

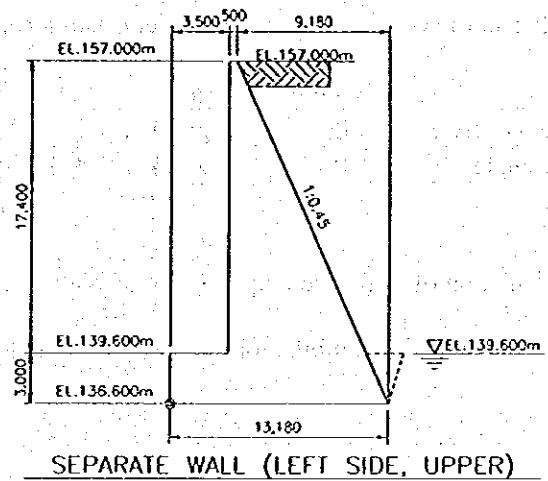
## **Control Portion**

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

### **(1) Left Side Upper Separate Wall of Control Portion**

#### **(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	$\gamma_c$	(tf/m <sup>3</sup> )	2.35	Thick structure
Unit weight of wetted backfill soil	$\gamma_t$	(tf/m <sup>3</sup> )	1.90	Wet density
Unit weight of submerged backfill soil	$\gamma_s$	(tf/m <sup>3</sup> )	0.90	Submerged density
Horizontal seismic coefficient	$K_h$	-	0.16	
Shear strength of foundation rock	$\tau_0$	(tf/m <sup>2</sup> )	45	CM-L class
Coefficient of internal friction of foundation rock	$f$	-	0.8	CM-L class

< 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	$\theta$	(degree)	24.2	V:H=1:0.45
Angle between ground surface and horizontal plane	$\alpha$	(degree)	0.0	100%
Internal friction angle of soil	$\phi$	(degree)	35.0	Sandy soil
Friction angle of soil to concrete	$\delta$	(degree)	23.3	$\delta = 2/3 \phi$

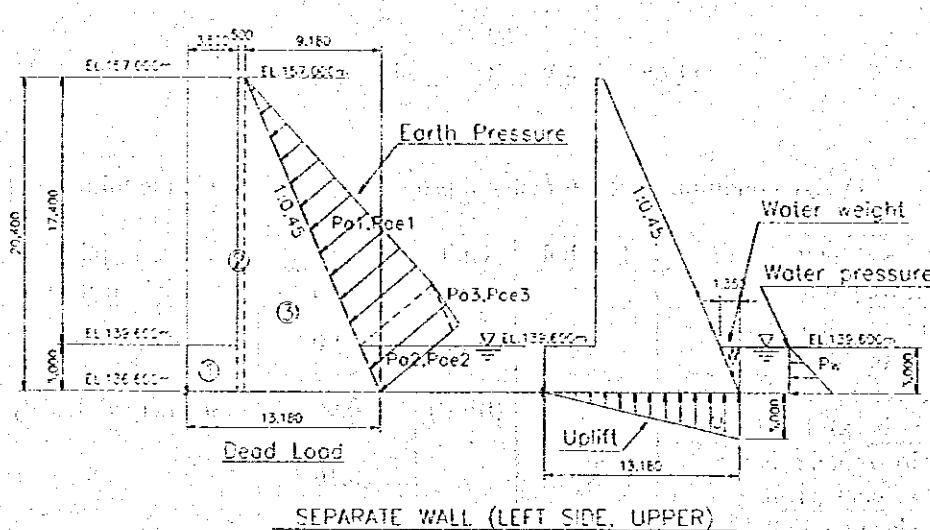
$$Kea = \frac{\cos^2(\phi - \theta_0 - \delta)}{\cos\theta_0 \cdot \cos^2\theta \cdot \cos(\theta + \theta_0 + \delta) \cdot \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

Kea : Coefficient of active earth pressure under seismic condition

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

### (b) Loading Calculation of 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)
1(concrete)	10.50	24.68	1.75	43.18	-3.95	1.50	-5.92
2(concrete)	10.20	23.97	3.75	89.89	-3.84	10.20	-39.12
3(concrete)	93.64	220.04	7.06	1,553.51	-35.21	6.80	-239.41
Total	114.34	268.69		1,686.58	-42.99		-284.45

### Earth Pressure without Earthquake

Coefficient of active earth pressure :  $K_a=0.481$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	102.12	9.22	941.53	-93.37	8.80	-821.69
Pa2	-	35.21	12.51	440.34	-32.20	1.50	-48.30
Pa3	-	1.44	12.73	18.30	-1.31	1.00	-1.31
Total	-	138.77		1,400.18	-126.89		-871.31

### 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 <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	116.93	9.22	1,078.10	-131.11	8.80	-1,153.78
Pae2	-	40.32	12.51	504.21	-45.21	1.50	-67.82
Pae3	-	1.65	12.73	20.96	-1.85	1.00	-1.85
Total	-	158.90		1,603.27	-178.17		-1,223.44

### Water Pressure

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W,Pw	2.03	2.03	12.73	25.78	-4.50	1.00	-4.50
Total		2.03		25.78	-4.50		-4.50

### Uplift

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-19.77	8.79	-173.71	-	-	-
Total		-19.77		-173.71	-		-

### (c) Stability Analysis of Left Side Upper Separate Wall

#### (i) Case 1 : Normal condition (without Earthquake)

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	268.7	0.0	1,686.6	0.0
Earth Pressure	138.8	-126.9	1,400.2	-871.3
Water Pressure	2.0	-4.5	25.8	-4.5
Uplift	-19.8	0.0	-173.7	0.0
Total	389.7	-131.4	2,938.8	-875.8

#### Safety against overturning

$$d = 5.294 \text{ m}$$

$$e = B/2 - d = 1.296 \text{ m} < 2.197 \text{ m} = b/6 \quad \text{OK}$$

#### Safety against shear

$$SF = (Vf + \tau_0 l)/H = 6.887 > 4$$

OK

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	268.7	-43.0	1,686.6	-284.4
Earth Pressure	158.9	-178.2	1,603.3	-1,223.4
Water Pressure	2.0	-4.5	25.8	-4.5
Uplift	-19.8	0.0	-173.7	0.0
Total	409.8	-225.7	3,141.9	-1,512.4

#### Safety against overturning

$$d = 3.976 \text{ m}$$

$$e = B/2 - d = 2.614 \text{ m} < 4.393 \text{ m} = b/3 \text{ OK}$$

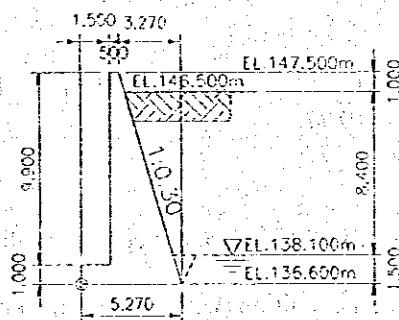
#### Safety against shear

$$SF = (Vf + \tau_0 l) / H = 4.081 > 4 \text{ OK}$$

### (2) Left Side Lower Separate Wall of Control Portion

#### (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	$\gamma_c$	(tf/m <sup>3</sup> )	2.35	Thick structure
Unit weight of wetted backfill soil	$\gamma_t$	(tf/m <sup>3</sup> )	1.90	Wet density
Unit weight of submerged backfill soil	$\gamma_s$	(tf/m <sup>3</sup> )	0.90	Submerged density
Horizontal seismic coefficient	$K_h$	-	0.16	100%
Shear strength of foundation rock	$\tau_0$	(tf/m <sup>2</sup> )	30	CL class
Coefficient of internal friction of foundation rock	f	-	0.7	CL class

< 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	$\theta$	(degree)	16.7	V:H=1:0.30
Angle between ground surface and horizontal plane	$\alpha$	(degree)	0.0	
Internal friction angle of soil	$\phi$	(degree)	35.0	Sandy soil
Friction angle of soil to concrete	$\delta$	(degree)	23.3	$\delta = 2/3 \phi$

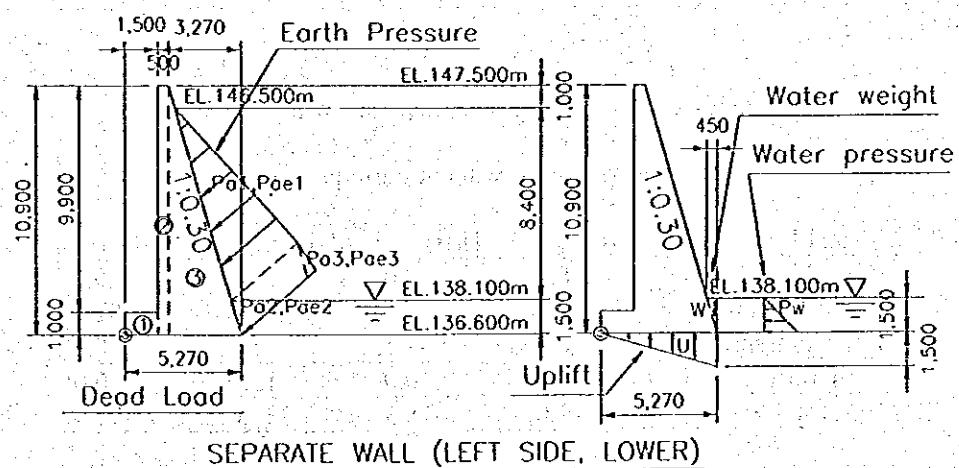
$$Kea = \frac{\cos^2(\phi - \theta_0 - \theta)}{\cos \theta_0 \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0 + \delta) \cdot \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

$Kea$  : Coefficient of active earth pressure under seismic condition

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

### (b) Loading Calculation of 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 <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	1.50	3.53	0.75	2.64	-0.56	0.50	-0.28
2(concrete)	5.45	12.81	1.75	22.41	-2.05	5.45	-11.17
3(concrete)	17.82	41.88	3.09	129.41	-6.70	3.63	-24.35
Total	24.77	58.21		154.47	-9.31		-35.80

**Earth Pressure without Earthquake**

Coefficient of active earth pressure :  $K_a=0.389$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	16.78	3.68	61.75	-19.97	4.30	-85.89
Pa2	-	5.99	5.05	30.23	-7.13	0.75	-5.35
Pa3	-	0.25	5.12	1.30	-0.30	0.50	-0.15
Total	-	23.03		93.28	-27.41		-91.39

**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 <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	19.15	3.68	70.47	-28.18	4.30	-121.16
Pae2	-	6.84	5.05	34.50	-10.06	0.75	-7.55
Pae3	-	0.29	5.12	1.48	-0.43	0.50	-0.21
Total	-	26.28		106.45	-38.67		-128.92

**Water Pressure**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	0.34	0.34	5.12	1.73	-1.13	0.50	-0.56
Total		0.34		1.73	-1.13		-0.56

**Uplift**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-3.95	3.51	-13.89	-	-	-
Total		-3.95		-13.89	-		-

**(c) Stability Analysis of Left Side Lower Separate Wall**

**(i) Case 1 : Normal condition (without Earthquake)**

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	58.2	0.0	154.5	0.0
Earth Pressure	23.0	-27.4	93.3	-91.4
Water Pressure	0.3	-1.1	1.7	-0.6
Uplift	-4.0	0.0	-13.9	0.0
Total	77.6	-28.5	235.6	-91.9

**Safety against overturning**

$$d = 1.850 \text{ m}$$

$$e = B/2 - d = 0.785 \text{ m} < 0.878 \text{ m} = b/6 \quad \text{OK}$$

**Safety against shear**

$$SF = (Vf + \tau_0 l)/H = 7.445 > 4$$

OK

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	58.2	-9.3	154.5	-35.8
Earth Pressure	26.3	-38.7	106.4	-128.9
Water Pressure	0.3	-1.1	1.7	-0.6
Uplift	-4.0	0.0	-13.9	0.0
Total	80.9	-49.1	248.8	-165.3

Safety against overturning

$$d = 1.032 \text{ m}$$

$$e = B/2 - d = 1.603 \text{ m} < 1.757 \text{ m} = b/3 \quad \text{OK}$$

Safety against shear

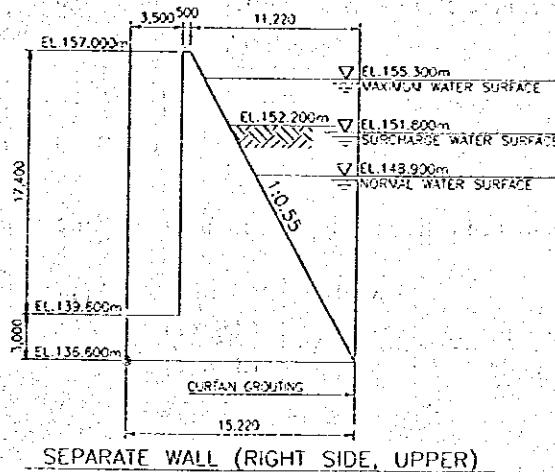
$$SF = (Vf + \tau_0 l) / H = 4.373 > 4 \quad \text{OK}$$

(3) Right Side Upper Separate Wall of Control Portion

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	$\gamma_c$	(tf/m <sup>3</sup> )	2.35	Thick structure
Unit weight of wetted pervious material (Dam)	$\gamma_t$	(tf/m <sup>3</sup> )	1.94	Wet density
Unit weight of submerged pervious material (Dam)	$\gamma_s$	(tf/m <sup>3</sup> )	1.16	Submerged density
Horizontal seismic coefficient	$K_h$	-	0.16	100%
Shear strength of foundation rock	$\tau_0$	(tf/m <sup>2</sup> )	45	CM-L class
Coefficient of internal friction of foundation rock	f	-	0.8	CM-L class

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

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

Kea : Coefficient of active earth pressure under seismic condition

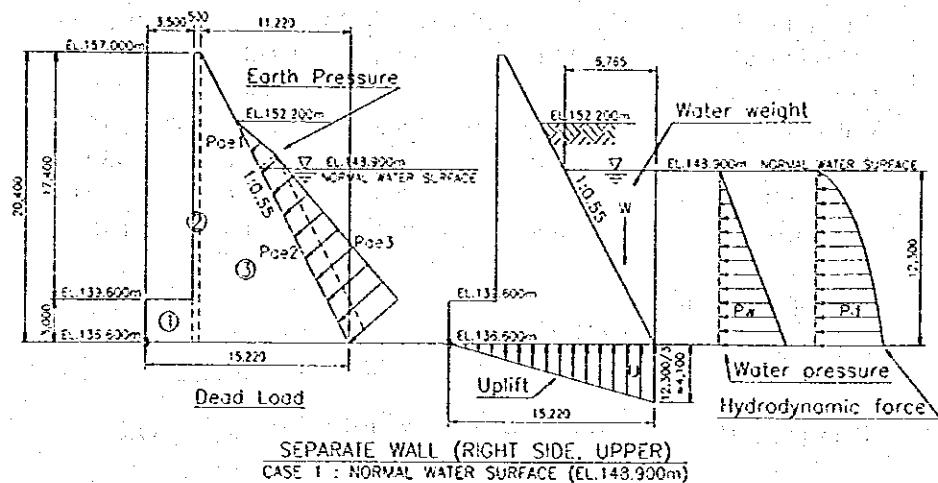
Item	Symbol	Unit	Value	Description
Friction angle of soil to concrete	$\delta_e$	(degree)	22.5	$\delta_e = 1/2 \phi$
Seismic composite angle	$\theta_0$	(degree)	-	$\tan \theta_0 = K_h$

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

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

(i) Loading Calculation

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	-3.95	1.50	-5.92
2(concrete)	10.20	23.97	3.75	89.89	-3.84	10.20	-39.12
3(concrete)	114.44	268.94	7.74	2,081.62	-43.03	6.80	-292.61
Total	135.14	317.59		2,214.69	-50.81		-337.65

#### Earth Pressure with Earthquake

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

Coefficient of active earth pressure :  $Kea=0.586$

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	4.83	7.85	37.91	-3.87	13.40	-51.82
Pae2	-	36.00	11.84	426.15	-28.83	6.15	-177.31
Pae3	-	40.12	12.97	520.11	-32.13	4.10	-131.72
Total	-	80.95		984.17	-64.82		-360.85

#### Water Pressure

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	-	41.60	12.97	539.41	-75.65	4.10	-310.14
Total	-	41.60		539.41	-75.65		-310.14

#### Hydrodynamic Force (due to Earthquake)

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pd	-	-	-	-	-14.12	4.92	-69.47
Total	-	-	-	-	-14.12	-	-69.47

#### Uplift

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-31.20	10.15	-316.59	-	-	-
Total	-	-31.20		-316.59	-	-	-

#### (ii) Stability Analysis (Normal Water Surface)

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	317.6	-50.8	2,214.7	-337.7
Earth Pressure	80.9	-64.8	984.2	-360.8
Water Pressure	41.6	-75.6	539.4	-310.1
Hydrodynamic	0.0	-14.1	0.0	-69.5
Uplift	-31.2	0.0	-316.6	0.0
Total	408.9	-205.4	3,421.7	-1,078.1

Safety against overturning

$$d = 5.731 \text{ m}$$

$$e = B/2 - d = 1.879 \text{ m} < 2.537 \text{ m} = b/6 \quad \text{OK}$$

Safety against shear

$$SF = (Vf + \tau_0 l) / H = 4.927 > 4$$

OK

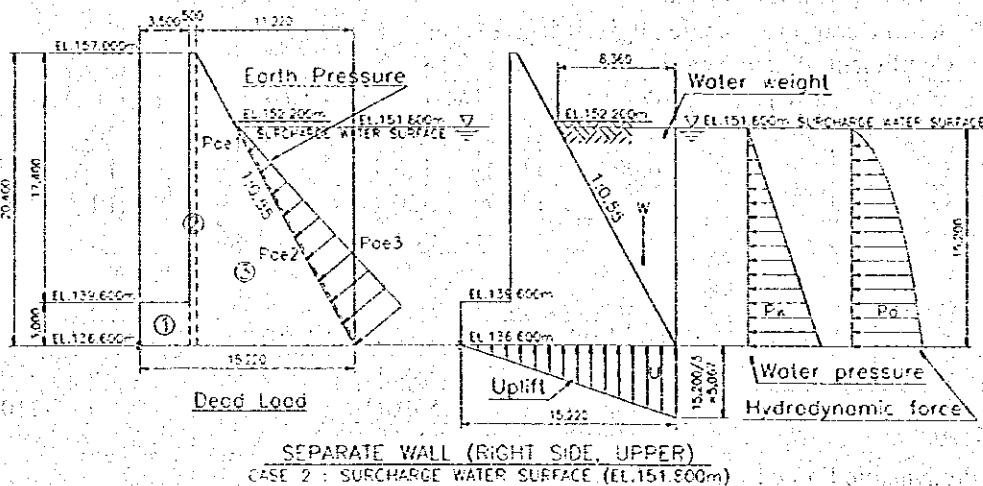
(c) Case 2 : Right Side Upper Separate Wall, Surcharge Water Surface :

EL.151.800m

Horizontal seismic coefficient : Kh=0.08 (50%)

(i) Loading Calculation

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



Each load is calculated hereinafter.

Dead Load

	A( $\text{m}^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	10.50	24.68	1.75	43.18	-1.97	1.50	-2.96
2(concrete)	10.20	23.97	3.75	89.89	-1.92	10.20	-19.56
3(concrete)	114.44	268.94	7.74	2,081.62	-21.52	6.80	-146.31
Total	135.14	317.59		2,214.69	-25.41		-168.83

### Earth Pressure with Earthquake

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

Coefficient of active earth pressure :  $Kea = 0.505$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	0.06	6.79	0.42	-0.05	15.33	-0.75
Pae2	-	4.65	11.04	51.32	-3.72	7.60	-28.29
Pae3	-	52.81	12.43	656.59	-42.29	5.07	-214.28
Total	-	57.52		708.32	-46.06		-243.32

### Water Pressure

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	-	63.54	12.43	789.96	-115.52	5.07	-585.30
Total		63.54		789.96	-115.52		-585.30

### Hydrodynamic Force (due to Earthquake)

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pd	-	-	-	-	-10.78	6.08	-65.55
Total		-		-	-10.78		-65.55

### Uplift

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-38.56	10.15	-391.23	-	-	-
Total		-38.56		-391.23			

### (ii) Stability Analysis (Surcharge Water Surface)

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	317.6	-25.4	2,214.7	-168.8
Earth Pressure	57.5	-46.1	708.3	-243.3
Water Pressure	63.5	-115.5	790.0	-585.3
Hydrodynamic	0.0	-10.8	0.0	-65.6
Uplift	-38.6	0.0	-391.2	0.0
Total	400.1	-197.8	3,321.8	-1,063.0

#### Safety against overturning

$$d = 5.646 \text{ m}$$

$$e = B/2 - d = 1.964 \text{ m} < 2.537 \text{ m} = b/6 \quad \text{OK}$$

#### Safety against shear

$$SF = (Vf + \tau_0 l)/H = 5.081 > 4$$

OK

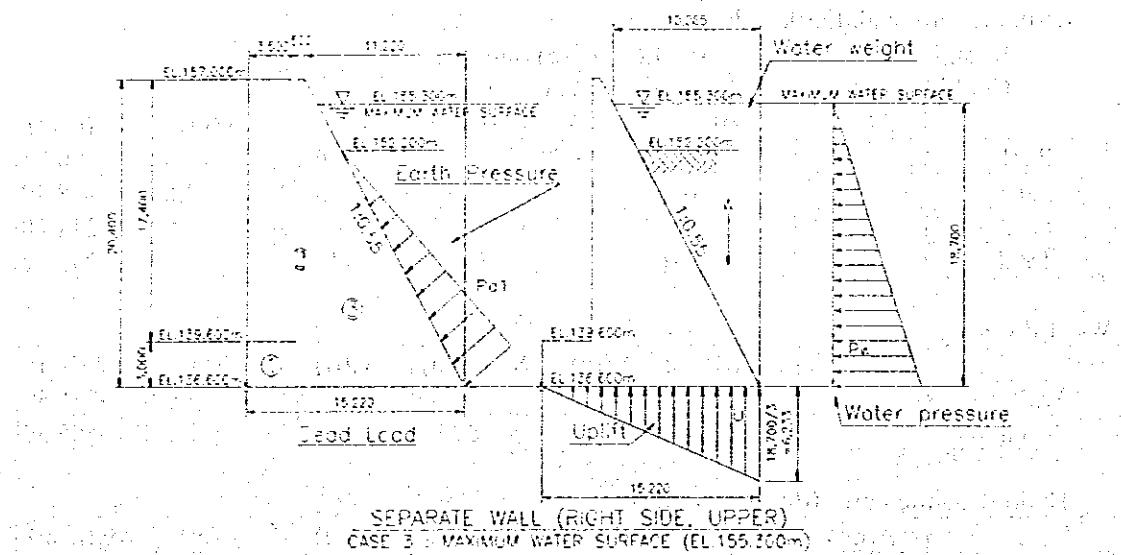
### (d) Case 3 : Right Side Upper Separate Wall, Maximum Water Surface

: EL. 155.300m

Horizontal seismic coefficient : Kh=0.0 (0%)

#### (i) Loading Calculation

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



Each load is calculated hereinafter.

### **Dead Load**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	10.50	24.68	1.75	43.18	0.00	1.50	0.00
2(concrete)	10.20	23.97	3.75	89.89	0.00	10.20	0.00
3(concrete)	114.44	268.94	7.74	2,081.62	0.00	6.80	0.00
Total	135.14	317.59		2,214.69	0.00		0.00

## **Earth Pressure without Earthquake**

Coefficient of active earth pressure :  $K_a=0.468$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pal	-	56.48	12.36	698.11	-34.19	5.20	-177.80
Total	-	56.48		698.11	-34.19		-177.80

## Water Pressure

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	-	96.16	11.79	1,133.94	-174.85	6.23	-1,089.87
Total		96.16		1,133.94	-174.85		-1,089.87

Uplift

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-47.44	10.15	-481.31	-	-	-
Total		-47.44		-481.31			

#### (ii) Stability Analysis (Maximum Water Surface)

**Normal condition (without Earthquake)**

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	317.6	0.0	2,214.7	0.0
Earth Pressure	56.5	-34.2	698.1	-177.8
Water Pressure	96.2	-174.8	1,133.9	-1,089.9
Uplift	-47.4	0.0	-481.3	0.0
Total	422.8	-209.0	3,565.4	-1,267.7

**Safety against overturning**

$$d = 5.435 \text{ m}$$

$$e = B/2 - d = 2.175 \text{ m} < 2.537 \text{ m} = b/6 \text{ OK}$$

**Safety against shear**

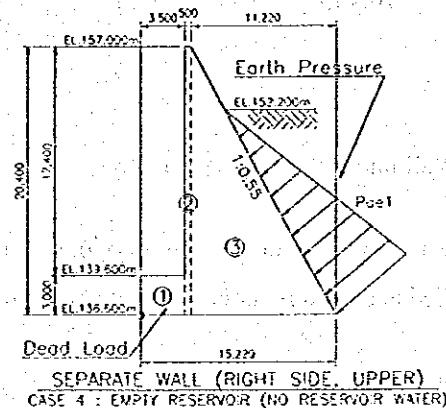
$$SF = (V_f + \tau_0 l) / H = 4.895 > 4 \text{ OK}$$

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

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

**(i) Loading Calculation**

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



Each load is calculated hereinafter.

**Dead Load**

	A( $\text{m}^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	10.50	24.68	1.75	43.18	-1.97	1.50	-2.96
2(concrete)	10.20	23.97	3.75	89.89	-1.92	10.20	-19.56
3(concrete)	114.44	268.94	7.74	2,081.62	-21.52	6.80	-146.31
Total	135.14	317.59		2,214.69	-25.41		-168.83

### Earth Pressure with Earthquake

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

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

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	93.03	12.36	1,149.83	-74.50	5.20	-387.40
Total	-	93.03		1,149.83	-74.50		-387.40

### (ii) Stability Analysis (Empty Reservoir)

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	317.6	-25.4	2,214.7	-168.8
Earth Pressure	93.0	-74.5	1,149.8	-387.4
Water Pressure	-	-	-	-
Hydrodynamic	-	-	-	-
Uplift	-	-	-	-
Total	410.6	-99.9	3,364.5	-556.2

#### Safety against overturning

$$d = 6.839 \text{ m}$$

$$e=B/2-d = 0.771 \text{ m} < 2.537 \text{ m} = b/6 \quad \text{OK}$$

#### Safety against shear

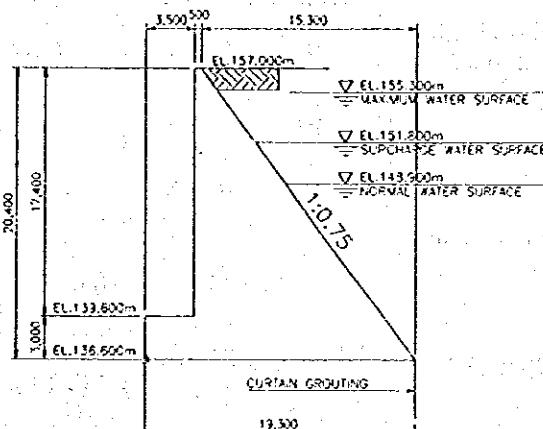
$$SF = (Vf + \tau_0 l) / H = 10.143 > 4 \quad \text{OK}$$

### (4) Right Side Separate Wall under the Impervious Zone

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.



**SEPARATE WALL (RIGHT SIDE, IMPERVIOUS ZONE)**

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

Item	Symbol	Unit	Value	Description
Unit weight of concrete	$\gamma_c$	(tf/m <sup>3</sup> )	2.35	Thick structure
Unit weight of wetted impervious material (Dam)	$\gamma_t$	(tf/m <sup>3</sup> )	2.11	Wet density
Unit weight of submerged impervious material (Dam)	$\gamma_s$	(tf/m <sup>3</sup> )	1.19	Submerged density
Horizontal seismic coefficient	$K_h$	-	0.16	100%
Shear strength of foundation rock	$\tau_0$	(tf/m <sup>2</sup> )	45	CM-L class
Coefficient of internal friction of foundation rock	$f$	-	0.8	CM-L class

< 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	$\theta$	(degree)	36.87	V:H=1:0.75
Angle between ground surface and horizontal plane	$\alpha$	(degree)	0.0	
Internal friction angle of soil	$\phi$	(degree)	30.0	Impervious material of Dam
Friction angle of soil to concrete	$\delta$	(degree)	20.0	$\delta = 2/3 \phi$

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

Kea : Coefficient of active earth pressure under seismic condition

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

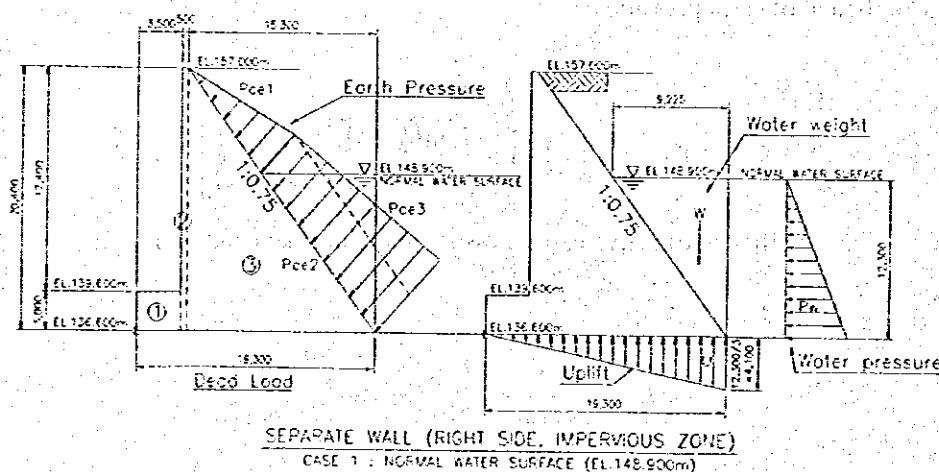
### (b) Case 1 : Right Side Separate Wall under the Impervious Zone,

Normal Water Surface : EL. 148.900m

Horizontal seismic coefficient : Kh=0.16 (100%)

#### (i) Loading Calculation

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



Each load is calculated hereinafter.

**Dead Load**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	10.50	24.68	1.75	43.18	-3.95	1.50	-5.92
2(concrete)	10.20	23.97	3.75	89.89	-3.84	10.20	-39.12
3(concrete)	156.06	366.74	9.10	3,337.34	-58.68	6.80	-399.01
Total	176.76	415.39		3,470.41	-66.46		-444.06

**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 <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	50.30	8.05	404.88	-39.48	15.00	-592.19
Pae2		152.75	14.69	2,243.50	-119.90	6.15	-737.39
Pae3		65.41	16.23	1,061.25	-51.34	4.10	-210.50
Total	-	268.45		3,709.63	-210.72		-1,540.08

**Water Pressure**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	-	56.73	16.23	920.51	-75.65	4.10	-310.14
Total		56.73		920.51	-75.65		-310.14

**Uplift**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-39.57	12.87	-509.07	-	-	-
Total		-39.57		-509.07	-	-	-

**(ii) Stability Analysis (Normal Water Surface)**

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	415.4	-66.46	3,470.4	-444.1
Earth Pressure	268.5	-210.7	3,709.6	-1,540.1
Water Pressure	56.7	-75.6	920.5	-310.1
Uplift	-39.6	0.0	-509.1	0.0
Total	701.0	-352.8	7,591.5	-2,294.3

**Safety against overturning**

$$d = 7.557 \text{ m} \\ e = B/2 - d = 2.093 \text{ m} < 3.217 \text{ m} = b/6 \quad \text{OK}$$

**Safety against shear**

$$SF = (Vf + \tau_0 l)/H = 4.051 > 4 \quad \text{OK}$$

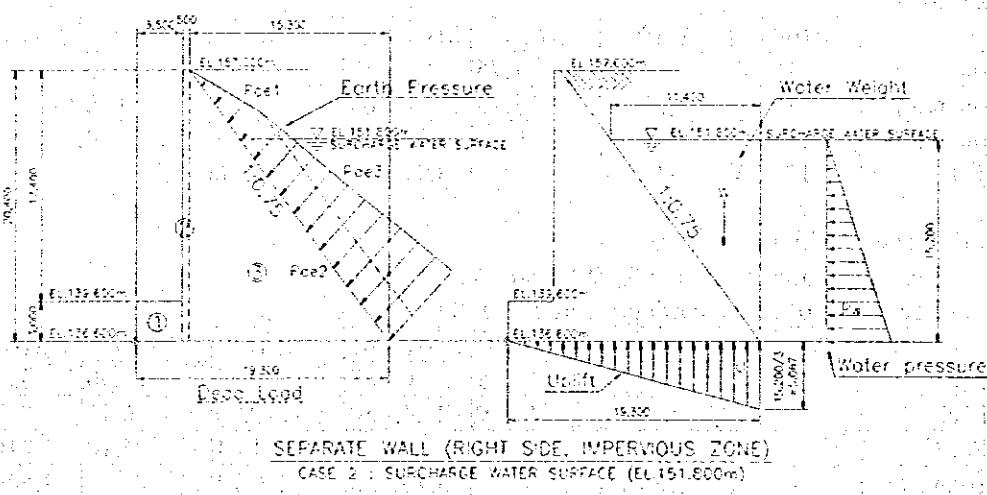
**(c) Case 2 : Right Side Separate Wall under the Impervious Zone,**

Surcharge Water Surface : EL.151.800m

Horizontal seismic coefficient : Kh=0.08 (50%)

**(i) Loading Calculation**

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



Each load is calculated hereinafter.

## Dead Load

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	10.50	24.68	1.75	43.18	-1.97	1.50	-2.96
2(concrete)	10.20	23.97	3.75	89.89	-1.92	10.20	-19.56
3(concrete)	156.06	366.74	9.10	3,337.34	-29.34	6.80	-199.51
Total	176.76	415.39		3,470.41	-33.23		-222.03

## Earth Pressure with Earthquake

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

Coefficient of active earth pressure : Kea=0.815

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	18.28	6.60	120.66	-14.35	16.93	-243.00
Pae2	-	106.88	13.60	1,453.55	-83.89	7.60	-637.60
Pae3	-	88.10	15.50	1,365.52	-69.15	5.07	-350.37
Total	-	213.26		2,939.73	-167.40		-1,230.97

### Water Pressure

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	-	86.64	15.50	1,342.92	-115.52	5.07	-585.30
Total		86.64		1,342.92	-115.52		-585.30

Uplift

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-48.89	12.87	-629.09	-	-	-
Total		-48.89		-629.09	-	-	-

#### (ii) Stability Analysis (Surcharge Water Surface)

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	415.4	-33.2	3,470.4	-222.0
Earth Pressure	213.3	-167.4	2,939.7	-1,231.0
Water Pressure	86.6	-115.5	1,342.9	-585.3
Uplift	-48.9	0.0	-629.1	0.0
Total	666.4	-316.1	7,124.0	-2,038.3

**Safety against overturning**

$$d = 7.632 \text{ m} \quad e = B/2 - d = 2.018 \text{ m} < 3.217 \text{ m} = b/6 \quad \text{OK}$$

**Safety against shear**

$$SF = (Vf + t_0 l) / H = 4.433 > 4 \quad \text{OK}$$

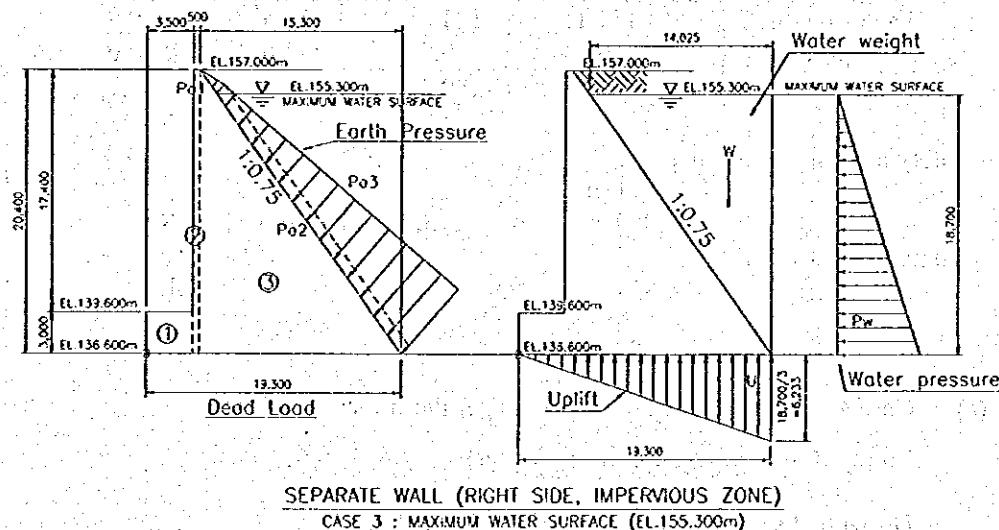
**(d) Case 3 : Right Side Separate Wall under the Impervious Zone,**

Maximum Water Surface : EL.155.300m

Horizontal seismic coefficient : Kh=0.0 (0%)

**(i) Loading Calculation**

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



Each load is calculated hereinafter.

**Dead Load**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	10.50	24.68	1.75	43.18	0.00	1.50	0.00
2(concrete)	10.20	23.97	3.75	89.89	0.00	10.20	0.00
3(concrete)	156.06	366.74	9.10	3,337.34	0.00	6.80	0.00
Total	176.76	415.39		3,470.41	0.00		0.00

**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	4.85	9.31	-1.25	19.27	-24.14
Pa2	-	42.23	12.29	518.96	-27.56	9.35	-257.72
Pa3	-	131.01	14.63	1,915.99	-85.50	6.23	-532.96
Total	-	175.16	-	2,444.26	-114.32	-	-814.82

**Water Pressure**

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	-	131.13	14.63	1,917.83	-174.85	6.23	-1,089.87
Total	-	131.13	-	1,917.83	-174.85	-	-1,089.87

**Uplift**

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-60.15	12.87	-773.95	-	-	-
Total	-	-60.15	-	-773.95	-	-	-

**(ii) Stability Analysis (Maximum Water Surface)**

**Normal condition (without Earthquake)**

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	415.4	0.0	3,470.4	0.0
Earth Pressure	175.2	-114.3	2,444.3	-814.8
Water Pressure	131.1	-174.8	1,917.8	-1,089.9
Uplift	-60.2	0.0	-774.0	0.0
Total	661.5	-289.2	7,058.5	-1,904.7

**Safety against overturning**

$$d = 7.791 \text{ m} \\ c = B/2 - d = 1.859 \text{ m} < 3.217 \text{ m} = b/6 \quad \text{OK}$$

**Safety against shear**

$$SF = (Vf + \tau_0 l)/H = 4.834 > 4 \quad \text{OK}$$

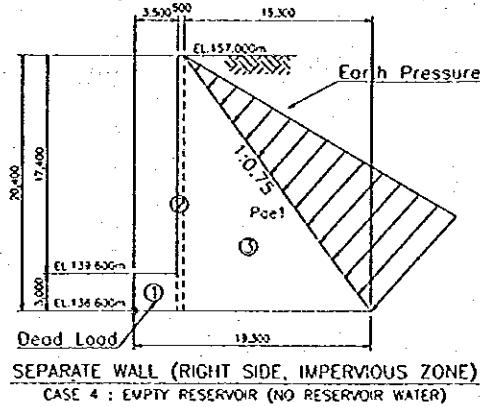
**(e) Case 4 : Right Side Separate Wall under the Impervious Zone,**

**Empty Reservoir (No Reservoir Water)**

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

**(i) Loading Calculation**

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



Each load is calculated hereinafter.

#### Dead Load

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	10.50	24.68	1.75	43.18	-1.97	1.50	-2.96
2(concrete)	10.20	23.97	3.75	89.89	-1.92	10.20	-19.56
3(concrete)	156.06	366.74	9.10	3,337.34	-29.34	6.80	-199.51
Total	176.76	415.39		34,70.41	-33.23		-222.03

#### Earth Pressure with Earthquake

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

Coefficient of active earth pressure :  $Kea=0.752$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	281.37	14.20	3,995.43	-220.86	6.80	-1,501.85
Total	-	281.37		3,995.43	-220.86		-1,501.85

#### (ii) Stability Analysis (Empty Reservoir)

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	415.4	-33.2	3,470.4	-222.0
Earth Pressure	281.4	-220.9	3,995.4	-1,501.8
Water Pressure	-	-	-	-
Uplift	-	-	-	-
Total	696.8	-254.1	7,465.8	-1,723.9

#### Safety against overturning

$$d = 8.241 \text{ m}$$

$$e = B/2 - d = 1.409 \text{ m} < 3.217 \text{ m} = b/6 \quad \text{OK}$$

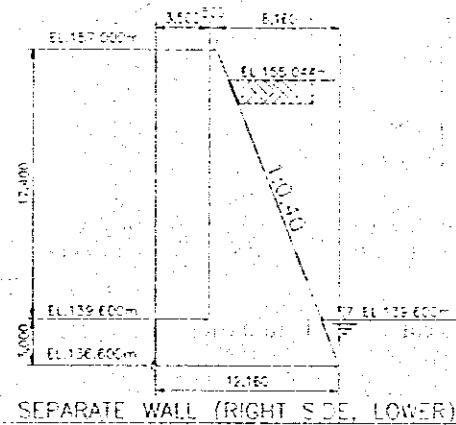
#### Safety against shear

$$SF = (Vf + \tau_b l)/H = 5.612 > 4 \quad \text{OK}$$

#### (5) Right Side Lower Separate Wall of Control Portion

(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	$\gamma_c$	(tf/m <sup>3</sup> )	2.35	Thick structure
Unit weight of wetted semi-pervious material (Dam)	$\gamma_t$	(tf/m <sup>3</sup> )	2.11	Wet density
Unit weight of submerged semi-pervious material (Dam)	$\gamma_s$	(tf/m <sup>3</sup> )	1.27	Submerged density
Horizontal seismic coefficient	$K_h$	-	0.16	100%
Shear strength of foundation rock	$\tau_0$	(tf/m <sup>2</sup> )	45	CM-L class
Coefficient of internal friction of foundation rock	$f$	-	0.8	CM-L class

< 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	$\theta$	(degree)	21.8	V:H=1:0.40
Angle between ground surface and horizontal plane	$\alpha$	(degree)	0.0	100%
Internal friction angle of soil	$\phi$	(degree)	35.0	Semi-pervious material of Dam
Friction angle of soil to concrete	$\delta$	(degree)	23.3	$\delta = 2/3 \phi$

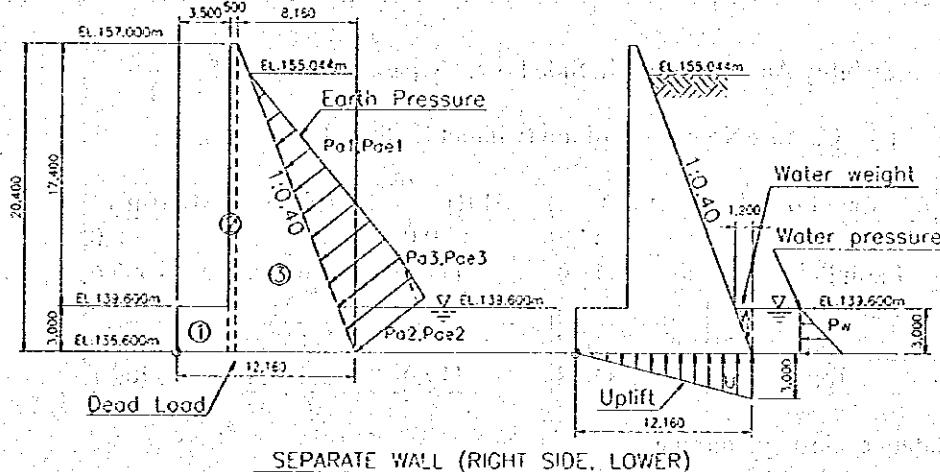
$$Kea = \frac{\cos^2(\phi - \theta_0 - \alpha)}{\cos\theta_0 \cdot \cos^2\theta \cdot \cos(\theta + \theta_0 + \delta) \cdot \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

Kea : Coefficient of active earth pressure under seismic condition

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

### (b) Loading Calculation of Right Side Lower Separate Wall

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



Each load is calculated hereinafter.

#### Dead Load

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	10.50	24.68	1.75	43.18	-3.95	1.50	-5.92
2(concrete)	10.20	23.97	3.75	89.89	-3.84	10.20	-39.12
3(concrete)	83.23	195.60	6.72	1,314.40	-31.30	6.80	-212.81
Total	103.93	244.24		1,447.47	-39.08		-257.85

### Earth Pressure without Earthquake

Coefficient of active earth pressure :  $K_a=0.449$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	80.07	8.90	712.64	-79.69	8.15	-649.31
Pa2	-	31.11	11.56	359.58	-30.96	1.50	-46.44
Pa3	-	1.82	11.76	21.38	-1.81	1.00	-1.81
Total	-	112.99		1,093.60	-112.46		-697.56

### Earth Pressure with Earthquake

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

Coefficient of active earth pressure :  $K_{ae}=0.575$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	91.62	8.90	815.46	-111.93	8.15	-911.99
Pae2	-	35.59	11.56	411.46	-43.48	1.50	-65.23
Pae3	-	2.08	11.76	24.47	-2.54	1.00	-2.54
Total	-	129.29		1,251.38	-157.95		-979.76

### Water Pressure

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W,Pw	1.80	1.80	11.76	21.17	-4.50	1.00	-4.50
Total		1.80		21.17	-4.50		-4.50

### Uplift

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-18.24	8.11	-147.87	-	-	-
Total		-18.24		-147.87	-		-

### (c) Stability Analysis of Right Side Lower Separate Wall

#### (i) Case 1 : Normal condition (without Earthquake)

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	244.2	0.0	1,447.5	0.0
Earth Pressure	113.0	-112.5	1,093.6	-697.6
Water Pressure	1.8	-4.5	21.2	-4.5
Uplift	-18.2	0.0	-147.9	0.0
Total	340.8	-117.0	2,414.4	-702.1

#### Safety against overturning

$$d = 5.025 \text{ m}$$

$$e = B/2 - d = 1.055 \text{ m} < 2.027 \text{ m} = b/6 \quad \text{OK}$$

#### Safety against shear

$$SF = (Vf + \tau_0 l)/H = 7.010 > 4 \quad \text{OK}$$

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	244.2	-39.1	1,447.5	-257.8
Earth Pressure	129.3	-158.0	1,251.4	-979.8
Water Pressure	1.8	-4.5	21.2	-4.5
Uplift	-18.2	0.0	-147.9	0.0
Total	357.1	-201.5	2,572.2	-1,242.1

Safety against overturning

$$d = 3.725 \text{ m}$$

$$c = B/2 - d = 2.355 \text{ m} < 4.053 \text{ m} = b/3 \quad \text{OK}$$

Safety against shear

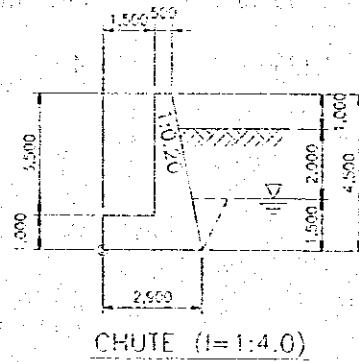
$$SF = (Vf + \tau_0 l) / H = 4.133 > 4 \quad \text{OK}$$

## Chute

### (1) 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	$\gamma_c$	(tf/m <sup>3</sup> )	2.50	Thin structure
Unit weight of wetted backfill soil	$\gamma_t$	(tf/m <sup>3</sup> )	1.90	Wet density
Unit weight of submerged backfill soil	$\gamma_s$	(tf/m <sup>3</sup> )	0.90	Submerged density
Horizontal seismic coefficient	$K_h$	-	0.16	100%
Shear strength of foundation rock	$\tau_0$	(tf/m <sup>2</sup> )	30	CL class
Coefficient of internal friction of foundation rock	$f$	-	0.7	CL class

< 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	$\theta$	(degree)	11.3	V:H=1:0.20
Angle between ground surface and horizontal plane	$\alpha$	(degree)	0.0	
Internal friction angle of soil	$\phi$	(degree)	35.0	Sandy soil
Friction angle of soil to concrete	$\delta$	(degree)	23.3	$\delta = 2/3 \phi$

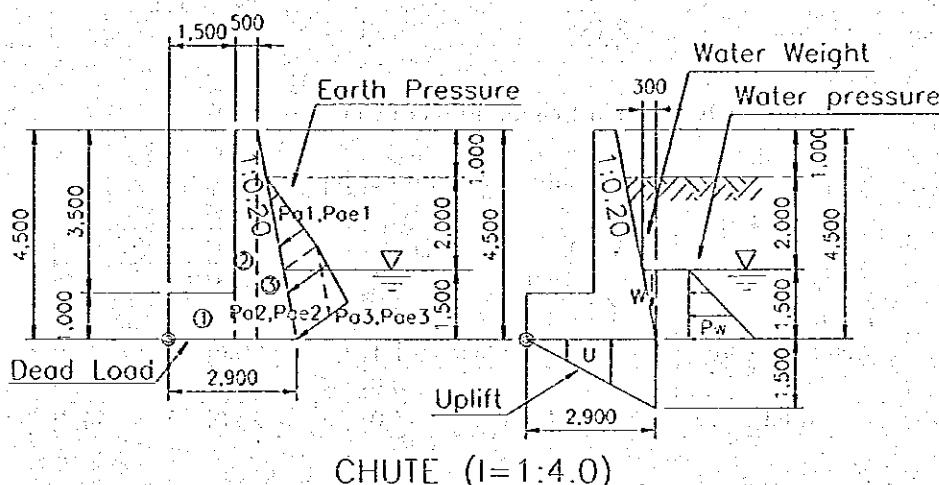
$$Kea = \frac{\cos^2(\phi - \theta_0 - \alpha)}{\cos \theta_0 \cdot \cos^2 \theta \cdot \cos(\theta + \theta_0 + \delta) \cdot \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

Kea : Coefficient of active earth pressure under seismic condition

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

### (b) Loading Calculation of 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	-0.60	0.50	-0.30
2(concrete)	2.25	5.63	1.75	9.84	-0.90	2.25	-2.03
3(concrete)	2.03	5.06	2.30	11.64	-0.81	1.50	-1.22
Total	5.78	14.44		24.30	-2.31		-3.54

**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	2.47	1.79	-1.05	2.17	-2.27
Pa2	-	1.09	2.75	2.99	-1.57	0.75	-1.18
Pa3	-	0.19	2.80	0.54	-0.28	0.50	-0.14
Total	-	2.00		5.32	-2.90		-3.59

**Earth Pressure with Earthquake**

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

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

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	0.82	2.47	2.03	-1.49	2.17	-3.24
Pae2	-	1.23	2.75	3.39	-2.24	0.75	-1.68
Pae3	-	0.22	2.80	0.61	-0.40	0.50	-0.20
Total	-	2.27		6.03	-4.13		-5.11

**Water Pressure**

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	0.23	0.23	2.80	0.63	-1.13	0.50	-0.56
Total		0.23		0.63	-1.13		-0.56

**Uplift**

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-2.18	1.93	-4.21	-	-	-
Total		-2.18		-4.21	-	-	-

**(c) Stability Analysis of Upstream Portion of Chute (i=1:4.0)**

**(i) Case 1 : Normal condition (without Earthquake)**

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.4	0.0	24.3	0.0
Earth Pressure	2.0	-2.9	5.3	-3.6
Water Pressure	0.2	-1.1	0.6	-0.6
Uplift	-2.2	0.0	-4.2	0.0
Total	14.5	-4.0	26.0	-4.2

**Safety against overturning**

$$d = 1.510 \text{ m}$$

$$e = B/2 - d = -0.060 \text{ m} < 0.483 \text{ m} = b/6 \quad \text{OK}$$

**Safety against shear**

$$SF = (Vf + \tau_0 l)/H = 24.133 > 4 \quad \text{OK}$$

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.4	-2.3	24.3	-3.5
Earth Pressure	2.3	-4.1	6.0	-5.1
Water Pressure	0.2	-1.1	0.6	-0.6
Uplift	-2.2	0.0	-4.2	0.0
Total	14.8	-7.6	26.8	-9.2

### Safety against overturning

$$d = 1.188 \text{ m}$$

$$e = B/2 - d = 0.262 \text{ m} < 0.967 \text{ m} = b/3 \quad \text{OK}$$

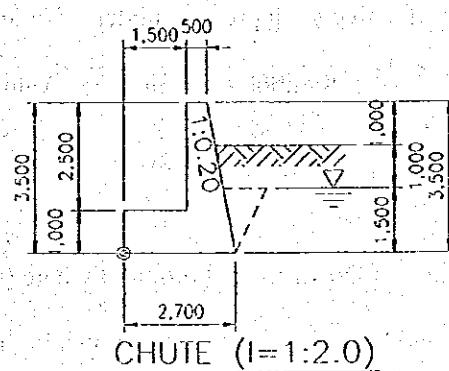
### Safety against shear

$$SF = (Vf + \tau_0 l) / H = 12.863 > 4 \quad \text{OK}$$

## (2) Downstream Portion of Chute ( $i=1:2.0$ )

### (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	$\gamma_c$	(tf/m <sup>3</sup> )	2.50	Thin structure
Unit weight of wetted backfill soil	$\gamma_t$	(tf/m <sup>3</sup> )	1.90	Wet density
Unit weight of submerged backfill soil	$\gamma_s$	(tf/m <sup>3</sup> )	0.90	Submerged density
Horizontal seismic coefficient	$K_h$	-	0.16	100%
Shear strength of foundation rock	$\tau_0$	(tf/m <sup>2</sup> )	30	CL class
Coefficient of internal friction of foundation rock	f	-	0.7	CL class

< Coefficient of earth pressure >

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

$K_a$  : Coeficient of active earth pressure under normal condition

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

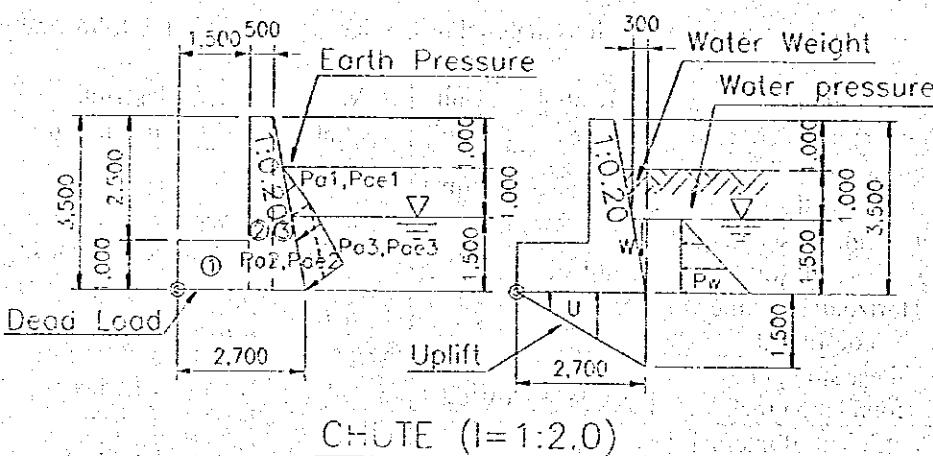
$$Kea = \frac{\cos^2(\phi - \theta_0 - \delta)}{\cos\theta_0 \cdot \cos^2\theta \cdot \cos(\theta + \theta_0 + \delta) \cdot \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}} \right]^2}$$

$Kea$  : Coeficient of active earth pressure under seismic condition

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

(b) Loading Calculation of Downstream Portion of Chute ( $i=1:2.0$ )

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



Each load is calculated hereinafter.

**Dead Load**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	1.50	3.75	0.75	2.81	-0.60	0.50	-0.30
2(concrete)	1.75	4.38	1.75	7.66	-0.70	1.75	-1.23
3(concrete)	1.23	3.06	2.23	6.84	-0.49	1.17	-0.57
Total	4.48	11.19		17.31	-1.79		-2.10

**Earth Pressure without Earthquake**

Coefficient of active earth pressure :  $K_a=0.335$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pa1	-	0.18	2.33	0.42	-0.26	1.83	-0.48
Pa2	-	0.54	2.55	1.39	-0.79	0.75	-0.59
Pa3	-	0.19	2.60	0.50	-0.28	0.50	-0.14
Total	-	0.92		2.31	-1.33		-1.21

**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 <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Pae1	-	0.21	2.33	0.48	-0.37	1.83	-0.68
Pae2	-	0.62	2.55	1.57	-1.12	0.75	-0.84
Pae3	-	0.22	2.60	0.57	-0.40	0.50	-0.20
Total	-	1.04		2.62	-1.89		-1.72

**Water Pressure**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	0.23	0.23	2.60	0.59	-1.13	0.50	-0.56
Total		0.23		0.59	-1.13		-0.56

**Uplift**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-2.03	1.80	-3.65	-	-	-
Total		-2.03		-3.65	-	-	-

**(c) Stability Analysis of Downstream Portion of Chute (i=1:2.0)**

**(i) Case 1 : Normal condition (without Earthquake)**

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	11.2	0.0	17.3	0.0
Earth Pressure	0.9	-1.3	2.3	-1.2
Water Pressure	0.2	-1.1	0.6	-0.6
Uplift	-2.0	0.0	-3.6	0.0
Total	10.3	-2.5	16.6	-1.8

**Safety against overturning**

$$d = 1.435 \text{ m}$$

$$e = B/2 - d = -0.085 \text{ m} < 0.450 \text{ m} = b/6 \quad \text{OK}$$

**Safety against shear**

$$SF = (Vf + \tau_0 l)/H = 35.965 > 4$$

OK

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	11.2	-1.8	17.3	-2.1
Earth Pressure	1.0	-1.9	2.6	-1.7
Water Pressure	0.2	-1.1	0.6	-0.6
Uplift	-2.0	0.0	-3.6	0.0
Total	10.4	-4.8	16.9	-4.4

Safety against overturning

$$d = 1.197 \text{ m}$$

$$e = B/2 - d = 0.153 \text{ m} < 0.900 \text{ m} = b/3 \quad \text{OK}$$

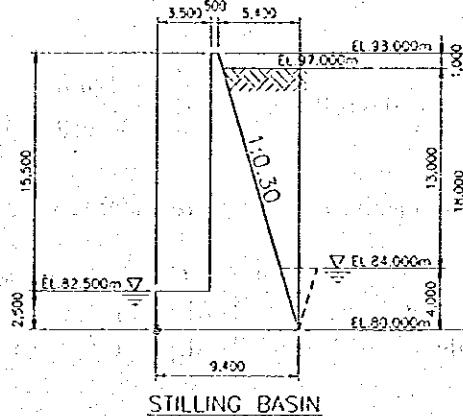
Safety against shear

$$SF = (Vf + \tau_0 l) / H = 18.371 > 4 \quad \text{OK}$$

## Stilling Basin

### (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	$\gamma_c$	(tf/m³)	2.35	Thick structure
Unit weight of wetted backfill soil	$\gamma_t$	(tf/m³)	1.90	Wet density
Unit weight of submerged backfill soil	$\gamma_s$	(tf/m³)	0.90	Submerged density
Horizontal seismic coefficient	$K_h$	-	0.16	100%
Shear strength of foundation rock	$\tau_0$	(tf/m²)	40	CM-L class
Coefficient of internal friction of foundation rock	f	-	0.8	CM-L class

< 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	$\theta$	(degree)	16.7	V:H=1:0.30
Angle between ground surface and horizontal plane	$\alpha$	(degree)	0.0	
Internal friction angle of soil	$\phi$	(degree)	35.0	Sandy soil
Friction angle of soil to concrete	$\delta$	(degree)	23.3	$\delta = 2/3 \phi$

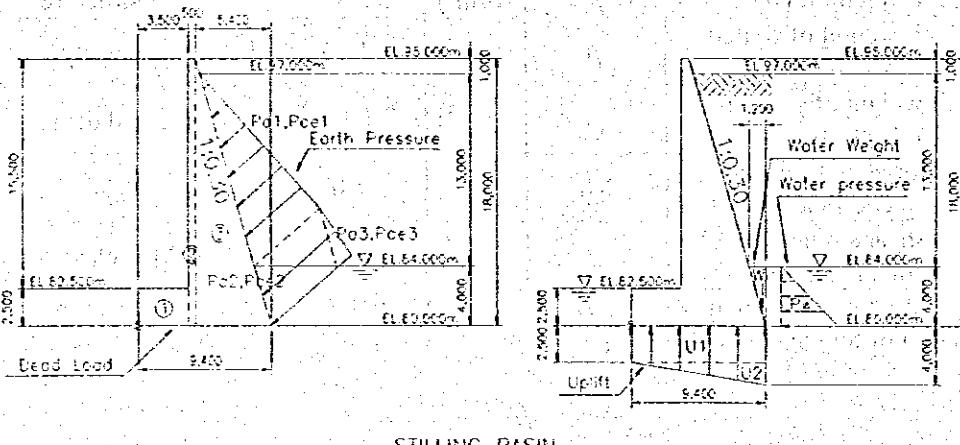
$$Kea = \frac{\cos^2(\phi - \theta_0 - \alpha)}{\cos \theta_0 \cdot \cos^2 \theta \cdot \cos(0 + \theta_0 + \delta) \cdot \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(0 + \theta_0 + \delta) \cdot \cos(0 - \alpha)}} \right]^2}$$

Kea : Coefficient of active earth pressure under seismic condition

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

### (b) Loading Calculation of 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)	8.75	20.56	1.75	35.98	-3.29	1.25	-4.11
2(concrete)	9.00	21.15	3.75	79.31	-3.38	9.00	-30.46
3(concrete)	48.60	114.21	5.80	662.42	-18.27	6.00	-109.64
Total	66.35	155.92		777.71	-24.95		-144.21

### 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	6.90	277.30	-47.84	8.33	-398.66
Pa2	-	24.73	8.80	217.63	-29.44	2.00	-58.88
Pa3	-	1.80	9.00	16.22	-2.15	1.33	-2.86
Total	-	66.72		511.15	-79.42		-460.40

### 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)
Pae1	-	45.86	6.90	316.45	-67.49	8.33	-562.39
Pae2	-	28.22	8.80	248.36	-41.53	2.00	-83.06
Pae3	-	2.06	9.00	18.51	-3.03	1.33	-4.04
Total	-	76.14		583.33	-112.04		-649.48

### Water Pressure

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
W, Pw	2.40	2.40	9.00	21.60	-8.00	1.33	-10.67
Total		2.40		21.60	-8.00		-10.67

### Uplift

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U1	-	-23.50	4.70	-110.45	-	-	-
U2	-	-7.05	6.27	-44.18	-	-	-
Total		-30.55		-154.63	-	-	-

### (c) Stability Analysis of Stilling Basin

#### (i) Case 1 : Normal condition (without Earthquake)

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	155.9	0.0	777.7	0.0
Earth Pressure	66.7	-79.4	511.2	-460.4
Water Pressure	2.4	-8.0	21.6	-10.7
Uplift	-30.6	0.0	-154.6	0.0
Total	194.5	-87.4	1,155.8	-471.1

#### Safety against overturning

$$d = 3.521 \text{ m}$$

$$e = B/2 - d = 1.179 \text{ m} < 1.567 \text{ m} = b/6 \quad \text{OK}$$

#### Safety against shear

$$SF = (Vf + \tau_0 l)/H = 6.618 > 4$$

OK

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

Total Load	V(tf)	H(tf)	Mx(tf-m)	My(tf-m)
Dead Load	155.9	-24.9	777.7	-144.2
Earth Pressure	76.1	-112.0	583.3	-649.5
Water Pressure	2.4	-8.0	21.6	-10.7
Uplift	-30.6	0.0	-154.6	0.0
Total	203.9	-145.0	1,228.0	-804.4

Safety against overturning

$$d = 2.078 \text{ m}$$

$$e = B/2 - d = 2.622 \text{ m} < 3.133 \text{ m} = b/3 \quad \text{OK}$$

Safety against shear

$$SF = (Vf + \tau_0 l) / H = 4.043 > 4 \quad \text{OK}$$

### 2.4.3 Structural Calculation

#### Design Condition

##### (1) Allowable Stress

Allowable stress of concrete and reinforcing steel bars are shown in the following table.

Item	Symbol	Unit	Value	Description
Allowable compressive stress of concrete	$\sigma_{ca}$	(kgf/cm <sup>2</sup> )	60	
Allowable tensile stress of concrete	$\sigma_{ta}$	(kgf/cm <sup>2</sup> )	3	
Allowable shear stress of concrete	$\tau_a$	(kgf/cm <sup>2</sup> )	5.5	
Allowable tensile or compressive stress of reinforcing steel bar	$\sigma_{sa}$	(kgf/cm <sup>2</sup> )	1,800	

Note : Minimum diameter of main reinforcing bar is D16 mm above.

In structural calculation, additional rate of allowable stress is applied to each condition of calculation. Required additional rates are shown in the following tables.

Structure facing Reservoir Water

Case	Condition of Reservoir	Earthquake	Additional Rate	
			Normal Condition	Earthquake Condition
1	Normal Water Surface	100%	1.0	1.5
2	Surcharge Water Surface	50%	1.0	1.5
3	Maximum Water Surface	0%	1.5	-
4	Empty Reservoir	50%	1.0	1.5

Structure not facing Reservoir Water

Case	Condition	Earthquake	Additional Rate
1	Normal Condition	0%	1.0
2	Earthquake Condition	100%	1.5

##### (2) Modules of Elasticity (Young's Module)

Young's Modules to be used in structural calculation of reinforced concrete are shown in the table below.

Module of Elasticity

Material	Symbol	Unit	Value
Concrete	$E_c$	(kgf/cm <sup>2</sup> )	140,000
Steel	$E_s$	(kgf/cm <sup>2</sup> )	2,100,000

Ratio of Young's Modules :  $n = E_s/E_c = 15$

## Overflow Weir

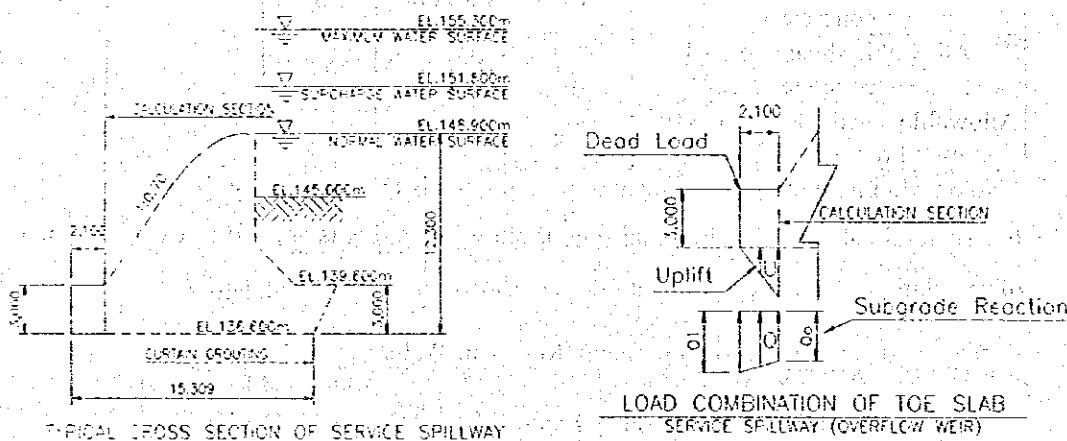
Overflow weir consists of two (2) portions, namely service spillway and emergency spillway.

### (1) Service Spillway

Structural calculation of toe slab is carried out for the Service Spillway.

#### (a) Basic design condition

Typical cross section and load combinations are shown in the following figures.



Design conditions are shown in the following tables.

Item	Symbol	Unit	Value	Description
Unit weight of concrete	$\gamma_c$	(tf/m <sup>3</sup> )	2.35	Thick structure
Unit weight of wetted backfill soil	$\gamma_t$	(tf/m <sup>3</sup> )	1.90	Wet density
Unit weight of submerged backfill soil	$\gamma_s$	(tf/m <sup>3</sup> )	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	$\theta$	(degree)	0.0	
Angle between ground surface and horizontal plane	$\alpha$	(degree)	0.0	
Internal friction angle of soil	$\phi$	(degree)	35.0	Sandy soil
Friction angle of soil to concrete	$\delta$	(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	$\delta_e$	(degree)	17.5	$\delta_e = 1/2 \phi$
Seismic composite angle	$\theta_0$	(degree)	various	$\tan\theta_0 = Kh$

(b) Case 1 : Toe slab of Service Spillway, Normal Water Surface : EL.148.900m

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

#### (i) Loading Calculation

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)	6.30	14.81	1.05	15.55	-	-	-
Total	6.30	14.81		15.55	-	-	-

##### Subgrade Reaction without Earthquake

$$Q_1 = 17.951 \text{ (tf/m}^2\text{)}, Q_0 = 17.815 \text{ (tf/m}^2\text{)}$$

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-37.55	1.05	-39.48	-	-	-
Total	-	-37.55		-39.48	-	-	-

##### Subgrade Reaction with Earthquake

$$Q_1 = 24.837 \text{ (tf/m}^2\text{)}, Q_0 = 22.813 \text{ (tf/m}^2\text{)}$$

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-50.03	1.06	-53.28	-	-	-
Total	-	-50.03		-53.28	-	-	-

##### Uplift

	A( $m^2$ )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-0.59	0.70	-0.41	-	-	-
Total	-	-0.59		-0.41	-	-	-

(ii) Structural Calculation (Normal Water Surface : EL.148.900m)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-37.55	0.00	-39.48	0.00
Uplift	-0.59	0.00	-0.41	0.00
Total	-23.34	0.00	-24.35	0.00

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

Stress calculation of concrete

$$\begin{aligned} \text{Shear stress } \tau_c &= 0.78 \text{ (kgf/m}^2\text{)} < 5.5 \text{ OK} \\ \text{Compressive stress } \sigma_c &= 1.62 \text{ (kgf/m}^2\text{)} < 60 \text{ OK} \\ \text{Tensile stress } \sigma_t &= -1.62 \text{ (kgf/m}^2\text{)} < -3 \text{ OK} \end{aligned}$$

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

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-50.03	0.00	-53.28	0.00
Uplift	-0.59	0.00	-0.41	0.00
Total	-35.82	0.00	-38.15	0.00

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

Stress calculation of concrete

$$\begin{aligned} \text{Shear stress } \tau_c &= 1.19 \text{ (kgf/m}^2\text{)} < 8.25 \text{ OK} \\ \text{Compressive stress } \sigma_c &= 2.54 \text{ (kgf/m}^2\text{)} < 90 \text{ OK} \\ \text{Tensile stress } \sigma_t &= -2.54 \text{ (kgf/m}^2\text{)} < -4.5 \text{ OK} \end{aligned}$$

(c) Case 2 : Toe slab of Service Spillway, Surcharge Water Surface : EL.151.800m

Horizontal seismic coefficient : Kh=0.08 (50%)

(i) Loading Calculation

Each load is calculated hereinafter.

Dead Load

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	6.30	14.81	1.05	15.55	-	-	-
Total	6.30	14.81		15.55	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 24.106 \text{ (tf/m}^2\text{)}, Q_0 = 22.339 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-48.77	1.06	-51.85	-	-	-
Total	-	-48.77		-51.85	-	-	-

**Subgrade Reaction with Earthquake**

$$Q_1 = 28.345 \text{ (tf/m}^2\text{)}, Q_0 = 25.413 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-56.45	1.07	-60.35	-	-	-
Total	-	-56.45		-60.35	-	-	-

**Uplift**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-0.73	0.70	-0.51	-	-	-
Total	-	-0.73		-0.51	-	-	-

**(ii) Structural Calculation (Surcharge Water Surface : EL.151.800m)**

**Normal condition (without Earthquake)**

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-48.77	0.00	-51.85	0.00
Uplift	-0.73	0.00	-0.51	0.00
Total	-34.69	0.00	-36.82	0.00

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

**Stress calculation of concrete**

$$\begin{aligned} \text{Shear stress } \tau_c &= 1.16 \text{ (kgf/m}^2\text{)} < 5.5 \text{ OK} \\ \text{Compressive stress } \sigma_c &= 2.45 \text{ (kgf/m}^2\text{)} < 60 \text{ OK} \\ \text{Tensile stress } \sigma_t &= -2.45 \text{ (kgf/m}^2\text{)} < -3 \text{ OK} \end{aligned}$$

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

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-56.45	0.00	-60.35	0.00
Uplift	-0.73	0.00	-0.51	0.00
Total	-42.37	0.00	-45.31	0.00

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

**Stress calculation of concrete**

$$\begin{aligned} \text{Shear stress } \tau_c &= 1.41 \text{ (kgf/m}^2\text{)} < 8.25 \text{ OK} \\ \text{Compressive stress } \sigma_c &= 3.02 \text{ (kgf/m}^2\text{)} < 90 \text{ OK} \\ \text{Tensile stress } \sigma_t &= -3.02 \text{ (kgf/m}^2\text{)} < -4.5 \text{ OK} \end{aligned}$$

**(d) Case 3 : Toe slab of Service Spillway, Maximum Water Surface : EL.155.300m**

Horizontal seismic coefficient : Kh=0.0 (0%)

**(i) Loading Calculation**

Each load is calculated hereinafter.

**Dead Load**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
I(concrete)	6.30	14.81	1.05	15.55	-	-	-
Total	6.30	14.81		15.55	-	-	-

**Subgrade Reaction without Earthquake**

$$Q_I = 28.383 \text{ (tf/m}^2\text{)} , Q_o = 25.511 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-56.59	1.07	-60.47	-	-	-
Total	-	-56.59		-60.47	-	-	-

**Uplift**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-0.90	0.70	-0.63	-	-	-
Total	-	-0.90		-0.63	-	-	-

**(ii) Structural Calculation (Maximum Water Surface : EL. 155.300m)**

**Normal condition (without Earthquake)**

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-56.59	0.00	-60.47	0.00
Uplift	-0.90	0.00	-0.63	0.00
Total	-42.68	0.00	-45.56	0.00

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

**Stress calculation of concrete**

Shear stress  $\tau_c = 1.42 \text{ (kgf/m}^2\text{)} < 8.25 \text{ OK}$

Compressive stress  $\sigma_c = 3.04 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$

Tensile stress  $\sigma_t = -3.04 \text{ (kgf/m}^2\text{)} < -4.5 \text{ OK}$

**(e) Case 4 : Toe slab of Service Spillway, Empty Reservoir (No Reservoir Water)**

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

**(i) Loading Calculation**

Each load is calculated hereinafter.

**Dead Load**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
I(concrete)	6.30	14.81	1.05	15.55	-	-	-
Total	6.30	14.81		15.55	-	-	-

### Subgrade Reaction without Earthquake

$$Q_1 = 11.557 \text{ (tf/m}^2\text{)}, Q_0 = 13.507 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-26.32	1.02	-26.92	-	-	-
Total	-	-26.32		-26.92	-		-

### Subgrade Reaction with Earthquake

$$Q_1 = 14.451 \text{ (tf/m}^2\text{)}, Q_0 = 15.603 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-31.56	1.04	-32.71	-	-	-
Total	-	-31.56		-32.71	-		-

### (ii) Structural Calculation (Empty Reservoir)

#### Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-26.32	0.00	-26.92	0.00
Uplift	0.00	0.00	0.00	0.00
Total	-11.51	0.00	-11.37	0.00

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

#### Stress calculation of concrete

$$\begin{aligned} \text{Shear stress } \tau_c &= 0.38 \text{ (kgf/m}^2\text{)} < 5.5 \text{ OK} \\ \text{Compressive stress } \sigma_c &= 0.76 \text{ (kgf/m}^2\text{)} < 60 \text{ OK} \\ \text{Tensile stress } \sigma_t &= -0.76 \text{ (kgf/m}^2\text{)} < -3 \text{ OK} \end{aligned}$$

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

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-31.56	0.00	-32.71	0.00
Uplift	0.00	0.00	0.00	0.00
Total	-16.75	0.00	-17.17	0.00

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

#### Stress calculation of concrete

$$\begin{aligned} \text{Shear stress } \tau_c &= 0.56 \text{ (kgf/m}^2\text{)} < 8.25 \text{ OK} \\ \text{Compressive stress } \sigma_c &= 1.14 \text{ (kgf/m}^2\text{)} < 90 \text{ OK} \\ \text{Tensile stress } \sigma_t &= -1.14 \text{ (kgf/m}^2\text{)} < -4.5 \text{ OK} \end{aligned}$$

### (f) Reinforcing Bar Arrangement

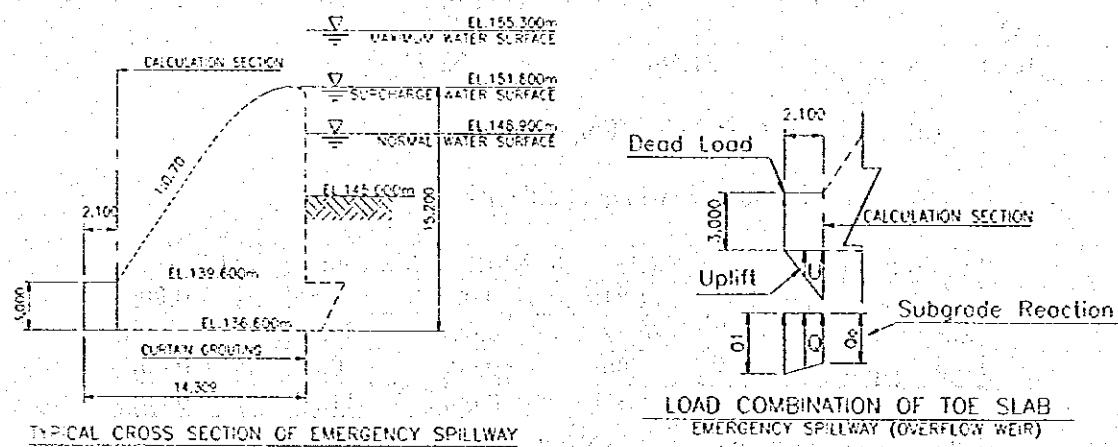
In all calculated cases and conditions, calculated stresses of concrete are smaller than allowable stresses. Therefore, the reinforcing bar arrangement is not necessary for toe slab of the Service Spillway.

## (2) Emergency Spillway

Structural calculation of toe slab is carried out for the Emergency Spillway.

### (a) Basic design condition

Typical cross section and load combinations are shown in the following figures.



Design conditions are shown in the following tables.

Item	Symbol	Unit	Value	Description
Unit weight of concrete	$\gamma_c$	(tf/m <sup>3</sup> )	2.35	Thick structure
Unit weight of wetted backfill soil	$\gamma_t$	(tf/m <sup>3</sup> )	1.90	Wet density
Unit weight of submerged backfill soil	$\gamma_s$	(tf/m <sup>3</sup> )	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	$\theta$	(degree)	0.0	
Angle between ground surface and horizontal plane	$\alpha$	(degree)	0.0	
Internal friction angle of soil	$\phi$	(degree)	35.0	Sandy soil
Friction angle of soil to concrete	$\delta$	(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	$\delta_e$	(degree)	17.5	$\delta_e = 1/2 \phi$
Seismic composite angle	$\theta_0$	(degree)	various	$\tan\theta_0 = Kh$

### (b) Case 1 : Toe slab of Emergency Spillway, Normal Water Surface : EL. 148.900m

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

#### (i) Loading Calculation

Each load is calculated hereinafter.

##### Dead Load

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	6.30	14.81	1.05	15.55	-	-	-
Total	6.30	14.81		15.55	-	-	-

##### Subgrade Reaction without Earthquake

$$Q_1 = 13.510 \text{ (tf/m}^2\text{)}, \quad Q_0 = 15.744 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-30.72	1.02	-31.43	-	-	-
Total	-	-30.72		-31.43	-	-	-

##### Subgrade Reaction with Earthquake

$$Q_1 = 25.045 \text{ (tf/m}^2\text{)}, \quad Q_0 = 23.898 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-51.39	1.06	-54.38	-	-	-
Total	-	-51.39		-54.38	-	-	-

##### Uplift

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-0.63	0.70	-0.44	-	-	-
Total	-	-0.63		-0.44	-	-	-

(ii) Structural Calculation (Normal Water Surface : EL.148.900m)

Normal condition (without Earthquake)

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-30.72	0.00	-31.43	0.00
Uplift	-0.63	0.00	-0.44	0.00
Total	-16.54	0.00	-16.33	0.00

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

Stress calculation of concrete

$$\begin{array}{lll} \text{Shear stress} & \tau_c = & 0.55 \text{ (kgf/m}^2\text{)} < 5.5 \text{ OK} \\ \text{Compressive stress} & \sigma_c = & 1.09 \text{ (kgf/m}^2\text{)} < 60 \text{ OK} \\ \text{Tensile stress} & \sigma_t = & -1.09 \text{ (kgf/m}^2\text{)} < -3 \text{ OK} \end{array}$$

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

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-51.39	0.00	-54.38	0.00
Uplift	-0.63	0.00	-0.44	0.00
Total	-37.22	0.00	-39.28	0.00

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

Stress calculation of concrete

$$\begin{array}{lll} \text{Shear stress} & \tau_c = & 1.24 \text{ (kgf/m}^2\text{)} < 8.25 \text{ OK} \\ \text{Compressive stress} & \sigma_c = & 2.62 \text{ (kgf/m}^2\text{)} < 90 \text{ OK} \\ \text{Tensile stress} & \sigma_t = & -2.62 \text{ (kgf/m}^2\text{)} < -4.5 \text{ OK} \end{array}$$

(c) Case 2 : Toe slab of Emergency Spillway, Surcharge Water Surface :  
EL.151.800m

Horizontal seismic coefficient : Kh=0.08 (50%)

(i) Loading Calculation

Each load is calculated hereinafter.

Dead Load

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
1(concrete)	6.30	14.81	1.05	15.55	-	-	-
Total	6.30	14.81		15.55	-	-	-

Subgrade Reaction without Earthquake

$$Q_1 = 21.573 \text{ (tf/m}^2\text{)}, Q_0 = 21.299 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-45.02	1.0522	-47.37	-	-	-
Total	-	-45.02		-47.37	-	-	-

**Subgrade Reaction with Earthquake**

$$Q_1 = 28.302 \text{ (tf/m}^2\text{)} , Q_0 = 26.047 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-57.07	1.0645	-60.75	-	-	-
Total	-	-57.07		-60.75	-		-

**Uplift**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-0.78	0.70	-0.55	-	-	-
Total		-0.78		-0.55	-		-

**(ii) Structural Calculation (Surcharge Water Surface : EL.151.800m)**

**Normal condition (without Earthquake)**

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-45.02	0.00	-47.37	0.00
Uplift	-0.78	0.00	-0.55	0.00
Total	-30.99	0.00	-32.37	0.00

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

**Stress calculation of concrete**

Shear stress	$\tau_c =$	1.03 (kgf/m <sup>2</sup> )	<	5.5 OK
Compressive stress	$\sigma_c =$	2.16 (kgf/m <sup>2</sup> )	<	60 OK
Tensile stress	$\sigma_t =$	-2.16 (kgf/m <sup>2</sup> )	<	-3 OK

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

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-57.07	0.00	-60.75	0.00
Uplift	-0.78	0.00	-0.55	0.00
Total	-43.04	0.00	-45.75	0.00

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

**Stress calculation of concrete**

Shear stress	$\tau_c =$	1.43 (kgf/m <sup>2</sup> )	<	8.25 OK
Compressive stress	$\sigma_c =$	3.05 (kgf/m <sup>2</sup> )	<	90 OK
Tensile stress	$\sigma_t =$	-3.05 (kgf/m <sup>2</sup> )	<	-4.5 OK

**(d) Case 3 : Toe slab of Emergency Spillway, Maximum Water Surface : EL.155.300m**

Horizontal seismic coefficient : Kh=0.0 (0%)

**(i) Loading Calculation**

Each load is calculated hereinafter.

**Dead Load**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
l(concrete)	6.30	14.81	1.05	15.55	-	-	-
Total	6.30	14.81		15.55	-	-	-

**Subgrade Reaction without Earthquake**

$$Q_1 = 33.421 \text{ (tf/m}^2\text{)}, Q_0 = 29.498 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-66.07	1.07	-70.81	-	-	-
Total	-	-66.07		-70.81	-	-	-

**Uplift**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
U	-	-0.96	0.70	-0.67	-	-	-
Total	-	-0.96		-0.67	-	-	-

**(ii) Structural Calculation of toe slab of Emergency Spillway, Maximum Water**

Surface : EL.155.300m

**Normal condition (without Earthquake)**

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-66.07	0.00	-70.81	0.00
Uplift	-0.96	0.00	-0.67	0.00
Total	-52.22	0.00	-55.94	0.00

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

**Stress calculation of concrete**

$$\text{Shear stress } \tau_c = 1.74 \text{ (kgf/m}^2\text{)} < 8.25 \text{ OK}$$

$$\text{Compressive stress } \sigma_c = 3.73 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$$

$$\text{Tensile stress } \sigma_t = -3.73 \text{ (kgf/m}^2\text{)} < -4.5 \text{ OK}$$

**(e) Case 4 : Toe slab of Emergency Spillway, Empty Reservoir (No Reservoir Water)**

Horizontal seismic coefficient : Kh=0.08 (50%)

**(i) Loading Calculation**

Each load is calculated hereinafter.

**Dead Load**

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
l(concrete)	6.30	14.81	1.05	15.55	-	-	-
Total	6.30	14.81		15.55	-	-	-

**Subgrade Reaction without Earthquake**

$$Q_1 = 4.593 \text{ (tf/m}^2\text{)}, Q_0 = 10.117 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-15.45	0.92	-14.19	-	-	-
Total	-	-15.45		-14.19	-		-

**Subgrade Reaction with Earthquake**

$$Q_1 = 9.604 \text{ (tf/m}^2\text{)}, Q_0 = 13.644 \text{ (tf/m}^2\text{)}$$

	A(m <sup>2</sup> )	V(tf)	X(m)	Mx(tf-m)	H(tf)	Y(m)	My(tf-m)
Q	-	-24.41	0.99	-24.15	-	-	-
Total	-	-24.41		-24.15	-		-

**(ii) Structural Calculation (Empty Reservoir)**

**Normal condition (without Earthquake)**

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-15.45	0.00	-14.19	0.00
Uplift	0.00	0.00	0.00	0.00
Total	-0.64	0.00	1.36	0.00

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

**Stress calculation of concrete**

Shear stress  $\tau_c = 0.02 \text{ (kgf/m}^2\text{)} < 5.5 \text{ OK}$

Compressive stress  $\sigma_c = -0.09 \text{ (kgf/m}^2\text{)} < 60 \text{ OK}$

Tensile stress  $\sigma_t = 0.09 \text{ (kgf/m}^2\text{)} < -3 \text{ OK}$

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

Total Load	V(=S)(tf)	H(=N)(tf)	Mx(tf-m)	My(tf-m)
Dead Load	14.81	0.00	15.55	0.00
Subgrade Reaction	-24.41	0.00	-24.15	0.00
Uplift	0.00	0.00	0.00	0.00
Total	-9.60	0.00	-8.60	0.00

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

**Stress calculation of concrete**

Shear stress  $\tau_c = 0.32 \text{ (kgf/m}^2\text{)} < 8.25 \text{ OK}$

Compressive stress  $\sigma_c = 0.57 \text{ (kgf/m}^2\text{)} < 90 \text{ OK}$

Tensile stress  $\sigma_t = -0.57 \text{ (kgf/m}^2\text{)} < -4.5 \text{ OK}$

**(f) Reinforcing Bar Arrangement**

In all calculated cases and conditions, calculated stresses of concrete are smaller than allowable stresses. Therefore, the reinforcing bar arrangement is not necessary for toe slab of the Emergency Spillway.