.51	1.17	-2.93	-	-	-
Total	-	-2.51		-2.93			

(ii-2) Structural Calculation of Toe Slab (Maximum Water Surface)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-166.46	0.00	-302.81	0.00
Uplift	-2.51	0.00	-2.93	0.00
Total	-144.29	0.00	-262.56	0.00

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

Stress calculation of concrete

Shear stress $\tau_c = 4.81 \text{ (kgf/m}^2\text{)} < 12 \text{ OK}$

Compressive stress $\sigma_c = 17.50 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$

Tensile stress $\sigma_t = -17.50 \text{ (kgf/m}^2\text{)} > -4.5 \text{ NG}$

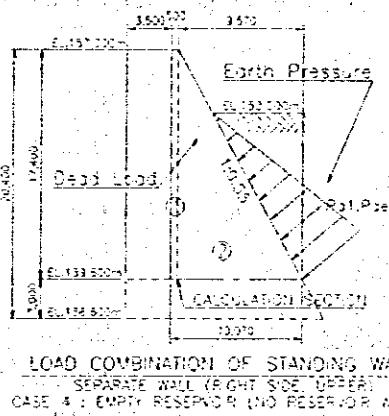
(e) Case 4 : Right Side Upper Separate Wall, Empty Reservoir (No Reservoir Water)

Horizontal seismic coefficient : $K_h = 0.08 \text{ (50%)}$

(i) Standing Wall of Right Side Upper Separate Wall
 (Empty Reservoir)

(i-1) Loading Calculation of Standing Wall (Empty Reservoir)

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)	8.70	20.45	-4.79	-97.83	-1.64	8.70	-14.23
2(concrete)	83.26	195.66	-1.35	-263.16	-15.65	5.80	-90.79
Total	91.96	216.10		-360.99	-17.29		-105.02

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a = 0.468$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pal	-	80.49	2.40	192.76	-48.72	4.80	-233.87
Total	-	80.49		192.76	-48.72		-233.87

Earth Pressure with Earthquake

Seismic composite angle : $\theta_0 = 4.6(\text{degree})$ ($\tan \theta_0 = K_h = 0.08$)

Coefficient of active earth pressure : $K_{ae} = 0.505$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	79.27	2.40	189.84	-63.48	4.80	-304.70
Total	-	79.27		189.84	-63.48		-304.70

(i-2) Structural Calculation of Standing Wall (Empty Reservoir)

Normal condition (without Earthquake)

Total Load	V(-N)(tf)	H(-S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	216.10	0.00	-360.99	0.00
Earth Pressure	80.49	-48.72	192.76	-233.87
Total	296.59	-48.72	-168.23	-233.87

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

Safety against overturning

$$e = -1.356 \text{ m} > 1.678 \text{ m} = b/6 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

Compressive stress	$\sigma_c =$	5.32 (kgf/m^2)	<	60	OK
Tensile stress	$\sigma_t =$	0.57 (kgf/m^2)	<	-3	OK

Seismic condition (with Earthquake); $K_h=0.08(50\%)$

Total Load	$V(=N)(\text{tf})$	$H(=S)(\text{tf})$	$M_x(\text{tf-m})$	$M_y(\text{tf-m})$
Dead Load	216.1	-17.3	-361.0	-105.0
Earth Pressure	79.3	-63.5	189.8	-304.7
Total	295.4	-80.8	-171.1	-409.7

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

Safety against overturning

$$e = -1.967 \text{ m} < 3.357 \text{ m} = b/3 \quad \text{OK}$$

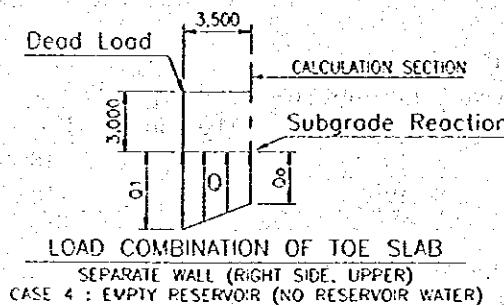
Stress calculation of concrete

Compressive stress	$\sigma_c =$	6.37 (kgf/m^2)	<	90	OK
Tensile stress	$\sigma_t =$	-0.50 (kgf/m^2)	<	-4.5	OK

(ii) Toe Slab of Right Side Upper Separate Wall (Empty Reservoir)

(ii-1) Loading Calculation of Toe Slab (Empty Reservoir)

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



Each load is calculated hereinafter.

Dead Load

	$A(\text{m}^2)$	$V(\text{tf})$	$X(\text{m})$	$M_x(\text{tf-m})$	$H(\text{tf})$	$Y(\text{m})$	$M_y(\text{tf-m})$
1(concrete)	10.50	24.68	1.75	43.18	-	-	-
Total	10.50	24.68		43.18	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 31.057 \text{ (tf/m}^2\text{)}, Q_0 = 29.921 \text{ (tf/m}^2\text{)}$$

	$A(\text{m}^2)$	$V(\text{tf})$	$X(\text{m})$	$M_x(\text{tf-m})$	$H(\text{tf})$	$Y(\text{m})$	$M_y(\text{tf-m})$
Q	-	-106.71	1.76	-187.91	-	-	-
Total	-	-106.71		-187.91	-	-	-

Subgrade Reaction with Earthquake

$$Q_1 = 38.754 \text{ (tf/m}^2\text{)}, Q_0 = 34.024 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-127.36	1.79	-227.71	-	-	-
Total	-	-127.36	-	-227.71	-	-	-

(ii-2) Structural Calculation of Toe Slab (Empty Reservoir)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-106.71	0.00	-187.91	0.00
Total	-82.04	0.00	-144.73	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c = 2.73 \text{ (kgf/m}^2\text{)}$	< 5.5	OK
Compressive stress	$\sigma_c = 9.65 \text{ (kgf/m}^2\text{)}$	< 60	OK
Tensile stress	$\sigma_t = -9.65 \text{ (kgf/m}^2\text{)}$	> -3	NG

Seismic condition (with Earthquake), Kh=0.08(50%)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-127.36	0.00	-227.71	0.00
Total	-102.69	0.00	-184.53	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c = 3.42 \text{ (kgf/m}^2\text{)}$	< 8.25	OK
Compressive stress	$\sigma_c = 12.30 \text{ (kgf/m}^2\text{)}$	< 90	OK
Tensile stress	$\sigma_t = -12.30 \text{ (kgf/m}^2\text{)}$	> -4.5	NG

(f) Calculation of reinforcing bar arrangement for Right Side Upper Separate Wall

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

(i) Standing Wall of Right Side Upper Separate Wall

[Calculation of reinforcing bar arrangement for Right Side Upper Separate Wall]

Member		Standing Wall			
Reservoir Water Surface		Normal	Surcharge	Maximum	Empty
Calculation condition		Seismic	Seismic	Normal	Seismic
Earthquake		100%	50%	0%	50%
Shape of member		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	802.2	792.4	884.36	580.8
N	tf	316.4	313.4	332.01	295.4
S	tf	147.2	143.8	152.38	80.8
B	cm	100	100	100	100
D	cm	997	997	997	997
A _c	cm ²	99700	99700	99700	99700
A _s	cm ²	D19@200 =14.20	D19@200 =14.20	D19@200 =14.20	D19@200 =14.20
P=A _s /(B × D)		0.00014	0.00014	0.00014	0.00014
N=E _s /E _c		15	15	15	15
X ₀	cm	739.4	741.4	702.3	906.6
K=X ₀ /D		0.742	0.744	0.704	0.909
M/(B × D ²)	kgf/cm ²	0.807	0.797	0.89	0.584
S/(B × D)	kgf/cm ²	1.476	1.442	1.528	0.81
(C)		10.626	10.626	10.655	11.158
(S)		3.702	3.662	4.472	1.112
(Z)		1.985	1.98	2.081	1.635
σ_c	kgf/cm ²	8.6	8.5	9.5	6.5
σ_s	kgf/cm ²	45	44	60	10
τ	kgf/cm ²	1.48	1.44	1.53	0.81
σ_{ca}	kgf/cm ²	90	90	90	90
σ_{sa}	kgf/cm ²	2700	2700	2700	2700
τ_a	kgf/cm ²	8.25	8.25	8.25	8.25

(ii) Toe Slab of Right Side Upper Separate Wall

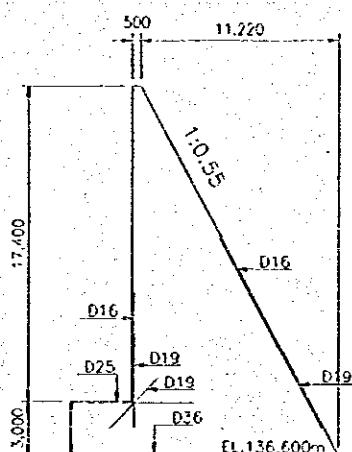
[Calculation of reinforcing bar arrangement for Right Side Upper Separate Wall
(Normal Case)]

Member		Toe Slab			
Reservoir Water Surface		Normal	Surcharge	Maximum	Empty
Calculation condition		Normal	Normal	Normal	Normal
Earthquake		0%	0%	0%	0%
Shape of member		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	172.81	201.75	262.56	144.73
N	tf	0	0	0	0
S	tf	97.01	112.24	144.29	82.04
B	cm	100	100	100	100
D	cm	290	290	290	290
A _c	cm ²	29000	29000	29000	29000
A _s	cm ²	D36@200 =51.00	D36@200 =51.00	D36@200 =51.00	D36@200 =51.00
P=A _s /(B × D)		0.00176	0.00176	0.00176	0.00176
N=E _s /E _c		15	15	15	15
X ₀	cm	59.4	59.4	59.4	59.4
K=X ₀ /D		0.205	0.205	0.205	0.205
M/(B × D ³)	kgf/cm ²	2.055	2.399	3.122	1.721
S/(B × D)	kgf/cm ²	3.345	3.87	4.976	2.829
(C)		10.48	10.48	10.48	10.48
(S)		40.686	40.686	40.686	40.686
(Z)		1.073	1.073	1.073	1.073
σ _c	kgf/cm ²	21.5	25.1	32.7	18
σ _s	kgf/cm ²	1254	1464	1905	1050
τ	kgf/cm ²	3.35	3.87	4.98	2.83
σ _{ca}	kgf/cm ²	60	60	90	60
σ _{sa}	kgf/cm ²	1800	1800	2700	1800
τ _a	kgf/cm ²	5.5	5.5	8.25	5.5

[Calculation of reinforcing bar arrangement for Right Side Upper Separate Wall]
(Seismic Case)

Member		Toe Slab		
Reservoir Water Surface		Normal	Surcharge	Empty
Calculation condition		Seismic	Seismic	Seismic
Earthquake	100%	50%	50%	
Shape of member		Rectangle	Rectangle	Rectangle
M	tf-m	249.68	245.72	184.53
N	tf	0	0	0
S	tf	137.24	135.07	102.69
B	cm	100	100	100
D	cm	290	290	290
A _c	cm ²	29000	29000	29000
A _s	cm ²	D36@200 =51.00	D36@200 =51.00	D36@200 =51.00
P=A _s (B × D)		0.00176	0.00176	0.00176
N=E _s /E _c		15	15	15
X ₀	cm	59.4	59.4	59.4
K=X ₀ /D		0.205	0.205	0.205
M/(B × D ²)	kgf/cm ²	2.969	2.922	2.194
S/(B × D)	kgf/cm ²	4.732	4.658	3.541
(C)		10.48	10.48	10.48
(S)		40.686	40.686	40.686
(Z)		1.073	1.073	1.073
σ _c	kgf/cm ²	31.1	30.6	23
σ _s	kgf/cm ²	1812	1783	1339
τ	kgf/cm ²	4.73	4.66	3.54
σ _{ca}	kgf/cm ²	90	90	90
σ _{sa}	kgf/cm ²	2700	2700	2700
τ _a	kgf/cm ²	8.25	8.25	8.25

Figure of main reinforcing bar arrangement is shown as follow.



SEPARATE WALL (RIGHT SIDE, UPPER)

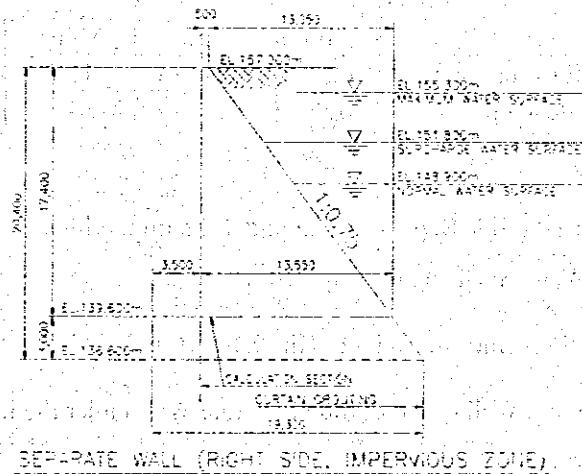
(4) Right Side Separate Wall under the Impervious Zone

Structural calculations of standing wall and toe slab are carried out for the Right Side Upper Separate Wall.

Since Right Side Separate Wall under the Impervious Zone faces to reservoir water, four (4) cases are studied accordingly conditions of reservoir water surface.

(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)	2.35	Thick structure
Unit weight of wetted impervious material (Dam)	γ_t	(tf/m ³)	2.11	Wet density
Unit weight of submerged impervious material (Dam)	γ_s	(tf/m ³)	1.19	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)	36.87	V:H=1:0.75
Angle between ground surface and horizontal plane	α	(degree)	0.0	
Internal friction angle of soil	ϕ	(degree)	30.0	Impervious material of Dam
Friction angle of soil to concrete	δ	(degree)	20.0	$\delta = 2/3 \phi$

$$Kea = \frac{\cos^2(\phi - \theta_0 - \alpha)}{\cos \theta_0 \cdot \cos^2 \theta \cdot \cos(0 + \theta_0 + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(0 + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

Kea : Coefficient of active earth pressure under seismic condition

Item	Symbol	Unit	Value	Description
Friction angle of soil to concrete	δ_e	(degree)	15.0	$\delta_e = 1/2 \phi$
Seismic composite angle	θ_0	(degree)	-	$\tan \theta_0 = Kh$

(b) Case 1 : Right Side Separate Wall under the Impervious Zone,

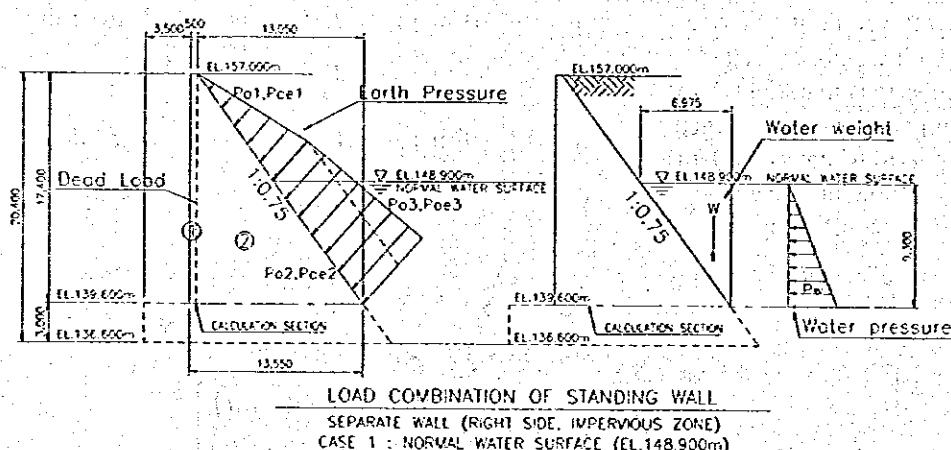
Normal Water Surface : EL.148.900m

Horizontal seismic coefficient : Kh=0.16 (100%)

(i) Standing Wall of Right Side Separate Wall under the Impervious Zone (Normal Water Surface)

(i-1) Loading Calculation of Standing Wall (Normal Water Surface)

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)	8.70	20.45	-6.53	-133.40	-3.27	8.70	-28.46
2(concrete)	113.54	266.81	-1.93	-513.60	-42.69	5.80	-247.60
Total	122.24	287.25		-647.01	-45.96		-276.06

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.752$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	43.58	-2.23	-96.97	-28.44	12.00	-341.33
Pa2	-	100.08	3.29	329.01	-65.32	4.65	-303.72
Pa3	-	32.40	4.45	144.19	-21.15	3.10	-65.56
Total	-	176.07		376.23	-114.91		-710.61

Earth Pressure with Earthquake

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

Coefficient of active earth pressure : $Kea=0.924$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	50.30	-2.23	-111.91	-39.48	12.00	-473.75
Pae2	-	115.49	3.29	379.68	-90.66	4.65	-421.55
Pae3	-	37.39	4.45	166.40	-29.35	3.10	-90.99
Total	-	203.18		434.18	-159.49		-986.29

Water Pressure

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	-	32.43	4.45	144.33	-43.25	3.10	-134.06
Total	-	32.43		144.33	-43.25		-134.06

(i-2) Structural Calculation of Standing Wall (Nominal Water Surface)

Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	287.3	0.0	-647.0	0.0
Earth Pressure	176.1	-114.9	376.2	-710.6
Water Pressure	32.4	-43.2	144.3	-134.1
Total	495.8	-158.2	-126.4	-844.7

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

Safety against overturning

$$e = -1.959 \text{ m} < 2.258 \text{ m} = b/6 \quad \text{OK}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 6.83 \text{ (kgf/m}^2\text{)} < 60 \quad \text{OK}$$

$$\text{Tensile stress } \sigma_t = 0.49 \text{ (kgf/m}^2\text{)} < 3 \quad \text{OK}$$

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

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	287.3	-46.0	-647.0	-276.1
Earth Pressure	203.2	-159.5	434.2	-986.3
Water Pressure	32.4	-43.2	144.3	-134.1
Total	522.9	-248.7	-68.5	-1,396.4

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

Safety against overturning

$$e = -2.802 \text{ m} < 4.517 \text{ m} = b/3 \quad \text{OK}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 8.65 \text{ (kgf/m}^2\text{)} < 90 \quad \text{OK}$$

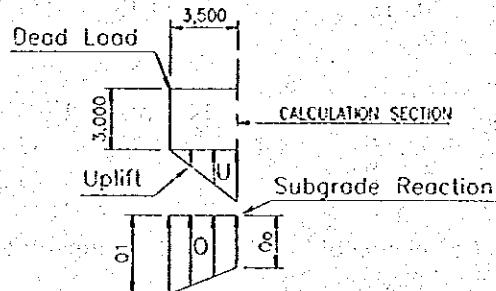
$$\text{Tensile stress } \sigma_t = -0.93 \text{ (kgf/m}^2\text{)} < -4.5 \quad \text{OK}$$

(ii) Toe Slab of Right Side Separate Wall under the Impervious Zone

(Normal Water Surface)

(ii-1) Loading Calculation of Toe Slab (Normal Water Surface)

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



LOAD COMBINATION OF TOE SLAB

SEPARATE WALL (RIGHT SIDE IMPERVIOUS ZONE)

CASE 1 : NORMAL WATER SURFACE (EL.148.900m)

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)	10.50	24.68	1.75	43.18	-	-	-
Total	10.50	24.68		43.18	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 46.423 \text{ (tf/m}^2\text{)}, Q_0 = 42.086 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-154.89	1.78	-275.48	-	-	-
Total	-	-154.89		-275.48	-	-	-

Subgrade Reaction with Earthquake
 $Q_1 = 59.960 \text{ (tf/m}^2\text{)}$, $Q_0 = 51.387 \text{ (tf/m}^2\text{)}$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-194.86	1.79	-349.75	-	-	-
Total	-	-194.86		-349.75	-		-

Uplift

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-1.30	1.17	-1.52	-	-	-
Total		-1.30		-1.52	-		-

(ii-2) Structural Calculation of Toe Slab (Normal Water Surface)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-154.89	0.00	-275.48	0.00
Uplift	-1.30	0.00	-1.52	0.00
Total	-131.52	0.00	-233.82	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c = 4.38 \text{ (kgf/m}^2\text{)}$	<	5.5	OK
Compressive stress	$\sigma_c = 15.59 \text{ (kgf/m}^2\text{)}$	<	60	OK
Tensile stress	$\sigma_t = -15.59 \text{ (kgf/m}^2\text{)}$	>	-3	NG

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	24.68	0.00	43.18	0.00
Subgrade Reaction	-194.86	0.00	-349.75	0.00
Uplift	-1.30	0.00	-1.52	0.00
Total	-171.48	0.00	-308.09	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c = 5.72 \text{ (kgf/m}^2\text{)}$	<	8.25	OK
Compressive stress	$\sigma_c = 20.54 \text{ (kgf/m}^2\text{)}$	<	90	OK
Tensile stress	$\sigma_t = -20.54 \text{ (kgf/m}^2\text{)}$	>	-4.5	NG

(c) Case 2 : Right Side Separate Wall under the Impervious Zone,

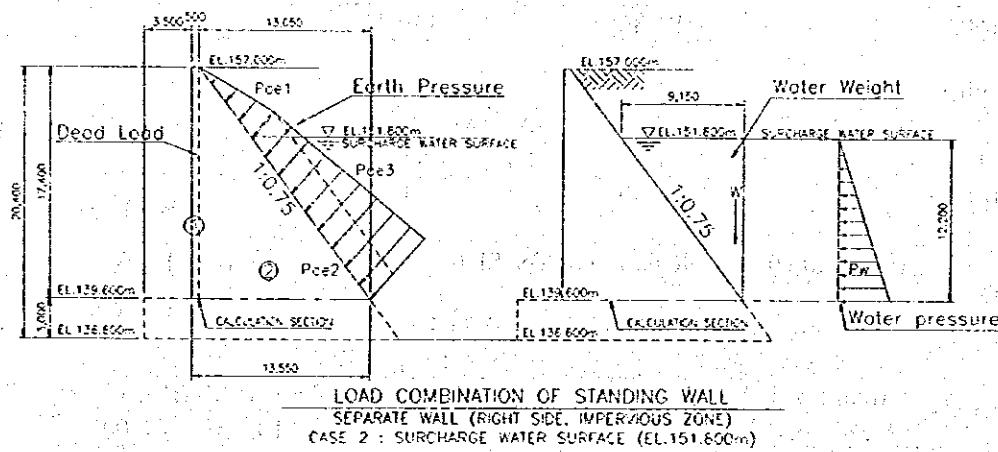
Surcharge Water Surface : EL.151.800m

Horizontal seismic coefficient : $K_h=0.08(50\%)$

(i) Standing Wall of Right Side Separate Wall under the Impervious Zone
 (Surcharge Water Surface)

(i-1) Loading Calculation of Standing Wall (Surcharge Water Surface)

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)	8.70	20.45	-6.53	-133.40	-1.64	8.70	-14.23
2(concrete)	113.54	266.81	-1.93	-513.60	-21.34	5.80	-123.80
Total	122.24	287.25		-647.01	-22.98		-138.03

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.752$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	17.96	-3.68	-66.01	-11.72	13.93	-163.34
Pa2	-	84.28	2.20	185.42	-55.01	6.10	-335.54
Pa3	-	55.76	3.73	207.71	-36.39	4.07	-147.99
Total	-	158.01		327.12	-103.12		-646.87

Earth Pressure with Earthquake

Seismic composite angle : $\theta_0=4.6(\text{degree})$ ($\tan\theta_0=Kh=0.08$)

Coefficient of active earth pressure : $K_{ea}=0.815$

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	18.28	-3.68	-67.19	-14.35	13.93	-199.95
Pae2	-	85.78	2.20	188.73	-67.34	6.10	-410.75
Pae3	-	56.75	3.73	211.41	-44.55	4.07	-181.17
Total	-	160.82		332.95	-126.24		-791.87

Water Pressure

	A(m^2)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	-	55.82	3.73	207.91	-74.42	4.07	-302.64
Total	-	55.82		207.91	-74.42		-302.64

(i-2) Structural Calculation of Standing Wall (Surcharge Water Surface)

Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	287.3	0.0	-647.0	0.0
Earth Pressure	158.0	-103.1	327.1	-646.9
Water Pressure	55.8	-74.4	207.9	-302.6
Total	501.1	-177.5	-112.0	-949.5

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

Safety against overturning

$$e = -2.118 \text{ m} < 2.258 \text{ m} = b/6 \quad \text{OK}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 7.17 \text{ (kgf/m}^2\text{)} < 60 \quad \text{OK}$$

$$\text{Tensile stress } \sigma_t = 0.23 \text{ (kgf/m}^2\text{)} < -3 \quad \text{OK}$$

Seismic condition (with Earthquake); Kh=0.08(50%)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	287.3	-23.0	-647.0	-138.0
Earth Pressure	160.8	-126.2	332.9	-791.9
Water Pressure	55.8	-74.4	207.9	-302.6
Total	503.9	-223.6	-106.1	-1,232.5

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

Safety against overturning

$$e = -2.657 \text{ m} < 4.517 \text{ m} = b/3 \quad \text{OK}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 8.09 \text{ (kgf/m}^2\text{)} < 90 \quad \text{OK}$$

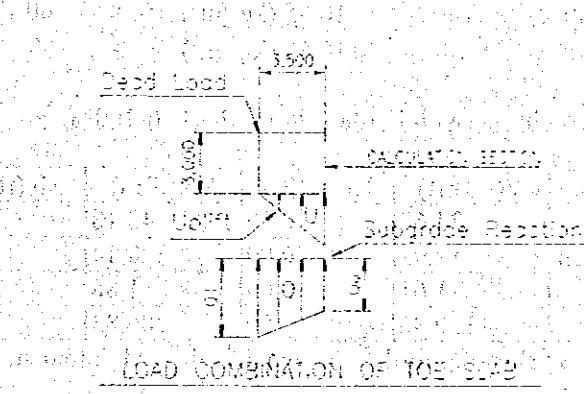
$$\text{Tensile stress } \sigma_t = -0.66 \text{ (kgf/m}^2\text{)} < -4.5 \quad \text{OK}$$

(ii) Toe Slab of Right Side Separate Wall under the Impervious Zone

(Surcharge Water Surface)

(iii-1) Loading Calculation of Toe Slab (Surcharge Water Surface)

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)	10.50	24.68	1.75	43.18	-	-	-
Total	10.50	24.68		43.18	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 49.041 \text{ (tf/m}^2\text{)}, \quad Q_0 = 43.707 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-162.31	1.78	-289.49	-	-	-
Total	-	-162.31		-289.49	-	-	-

Subgrade Reaction with Earthquake

$$Q_1 = 56.193 \text{ (tf/m}^2\text{)}, \quad Q_0 = 48.335 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-182.92	1.79	-328.14	-	-	-
Total	-	-182.92		-328.14	-	-	-

Uplift

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-1.61	1.17	-1.88	-	-	-
Total	-	-1.61		-1.88	-	-	-

(ii-2) Structural Calculation of Toe Slab (Surcharge Water Surface)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	25	0	43	0
Subgrade Reaction	-162	0	-289	0
Uplift	-2	0	-2	0
Total	-139	0	-248	0

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

Stress calculation of concrete

Shear stress $\tau_c = 4.64 \text{ (kgf/m}^2\text{)} < 5.5 \text{ OK}$

Compressive stress $\sigma_c = 16.55 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$

Tensile stress $\sigma_t = -16.55 \text{ (kgf/m}^2\text{)} > -3 \text{ NG}$

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

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-182.92	0.00	-328.14	0.00
Uplift	-1.61	0.00	-1.88	0.00
Total	-159.86	0.00	-286.83	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c =$	5.33 (kgf/m ²)	<	8.25	OK
Compressive stress	$\sigma_c =$	19.12 (kgf/m ²)	<	90	OK
Tensile stress	$\sigma_t =$	-19.12 (kgf/m ²)	>	-4.5	NG

(d) Case 3 : Right Side Separate Wall under the Impervious Zone,

Maximum Water Surface : EL.155.300m

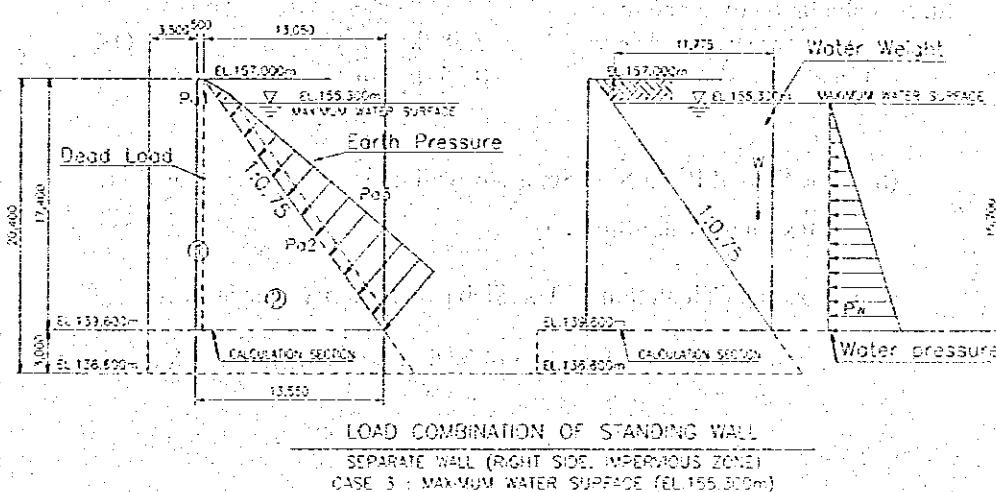
Horizontal seismic coefficient : Kh=0.0 (0%)

(i) Standing Wall of Right Side Separate Wall under the Impervious Zone

(Maximum Water Surface)

(i-1) Loading Calculation of Standing Wall (Maximum Water Surface)

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)	8.70	20.45	-6.53	-133.40	-	-	-
2(concrete)	113.54	266.81	-1.93	-513.60	-	-	-
Total	122.24	287.25		-647.01	-	-	-

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.752$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	1.92	-5.43	-10.41	-1.25	16.27	-20.38
Pa2	-	35.46	0.89	31.47	-23.14	7.85	-181.67
Pa3	-	92.34	2.85	263.18	-60.27	5.23	-315.40
Total	-	129.72		284.24	-84.66		-517.45

Water Pressure

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw		92.43	2.85	263.44	-123.25	5.23	-644.98
Total		92.43		263.44	-123.25		-644.98

(i-2) Structural Calculation of Standing Wall (Maximum Water Surface)

Normal condition (without Earthquake)

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	287.3	0.0	-647.0	0.0
Earth Pressure	129.7	-84.7	284.2	-517.4
Water Pressure	92.4	-123.2	263.4	-645.0
Total	509.4	-207.9	-99.3	-1,162.4

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

Safety against overturning

$$e = -2.477 \text{ m} > 2.258 \text{ m} = b/6 \quad \boxed{\text{NG}}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 7.88 \text{ (kgf/m}^2\text{)} < 90 \quad \text{OK}$$

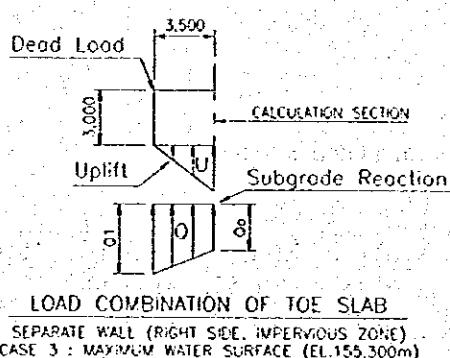
$$\text{Tensile stress } \sigma_t = -0.36 \text{ (kgf/m}^2\text{)} < -4.5 \quad \text{OK}$$

(ii) Toe Slab of Right Side Separate Wall under the Impervious Zone

(Maximum Water Surface)

(ii-1) Loading Calculation of Toe Slab (Maximum Water Surface)

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)	10.50	24.68	1.75	43.18	-	-	-
Total	10.50	24.68		43.18			

Subgrade Reaction without Earthquake

$$Q_1 = 54.087 \text{ (tf/m}^2\text{)}, \quad Q_o = 46.902 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-176.73	1.79	-316.61	-	-	-
Total	-	-176.73		-316.61	-	-	-

Uplift

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-1.98	1.17	-2.31	-	-	-
Total	-	-1.98		-2.31	-	-	-

(ii-2) Structural Calculation of Toe Slab (Maximum Water Surface)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-176.73	0.00	-316.61	0.00
Uplift	-1.98	0.00	-2.31	0.00
Total	-154.03	0.00	-275.74	0.00

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

Stress calculation of concrete

Shear stress $\tau_c = 5.13 \text{ (kgf/m}^2\text{)} < 8.25 \text{ OK}$

Compressive stress $\sigma_c = 18.38 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$

Tensile stress $\sigma_t = -18.38 \text{ (kgf/m}^2\text{)} > -4.5 \text{ NG}$

(e) Case 4 : Right Side Separate Wall under the Impervious Zone,

Empty Reservoir (No Reservoir Water)

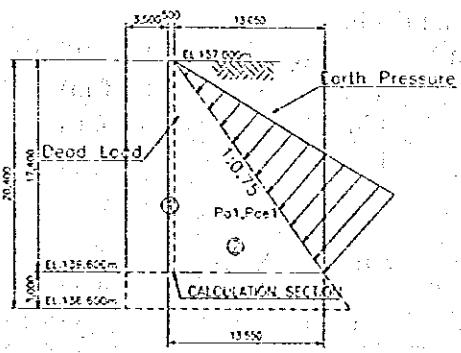
Horizontal seismic coefficient : Kh=0.08 (50%)

(i) Standing Wall of Right Side Separate Wall under the Impervious Zone

(Empty Reservoir)

(i-1) Loading Calculation of Standing Wall (Empty Reservoir)

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



LOAD COMBINATION OF STANDING WALL
SEPARATE WALL (RIGHT SIDE, INFERIOR ZONE)
CASE 4 : EMPTY RESERVOIR (NO RESERVOIR WATER)

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)	8.70	20.45	-6.53	-133.40	-1.64	8.70	-14.23
2(concrete)	113.54	266.81	-1.93	-513.60	-21.34	5.80	-123.80
Total	122.24	287.25		-647.01	-22.98		-138.03

Earth Pressure without Earthquake

Coefficient of active earth pressure : $K_a=0.752$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pal	-	201.12	2.43	487.71	-131.26	5.80	-761.29
Total	-	201.12		487.71	-131.26		-761.29

Earth Pressure with Earthquake

Seismic composite angle : $\theta_0=4.6(\text{degree})$ ($\tan\theta_0=Kh=0.08$)

Coefficient of active earth pressure : $Kea=0.815$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pael	-	204.70	2.43	496.39	-160.68	5.80	-931.93
Total	-	204.70		496.39	-160.68		-931.93

(i-2) Structural Calculation of Standing Wall (Empty Reservoir)

Normal condition (without Earthquake)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	287.25	0.00	-647.01	0.00
Earth Pressure	201.12	-131.26	487.71	-761.29
Total	488.37	-131.26	-159.30	-761.29

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

Safety against overturning

$$e = -1.885 \text{ m} < 2.258 \text{ m} = b/6 \quad \text{OK}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 6.61 \text{ (kgf/m}^2\text{)} < 60 \quad \text{OK}$$

$$\text{Tensile stress } \sigma_t = 0.60 \text{ (kgf/m}^2\text{)} < -3 \quad \text{OK}$$

Seismic condition (with Earthquake); Kh=0.08(50%)

Total Load	V(=N)(tf)	H(=S)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	287.3	-23.0	-647.0	-138.0
Earth Pressure	204.7	-160.7	496.4	-931.9
Total	492.0	-183.7	-150.6	-1,070.0

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

Safety against overturning

$$e = -2.481 \text{ m} < 4.517 \text{ m} = b/3 \quad \text{OK}$$

Stress calculation of concrete

$$\text{Compressive stress } \sigma_c = 7.62 \text{ (kgf/m}^2\text{)} < 90 \quad \text{OK}$$

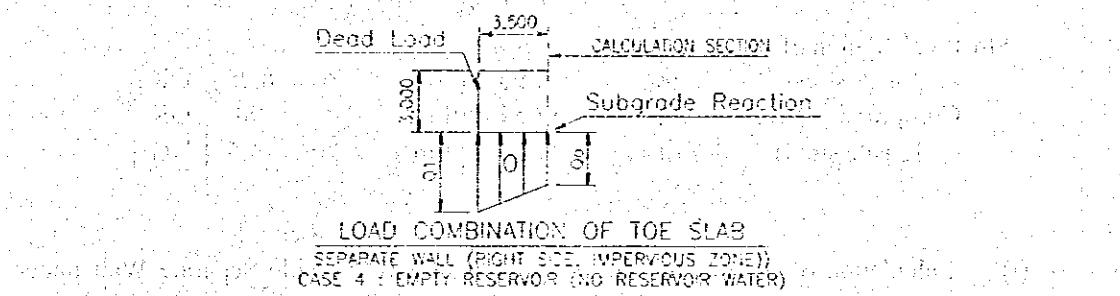
$$\text{Tensile stress } \sigma_t = -0.36 \text{ (kgf/m}^2\text{)} < -4.5 \quad \text{OK}$$

(ii) Toe Slab of Right Side Separate Wall under the Impervious Zone

(Empty Reservoir)

(ii-1) Loading Calculation of Toe Slab (Empty Reservoir)

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)	10.50	24.68	1.75	43.18	-	-	-
Total	10.50	24.68	-	43.18	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 44.014 \text{ (tf/m}^2\text{)}, Q_o = 41.052 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-148.87	1.77	-263.54	-	-	-
Total	-	-148.87	-	-263.54	-	-	-

Subgrade Reaction with Earthquake

$$Q_1 = 51.914 \text{ (tf/m}^2\text{)}, Q_o = 46.179 \text{ (tf/m}^2\text{)}$$

	A(m ²)	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-171.66	1.78	-306.27	-	-	-
Total	-	-171.66	-	-306.27	-	-	-

(ii-2) Structural Calculation of Toe Slab (Empty Reservoir)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-148.87	0.00	-263.54	0.00
Total	-124.19	0.00	-220.36	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c =$	4.14 (kgf/m ²)	<	5.5	OK
Compressive stress	$\sigma_c =$	14.69 (kgf/m ²)	<	60	OK
Tensile stress	$\sigma_t =$	-14.69 (kgf/m ²)	>	-3	NG

Seismic condition (with Earthquake), Kh=0.08(50%)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	24.68	0.00	43.18	0.00
Subgrade Reaction	-171.66	0.00	-306.27	0.00
Total	-146.99	0.00	-263.09	0.00

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

Stress calculation of concrete

Shear stress	$\tau_c =$	4.90 (kgf/m ²)	<	8.25	OK
Compressive stress	$\sigma_c =$	17.54 (kgf/m ²)	<	90	OK
Tensile stress	$\sigma_t =$	-17.54 (kgf/m ²)	>	-4.5	NG

- (f) Calculation of reinforcing bar arrangement for Right Side Separate Wall under the Impervious Zone

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

- (i) Standing Wall of Right Side Separate Wall under the Impervious Zone

In all calculated cases and conditions, calculated stresses of concrete are smaller than allowable stresses. Therefore, the reinforcing bar arrangement is not necessary for Standing Wall of the Right Side Separate Wall under the Impervious Zone.

- (ii) Toe Slab of Right Side Separate Wall under the Impervious Zone

[Calculation of reinforcing bar arrangement
for Right Side Separate Wall under the Impervious Zone]

(Normal Case)

Member		Toe Slab			
Reservoir Water Surface		Normal	Surcharge	Maximum	Empty
Calculation condition		Normal	Normal	Normal	Normal
Earthquake		0%	0%	0%	0%
Shape of member		Rectangle	Rectangle	Rectangle	Rectangle
M	tf-m	233.82	248.0	275.74	220.36
N	tf	0	0	0	0
S	tf	131.51	139.0	154.03	124.19
B	cm	100	100	100	100
D	cm	290	290	290	290
A _c	cm ²	29000	29000	29000	29000
A _s	cm ²	D36@200 =51.00	D36@200 =51.00	D36@200 =51.00	D36@200 =51.00
P=A _s /(B × D)		0.00176	0.00176	0.00176	0.00176
N=E _s /E _c		15	15	15	15
X ₀	cm	59.4	59.4	59.4	59.4
K=X ₀ /D		0.205	0.205	0.205	0.205
M/(B × D ²)	kgf/cm ²	2.78	2.949	3.279	2.62
S/(B × D)	kgf/cm ²	4.535	4.793	5.311	4.282
(C)		10.48	10.48	10.48	10.48
(S)		40.686	40.686	40.686	40.686
(Z)		1.073	1.073	1.073	1.073
σ _c	kgf/cm ²	29.1	30.9	34.4	27.5
σ _s	kgf/cm ²	1697	1800	2001	1599
τ	kgf/cm ²	4.53	4.79	5.31	4.28
σ _{ca}	kgf/cm ²	60	60	90	60
σ _{sa}	kgf/cm ²	1800	1800	2700	1800
τ _a	kgf/cm ²	5.5	5.5	8.25	5.5

(Seismic Case)

Member		Toe Slab		
Reservoir Water Surface		Normal	Surcharge	Empty
Calculation condition	Seismic	Seismic	Seismic	Seismic
Earthquake	100%	50%	50%	
Shape of member	Rectangle	Rectangle	Rectangle	
M	tf-m	308.09	286.83	263.09
N	tf	0	0	0
S	tf	171.48	159.86	146.99
B	cm	100	100	100
D	cm	290	290	290
A _c	cm ²	29000	29000	29000
A _s	cm ²	D36@200 =51.00	D36@200 =51.00	D36@200 =51.00
P=A _s /(B × D)		0.00176	0.00176	0.00176
N=E _s /E _c		15	15	15
X ₀	cm	59.4	59.4	59.4
K=X ₀ /D		0.205	0.205	0.205
M/(B × D ²)	kgf/cm ²	3.663	3.411	3.128
S/(B × D)	kgf/cm ²	5.913	5.512	5.069
(C)		10.48	10.48	10.48
(S)		40.686	40.686	40.686
(Z)		1.073	1.073	1.073
σ_c	kgf/cm ²	38.4	35.7	32.8
σ_s	kgf/cm ²	2236	2081	1909
τ	kgf/cm ²	5.91	5.51	5.07
σ_{ca}	kgf/cm ²	90	90	90
σ_{sa}	kgf/cm ²	2700	2700	2700
τ_a	kgf/cm ²	8.25	8.25	8.25

Figure of main reinforcing bar arrangement is shown as follow.

