

### **3.7 Structural Design of Powerhouse**

The powerhouse of the Jatibalang Multipurpose Project is located on the right side of the stilling basin of the spillway. The outer wall of the powerhouse structure under elevation 98.00 m is a part of the guide wall of the spillway.

The powerhouse under EL. 98.00 m is divided into two spaces. One is for turbine, generator and accessories, and the other is for control and operation rooms of the power generation. Facilities for water supply are installed in the room at El.84.90m. At the bottom of the powerhouse, a pump pit is made to collect seepage water through the concrete walls from the ground. The water will be pumped up and drained to the spillway through the steel pipe on the wall.

The tailrace, 2.0 m high and 2.0 m wide, is running through the foot of the spillway after the powerhouse. At the end of the tailrace, a gate is equipped for inspection and maintenance of the tailrace. An air shaft made of reinforced concrete is furnished beside the powerhouse to release the water pressure in the tailrace at the sudden stop in case of full water condition.

The stability analysis and structural calculation of the powerhouse are principally carried out in accordance with the formulas and parameters as stipulated in the Design Criteria Report, Vol.2, March 1999.

#### **3.7.1 Stability of Powerhouse**

The stability analysis is performed to assess the potential for failure and to assess remedial treatments when necessary. Reference to the dimensions of the powerhouse is made in Chapter 3.1.

##### **1) Calculation Cases**

The stability analysis of the powerhouse is carried out for the following three cases:

- a. Normal Condition : A situation in which the powerhouse is being operated at the maximum plant discharge of  $Q=3.0 \text{ m}^3/\text{s}$ .

- b. Flood Condition : A situation in which the water level in the stilling basin is subject to the 100 year return period event ( $Q=340 \text{ m}^3/\text{s}$ ).
- c. Seismic Condition : A situation in which the powerhouse is being operated at the maximum power discharge of  $Q=3 \text{ m}^3/\text{s}$  in case that an earthquake may occur in the neighborhood of the powerhouse.

## 2) Allowable Stability Conditions

The allowable conditions for evaluating the powerhouse stability are given below.

**Stability Conditions**

	Normal condition	Flood condition	Seismic condition
Against overturning	$e < B/6$	$e < B/6$	$e < B/3$
Against sliding	$F_s \geq 1.5$	$F_s \geq 1.5$	$F_s \geq 1.2$
Bearing capacity of foundation	$q \leq Q_a$	$q \leq Q_a$	$q \leq 1.5Q_a$

Notes :  $e$  = eccentricity;  $B$  = width of base;  $F_s$  = safety factor;  $q$  = principal stress;

$Q_a$  = allowable compressive strength of foundation.

The evaluation formulae used for the stability analysis of the powerhouse are as follows.

### a) Stability against Overturning

The following formula is used for the stability evaluation against overturning:

$$e = |B/2 - d| = |B/2 - [(\sum Vx + \sum Hy)/\sum V]|$$

Where

$e$  : eccentricity of resultant force (m)

$B$  : width of base (m)

$d$  : distance between the acting point of the resultant force and the reference point (m)

$\sum V$  : resultant vertical force above base (tf)

$\Sigma H$  : resultant horizontal force above base (tf)

X : distance from the acting point of the resultant vertical force to the reference point (m)

Y : distance from the acting point of the resultant horizontal force to the reference point (m)

### b) Stability against Sliding

Henry's formula is used for the stability evaluation against sliding:

$$F_s = (\tau_0 BL + f \sum V) / \sum H$$

Where

$F_s$  : safety factor

$\tau_0$  : shear strength of rock foundation ( $\tau_0 = 50 \text{ tf/m}^2$ )

B : width of base (m)

L : length of base (m)

f : friction coefficient ( $f=0.8$ )

$\sum V$  : resultant vertical force above base (tf)

$\sum H$  : resultant horizontal force above base (tf)

### c) Bearing Capacity of Foundation

The maximum principal stress should be kept within the allowable rock bearing capacity. The maximum and minimum principal stresses can be obtained by:

$$q_{\max}, q_{\min} = \sum V (1 \pm 6e/B) / (BL)$$

Where

$q_{\max}, q_{\min}$  : maximum and minimum principal stresses ( $\text{tf/m}^2$ )

B : width of base (m)

L : length of base (m)

e : eccentricity (m)

$\sum V$  : resultant vertical force above base (tf)

### 3) Design Parameters

The computed parameters used for evaluating the powerhouse stability are given below.

**Characteristic Parameters**

No.	Item	Parameters	
(1)	Unit Weight	Concrete	2.35
		Reinforced concrete	2.5
		Soil (wet)	1.9
		Soil (under water)	0.9
		Water	1.0
(2)	Seismic Coefficient	Horizontal	0.16
		Vertical	0
(3)	Water Level in Stilling Basin	Normal & seismic conditions	82.631
		Flood condition	92.080
(4)	Groundwater Level at Mountain side	Normal & seismic conditions	84.900
		Flood condition	84.800
(5)	Characteristic Value of Rock Foundation	Compressive strength	100
		Shearing stress	50
		Internal friction angle	38.7°
		Internal friction coefficient	0.8
(6)	Characteristic Value of Soil	Cohesion	0
		Internal friction angle	35°

### 4) Loads and Load Combination

In order to compute the loads acting on the powerhouse accurately, the powerhouse was divided into four portions along the length direction. The profile and typical cross sections used for calculating the loads are shown in Fig.3.7.1. The loads acting on each portion under normal, seismic and flood conditions are shown in Figs. 3.7.2 ~3.7.3. The length of each portion is given below.

### Portions for Calculating Loads

Portion	Length of portion (m)	Typical section
B-B	5.000	B-B
C-C	9.366	C-C
D-D	7.634	D-D
E-E	8.000	E-E

The following loads are considered in the computations.

#### a) Self Weight

The self-weight of every structure of the powerhouse can be obtained by:

$$W = \gamma V$$

Where

$W$  : self weight (tf)

$\gamma$  : specific weight ( $\text{tf/m}^3$ )

$V$  : volume ( $\text{m}^3$ )

It should be noted that the weight of the upper structure of the powerhouse is assumed to be 80tf/m and the coordinates of the acting point are determined as  $X=9.5\text{m}$  and  $y=24\text{m}$ .

#### b) Hydrostatic Pressure

The water level in the stilling basin for the normal and seismic conditions is El.82.631m compared to the water level at El.92.08m for the flood case ( $Q=340 \text{ m}^3/\text{s}$ ). The groundwater level at the mountainside is assumed to be 84.9m for the normal and seismic conditions and El.84.8m for the flood case in consideration of the most disadvantageous combination. The hydrostatic pressure at the two sides is computed by

$$P_w = \gamma_w h$$

Where

$P_w$  : hydrostatic pressure ( $\text{tf/ m}^2$ )

$\gamma_w$  : specific weight of water (tf/m<sup>3</sup>)

$h$  : water depth (m)

### c) Earth Pressure

The level of the backfill soil at the mountainside is El.97.00m. The following formulae are employed for calculating the earth pressures under the normal, seismic and flood conditions.

For normal and flood conditions

$$P_a = K_a \cdot \gamma \cdot h + K_a \cdot q$$

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

Where

$P_a$  : active earth pressure (tf/m<sup>2</sup>)

$K_a$  : coefficient of active earth pressure

$h$  : soil depth (m)

$q$  : surcharge under normal and flood conditions (tf/m<sup>2</sup>)

$\gamma$  : unit weight of soil (tf/m<sup>3</sup>)

$\phi$  : internal friction angle of soil (degree)

$\alpha$  : angle between ground surface and horizontal plane (degree)

$\theta$  : angle between wall and vertical plane (degree)

$\delta$  : friction angle of soil to wall, the value of  $\delta$  is given below

Friction Angle of Soil to Wall

Structure type	Type of friction angle	Friction angle $\delta$ (°)		
		Normal condition	Flood condition	Seismic condition
Gravity structure	Soil to concrete	$\phi/3$	$\phi/3$	0
Other	Soil to soil	$\phi$	$\phi$	$\phi/2$

Notes:  $\phi$  = internal friction angle.

**For seismic condition**

$$P_{ea} = K_{ea} \cdot \gamma \cdot h + K_{ea} \cdot q'$$

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

Where

$P_{ea}$  : active earth pressure under seismic condition ( $\text{tf/m}^2$ )

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

$q'$  : surcharge under seismic condition ( $\text{tf/m}^2$ )

$\theta_0$  : resultant angle due to earthquake,  $\theta_0 = \tan^{-1} K_h$  (degree)

$K_h$  : horizontal seismic coefficient

The definitions of the other symbols are the same as the above.

The resultant soil force and horizontal and vertical components of the resultant soil force at i-layer per unit length are computed by

$$P_i = 0.5(p_{i-1} + p_i)h / \cos\theta$$

$$P_{ih} = P_i \cos(\theta + \delta)$$

$$P_{iv} = P_i \sin(\theta + \delta)$$

Where

$P_i$  : resultant soil force at i-layer per unit length ( $\text{tf/m}$ )

$p_{i-1}$  : earth pressure at (i-1)-layer ( $\text{tf/m}^2$ )

$p_i$  : earth pressure at i-layer ( $\text{tf/m}^2$ )

$P_{ih}$  : horizontal component of soil force at i-layer ( $\text{tf/m}$ )

$P_{iv}$  : vertical component of soil force at i-layer ( $\text{tf/m}$ )

The definitions of the angles of  $\theta$  and  $\delta$  are the same as the above.

**d) Uplift Pressure**

The uplift pressure is assumed to vary linearly along the base, and the values at the mountain side and stilling basin are equal to the full hydrostatic pressures at the two sides.

### e) Inertia due to Seismic Motion

The horizontal inertia due to an earthquake is computed by

$$I = K_h W$$

Where

$I$  : horizontal inertial force due to an earthquake (tf)

$K_h$  : horizontal seismic coefficient

$W$  : self weight (tf)

The combinations of the above-mentioned loads for different cases are given below.

Combinations of Loads for Stability Calculation

Load	Normal condition	Flood condition	Seismic condition
Self weight	✓	✓	✓
Hydrostatic pressure	✓	✓	✓
Earth pressure	✓	✓	✓
Uplift pressure	✓	✓	✓
Seismic inertia			✓

### 5) Computation Results

The computed results are shown in Tables 3.7.1~3.7.8. It can be found that the powerhouse is safe for any case since the computed values of the eccentricity and maximum stress are smaller than the allowable values and the safety factors are larger than the allowable values for each case.

**Table 3.7.1(1/8) Self Weight of B-B Portion under Normal and Earthquake Conditions**

Reference Section: B-B

Material ID	Part ID	Length in $x-y$ direction		Length in $z-z'$ or Triangle direction		Volume $V_i$ ( $m^3$ )	Unit weight $\gamma_i$ ( $tf/m^3$ )	Weight $W_i$ ( $tf$ )	$x_i$ (m)	$y_i$ (m)	Moment about $x$ axis $x_i * W_i$ (tf.m)	Moment about $y$ axis $y_i * W_i$ (tf.m)	Remarks	
		$x_i$ (m)	$y_i$ (m)	$b_i$ (m)	$a_i$ (m)									
Reinforced Concrete	1	1.00	15.50	5.00	1.00	77.50	2.50	193.75	3.50	10.25	678.13	1985.94		
	2	1.00	15.00	5.00	0.50	37.50	2.50	93.75	5.35	1.00	501.56	937.50		
	3	11.00	1.00	5.00	1.00	55.00	2.50	137.50	10.50	17.00	1443.75	2337.50		
	3a	1.00	0.80	3.00	1.00	2.40	2.50	6.00	11.76	16.10	70.58	96.60		
	3b	1.00	0.80	3.00	1.00	2.40	2.50	6.00	7.24	16.10	43.43	96.60		
	4	2.00	11.60	2.00	1.00	46.40	2.50	116.00	15.00	10.70	1740.00	1241.20	Column	
	4a	2.00	1.50	3.00	1.00	9.00	2.50	22.50	15.00	15.75	337.50	354.38		
	4b	9.00	1.50	2.00	1.00	27.00	2.50	67.50	9.50	15.75	641.25	1063.13		
	5	11.00	2.10	5.00	1.00	115.50	2.50	288.75	10.50	3.85	3031.88	1111.69		
	6	0.84	2.80	5.00	0.50	5.88	2.50	14.70	5.28	1.87	77.62	27.44		
	7	5.00	2.50	5.00	1.00	62.50	2.50	156.25	2.50	1.25	390.63	195.31		
Water	8	3.00	0.13	5.00	1.00	1.97	1.00	1.97	1.50	2.57	2.95	5.04		
Backfill soil	9	9.00	10.10	5.00	1.00	454.50	1.90	863.55	9.50	9.95	8203.73	8592.32	under EL 95	
	10	9.00	1.50	3.00	1.00	40.50	1.90	76.95	9.50	15.75	731.03	1211.96	above EL 95	
	11	1.00	0.80	3.00	-1.00	-2.40	1.90	-4.56	11.76	16.10	-53.64	-73.42	Deduction	
	12	2.00	10.10	3.00	1.00	-2.40	1.90	-4.56	7.24	16.10	-33.01	-73.42	Deduction	
Upper structure	Wup			5.00					400.00	9.50	24.00	3800.00	9600.00	
	Crane									15.70	9.50	23.50	1491.5	368.95 Crane
									993.85		2566.89		23483.61	30224.36

 $\Sigma$  Notes: Weight of upper structure( excluding crane ),  $W_{up}$ , is assumed as 80 tf/m.

$$X = \sum x_i * W_i / \sum V_i = 9.15$$

$$Y = \sum y_i * W_i / \sum V_i = 11.77$$

Inertial force during seismic motion

$$Kh = 0.16$$

$$I = KhW = -410.702$$

$x_i$ =Distance between centroid and reference axis  $y_i$ .  
 $y_i$ =Distance between centroid and reference axis  $x_i$ .

**Table 3.7.1(2/8) Self Weight of B-B Portion under Flood condition**  
**Reference Section: B-B**

Material ID	Length in x-direction (m)	Length in y-direction (m)	Length in z-direction (m)	Volume V <sub>i</sub> (m <sup>3</sup> )	Unit weight γ <sub>i</sub> (tf/m <sup>3</sup> )	Weight W <sub>i</sub> (tf)	xi (m)	yi (m)	Moment about x-axis xi*W <sub>i</sub> (tf.m)	Moment about y-axis yi*W <sub>i</sub> (tf.m)	Remarks	
Reinforced Concrete												
1	1.00	15.50	5.00	1.00	77.50	2.50	193.75	3.50	10.25	678.13	1985.94	
2	1.00	15.00	5.00	0.50	37.50	2.50	93.75	5.35	10.00	501.56	937.50	
3	11.00	1.00	5.00	1.00	55.00	2.50	137.50	10.50	17.00	1443.75	2337.50	
3a	1.00	0.80	3.00	1.00	2.40	2.50	6.00	11.76	16.10	70.58	96.60	
3b	1.00	0.80	3.00	1.00	2.40	2.50	6.00	7.24	16.10	43.43	96.60	
4	2.00	11.60	2.00	1.00	46.40	2.50	116.00	15.00	10.70	1740.00	1241.20 Column	
4a	2.00	1.50	3.00	1.00	9.00	2.50	22.50	15.00	15.75	337.50	354.38	
4b	9.00	1.50	2.00	1.00	27.00	2.50	67.50	9.50	15.75	641.25	1063.13 Beam	
5	11.00	2.10	5.00	1.00	115.50	2.50	288.75	10.50	3.85	3031.88	1111.69	
6	0.84	2.80	5.00	0.50	5.88	2.50	14.70	5.28	1.87	77.62	27.44	
7	5.00	2.50	5.00	1.00	62.50	2.50	156.25	2.50	1.25	390.63	195.31	
Water	8	3.00	9.58	5.00	1.00	143.70	1.00	143.70	1.50	7.29	215.55	1047.57
Backfill soil	9	9.00	10.10	5.00	1.00	454.50	1.90	863.55	9.50	9.95	8203.73	8592.32 under EL 95
	10	9.00	1.50	3.00	1.00	40.50	1.90	76.95	9.50	15.75	731.03	1211.96 above EL 95
	11											
	(-3a)	1.00	0.80	3.00	-1.00	-2.40	-1.90	-4.56	11.76	16.10	-53.64	-73.42 Deduction
	11											
	(-3b)	1.00	0.80	3.00	-1.00	-2.40	1.90	-4.56	7.24	16.10	-33.01	-73.42 Deduction
	12	2.00	10.10	3.00	1.00	60.60	1.90	115.14	15.00	9.95	1727.10	1145.64
Upper structure	Wup							400.00	9.50	24.00	3800.00	9600.00
	Crane								15.70	9.50	23.50	149.15 368.95 Crane
	20											
								1135.58	2708.62	23696.21	31266.90	

Notes: Weight of upper structure( excluding crane ), Wup, is assumed as  
 $X = \sum x_i * W_i / \sum W_i = 8.75$   
 $Y = \sum y_i * W_i / \sum W_i = 11.54$

$\sum z_i$   
 $x_i = \text{Distance between centroid and reference axis } Y;$   
 $y_i = \text{Distance between centroid and reference axis } X;$





**Table 3.7.1(5/8) Self Weight of D-D Portion under Normal and Earthquake Conditions**

Reference Section: D-D

Materal ID	Part ID	Length in x-direction ai (m)	Length in y-direction bi (m)	Length in z-direction ci (m)	Volume V (m <sup>3</sup> )	Unit weight γ <sub>i</sub> (tf/m <sup>3</sup> )	Weight W <sub>i</sub> (tf)	xi	yi (m)	xi*W <sub>i</sub> (tfm)	Moment about y axis yi*W <sub>i</sub> (tfm)	Moment about x axis xi*W <sub>i</sub> (tfm)	Moment about y axis yi (m)	Moment about x axis xi (m)	Remarks
Reinforced Concrete	1	3.00	2.50	7.634	1.00	57.26	2.50	143.14	1.50	214.71	214.71	214.71	178.92		
	2	11.50	2.30	7.634	1.00	201.92	2.50	504.80	8.75	-11.5	4416.98	-530.52			
	2a	0.69	2.30	7.634	0.50	6.06	2.50	15.14	14.73	-0.77	223.07	-11.61			
	2b	0.69	2.30	7.634	0.50	6.06	2.50	15.14	2.77	-0.77	41.95	-11.61			
	2c	9.00	4.90	7.634	1.00	336.66	2.50	841.65	9.50	2.45	7995.66	2062.04			
	3	2.00	17.50	7.634	1.00	267.19	2.50	667.98	4.00	8.75	2671.90	5844.78			
	4	2.00	11.00	7.634	1.00	167.95	2.50	419.87	15.00	5.50	6298.05	2309.29			
	4a	1.00	1.00	7.634	0.50	3.82	2.50	9.54	15.33	11.33	-146.32	108.15			
	4b	1.00	6.50	7.634	1.00	49.62	2.50	124.05	14.50	14.25	1798.76	1767.75			
	5	1.00	0.50	7.634	1.00	3.82	2.50	9.54	3.50	17.75	33.40	169.38			
	6	1.00	0.50	7.634	1.00	3.82	2.50	9.54	13.50	17.25	128.82	164.61			
	7	2.10	1.10	3.000	-1.00	-6.93	2.50	-17.33	12.95	4.35	-224.36	-75.36			
	8	2.00	5.20	3.000	-1.00	-31.20	2.50	-78.00	6.00	2.60	-468.00	-202.80			
	9	5.80	3.10	5.100	-1.00	-91.70	2.50	-229.25	10.50	1.25	-240.70	-286.56			
Water	10	3.00	0.13	7.634	1.00	3.00	1.00	3.00		1.50	2.57	4.50	7.70		
Backfill soil	11	1.00	1.00	7.634	0.50	3.82	1.90	7.25	15.33	12.33	111.20	89.45			
	12	1.00	5.00	7.634	1.00	38.17	1.90	72.52	15.50	14.50	1124.11	1051.58			
Upper structure	W <sub>UP</sub>			7.634				610.72	9.50	24.00	5801.84	14657.28			
Turbine									11.84	10.50	5.30	124.30	68.66		
Generator									11.84	10.50	5.30	124.30	68.66		
								1019.32			3153.00		28160.44	27379.78	

Notes: Weight of upper structure( excluding crane ), W<sub>up</sub>, is assumed as  
 $X = \sum x_i * W_i / \sum W_i = 8.93$   
 $Y = \sum y_i * W_i / \sum W_i = 8.68$

Acting point of inertial force  
 $K_h = 0.16$   
 $I = K_h W = -504.48$

Inertial force during seismic motion

$\Sigma$  Runner of generator = 5.92 ton  
 $x_i =$ Distance between centroid and reference axis Y;  
 $y_i =$ Distance between centroid and reference axis X;

$W_i =$ Weight of upper structure( excluding crane )

## Reference Section: E-E

Table 3.7.1(6/8) Self Weight of D-D Portion under Flood condition

Material ID	Part ID	Length in x <sup>-</sup> direction			Length in y <sup>-</sup> or z <sup>-</sup> direction			Volume V <sub>i</sub> (m <sup>3</sup> )	Weight W <sub>i</sub> (tf) (tf/m <sup>3</sup> )	Unit weight γ <sub>i</sub>	xi (m)	yi (m)	xi*W <sub>i</sub> (tfm)	yi*W <sub>i</sub> (tfm)	Moment about y axis	Moment about x axis	Remarks	
		a <sub>i</sub> (m)	b <sub>i</sub> (m)	c <sub>i</sub> (m)	a <sub>i</sub> (m)	b <sub>i</sub> (m)	c <sub>i</sub> (m)											
Reinforced Concrete	1	3.00	2.50	7.634	1.00	57.26	2.50	143.14	1.50	1.25	214.71	178.92						
	2	11.50	2.30	7.634	1.00	201.92	2.50	504.80	8.75	-1.15	4416.98	-580.52						
	2a	0.69	2.30	7.634	0.50	6.06	2.50	15.14	14.73	-0.77	223.07	-11.61						
	2b	0.69	2.30	7.634	0.50	6.06	2.50	15.14	2.77	-0.77	41.95	-11.61						
	2c	9.00	4.90	7.634	1.00	33.66	2.50	841.65	9.50	2.45	7995.66	2062.04						
	3	2.00	17.50	7.634	1.00	267.19	2.50	667.98	4.00	8.75	2671.90	5844.78						
	4	2.00	11.00	7.634	1.00	16.95	2.50	419.87	15.00	5.50	6298.05	2309.29						
	4a	1.00	1.00	7.634	0.50	3.82	2.50	9.54	15.33	11.33	146.32	108.15						
	4b	1.00	6.50	7.634	1.00	49.62	2.50	124.05	14.50	14.25	1798.76	1767.75						
	5	1.00	0.50	7.634	1.00	3.82	2.50	9.54	3.50	17.75	33.40	169.38						
	6	1.00	0.50	7.634	1.00	3.82	2.50	9.54	13.50	17.25	128.82	164.61						
	7	2.10	1.10	3.000	-1.00	-6.93	2.50	-17.33	12.95	4.35	-224.36	-75.36						
	8	2.00	5.20	3.000	-1.00	-31.20	2.50	-78.00	6.00	2.60	-468.00	-202.80						
	9	5.80	3.10	5.100	-1.00	-91.70	2.50	-229.25	10.50	1.25	-2407.07	-286.56						
Water	10	3.00	9.58	7.634	1.00	219.40	1.00	219.40	1.50	7.29	329.10	1599.43						
Backfill soil	11	1.00	1.00	7.634	0.50	3.82	1.90	7.25	15.33	12.33	111.20	89.45						
	12	1.00	5.00	7.634	1.00	38.17	1.90	72.52	15.50	14.50	1124.11	1051.58						
Upper structure	Wup			7.634							610.72	9.50	24.00	5801.84	14657.28			
Turbine											11.84	10.50	5.80	124.30	68.66			
Generator											11.84	10.50	5.80	124.30	68.66			
														1235.72	33369.40	28485.04	28971.52	

Notes: Weight of upper structure(excluding crane), Wup, is assumed as

$$X = \sum x_i * W_i / \sum W_i = 8.45$$

$$Y = \sum y_i * W_i / \sum W_i = 8.60$$

Acting point of inertial force

Σ tf/m. Runner of generator = 80 ton

$$xi = \sum x_i * W_i / \sum W_i$$

$$yi = \sum y_i * W_i / \sum W_i$$

Table 3.7.1(7/8) Self Weight of E-E Portion under Normal and Earthquake Conditions

Reference Section: E-E

Material ID	Part ID	Length in x-- direction (m)	Length in y-- direction (m)	Length in z-- direction (m)	Volume or Triangle in xy plane (1.00 or 0.5)	Unit weight $\gamma_i$ (tf/m <sup>3</sup> )	Weight W <sub>i</sub> (tf)	Weight x <sub>i</sub>	Weight y <sub>i</sub>	Moment about y axis x <sub>i</sub> *W <sub>i</sub> (tfm)	Moment about x axis y <sub>i</sub> *W <sub>i</sub> (tfm)	Remarks
Reinforced Concrete	1	3.00	2.50	8.00	1.00	60.00	2.50	150.00	1.50	1.25	225.00	187.50
	2	6.00	4.00	8.00	1.00	192.00	2.50	480.00	6.00	0.80	2830.00	384.00
	3a	1.20	4.00	8.00	0.50	19.20	2.50	48.00	9.40	1.47	451.20	70.40
	3	13.00	2.10	8.00	1.00	218.40	2.50	546.00	9.50	3.85	5137.00	2162.10
	4	2.00	12.60	8.00	1.00	201.60	2.50	504.00	4.00	11.20	2016.00	5644.80
	5	2.00	6.10	8.00	1.00	97.60	2.50	244.00	15.00	7.95	3660.00	1939.80
	5a	1.00	1.00	8.00	0.50	4.00	2.50	10.00	15.33	11.33	153.33	113.33
	6	9.00	1.00	8.00	1.00	72.00	2.50	180.00	9.50	12.50	1710.00	2250.00
	7	1.00	0.50	8.00	1.00	4.00	2.50	10.00	3.50	17.75	35.00	177.50
	8	1.00	6.50	8.00	1.00	52.00	2.50	130.00	14.50	14.25	1835.00	1852.50
	9	9.00	0.70	8.00	1.00	50.40	2.50	126.00	9.50	17.15	1197.00	2160.90
	10	9.00	11.90	2.00	1.00	214.20	2.50	535.50	9.50	10.85	5087.25	5810.17
	11	9.00	11.90	1.00	1.00	107.10	2.50	267.75	9.50	10.85	2543.63	2905.09 Wall
	12	2.00	2.00	8.00	-1.00	-32.00	2.50	-80.00	6.00	1.80	-480.00	-144.00
	13	4.00	3.00	2.00	-1.00	-24.00	2.50	-60.00	9.50	6.40	-570.00	-384.00
	14	3.00	2.50	2.00	-1.00	-15.00	2.50	-37.50	9.00	14.25	-337.50	-534.38
Water	15	3.00	0.13	8.00	1.00	3.14	1.00	3.14	1.50	2.57	4.72	8.07
Backfill soil	16	1.00	1.00	7.634	0.50	3.82	1.90	7.25	1.533	12.33	111.20	89.45
	17	1.00	5.00	7.634	1.00	38.17	1.90	72.52	15.50	14.50	1124.11	1051.58
Upper structure	W <sub>up</sub>							610.72	9.50	24.00	5801.84	14657.28
											32684.77	40342.10
												80 tf/m.

 $\Sigma$  Notes: Weight of upper structure (excluding crane), W<sub>up</sub>, is assumed as

$X = \sum x_i * W_i / \sum W_i = 8.72$

$Y = \sum y_i * W_i / \sum W_i = 1.077$

Inertial force during seismic motion

$K_h = 0.16$

$I = K_h W = -599.582$

Acting point of inertial force

$x_i = \text{Distance between centroid and reference axis } y$   
 $y_i = \text{Distance between centroid and reference axis } x$

Table 3.7.1(8/8) Self Weight of E-E Portion under Flood condition

Reference Section: E-E

Material ID	Part ID	Length in z-direction (m)			Volume $V_i$ ( $m^3$ )	Unit weight $\gamma_i$ ( $kN/m^3$ )	Weight $W_i(tf)$	$x_i$ (m)	$y_i$ (m)	$x_i * W_i(tfm)$	Moment about x axis	Moment about y axis	Remarks
		$x$ -direction	$y$ -direction	$z$ -direction									
ai (m)	bi (m)	ci (m)											
Reinforced Concrete	1	3.00	2.50	8.00	1.00	60.00	2.50	150.00	1.50	1.25	225.00	187.50	
	2	6.00	4.00	8.00	1.00	192.00	2.50	480.00	6.00	0.80	2880.00	384.00	
	2a	1.20	4.00	8.00	0.50	19.20	2.50	48.00	9.40	1.47	451.20	70.40	
	3	13.00	2.10	8.00	1.00	218.40	2.50	546.00	9.50	3.85	5187.00	2102.10	
	4	2.00	12.60	8.00	1.00	201.60	2.50	504.00	4.00	11.20	2016.00	5644.80	
	5	2.00	6.10	8.00	1.00	97.60	2.50	244.00	15.00	7.95	3660.00	1939.80	
	5a	1.00	1.00	8.00	0.50	4.00	2.50	10.00	15.33	11.33	153.33	113.33	
	6	9.00	1.00	8.00	1.00	72.00	2.50	180.00	9.50	12.50	1710.00	2250.00	
	7	1.00	0.50	8.00	1.00	4.00	2.50	10.00	3.50	17.75	35.00	177.50	
	8	1.00	6.50	8.00	1.00	52.00	2.50	130.00	14.50	14.25	1885.00	1852.50	
	9	9.00	0.70	8.00	1.00	50.40	2.50	126.00	9.50	17.15	1197.00	2160.90	
	10	9.00	11.90	2.00	1.00	214.20	2.50	535.50	9.50	10.85	5087.25	5810.17	
	11	9.00	11.90	1.00	1.00	107.10	2.50	267.75	9.50	10.85	2543.63	2905.09	Wall
	12	2.00	2.00	8.00	-1.00	-32.00	2.50	-80.00	6.00	1.80	-480.00	-144.00	
	13	4.00	3.00	2.00	-1.00	-24.00	2.50	-60.00	9.50	6.40	-570.00	-384.00	
	14	3.00	2.50	2.00	-1.00	-15.00	2.50	-37.50	9.00	14.25	-337.50	-534.38	
Water	15	3.00	9.58	8.00	1.00	229.92	1.00	229.92	1.50	7.29	344.88	1676.12	
Backfill soil	16	1.00	1.00	7.634	0.50	3.82	1.90	7.25	15.33	12.33	111.20	89.45	
	17	1.00	5.00	7.634	1.00	38.17	1.90	72.52	15.50	14.50	1124.11	1051.58	
Upper structure				7.634				610.72	9.50	24.00	5801.84	14657.28	
											33024.94	42010.15	
											3974.17		
												80	
													tf/m.

Notes: Weight of upper structure(excluding crane),  $W_{up}$ , is assumed as  
 $X = \sum x_i * W_i / \sum W_i = 8.31$   
 $Y = \sum y_i * W_i / \sum W_i = 10.57$   
 Acting point of inertial force

**Table 3.7.2(1/3) Calculated Results of B-B Portion under Normal Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-60.03		1.63		-98.04
2		17.31		0.88		15.18
3						
4						
5						
$\Sigma$	0.00	-42.72				-82.86

$$Y = \sum H_i * y_i / \sum H_i = 1.94$$

$$ci(m) = 5.0$$

xi=Distance between centroid and reference axis y;

yi=Distance between centroid and reference axis x;

ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	99.61	-142.26	16.00	8.933	1593.77	-1270.85
2	34.58	-49.38	16.00	3.850	553.21	-190.11
3	1.42	-2.03	16.00	3.500	22.74	-7.10
4						
5						
$\Sigma$	135.61	-193.67			2169.72	-1468.06

$$X = \sum V_i * x_i / \sum V_i = 16.00$$

$$Y = \sum H_i * y_i / \sum H_i = 7.58$$

$$ci(m) = 5.0$$

xi=Distance between centroid and reference axis y;

yi=Distance between centroid and reference axis x;

ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-65.78		2.50		-164.44	
2	-28.36		3.33		-94.54	
3	-5.88		5.28		-31.05	
4	-124.32		10.92		-1357.57	
5						
$\Sigma$	-224.34					-1647.60

$$X = \sum V_i * x_i / \sum V_i = 7.34$$

$$|c_i|(m) = 5.0$$

$x_i$ =Distance between centroid and reference axis y;  
 $y_i$ =Distance between centroid and reference axis x;  
 $c_i$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component $V(tf)$	Horizontal component $H(tf)$	X (m)	Y (m)	Moment about y axis $V*X(tfm)$	Moment about x axis $H*Y(tfm)$
Self weight	2566.89		9.15		23483.61	
Hydrostatic pressure		-42.72		1.94		-82.86
Earth pressure	135.61	-193.67	16.00	7.58	2169.72	-1468.06
Uplift pressure	-224.34		7.34		-1647.60	
Total	2478.16	-236.39			24005.74	-1550.93

$X = \sum V_i * x_i / \sum V = 9.69$  X=Distance between centroid to reference axis x;  
 $Y = \sum H_i * y_i / \sum H = 6.56$  Y=Distance between centroid to reference axis y;

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V = 9.06 \text{ (m)}$$

#### 3) Against overturning ( $B=16$ )

$$e = |B/2 - d| = 1.06 < B/6 = 2.67 \text{ OK}$$

$$B = 16.00 \text{ (m)}$$

#### 4) Against sliding

$$F_s = (\tau_0 * B * c_i + f * \sum V) / |\sum H| = 25.31 > 1.5 \text{ OK}$$

$$\tau_0 = 50 \text{ (tf/m}^2\text{)}$$

$$f = 0.8$$

#### 5) Bearing capacity ( $B=16$ )

$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{max} = 216.5 < Q_a * c_i = 500 \text{ OK}$$

$$Q_{min} = 93.3 < Q_a * c_i = 500 \text{ OK}$$

$$Q_a = 100 \text{ (tf/m}^2\text{)}$$

**Table 3.7.2(2/3) Calculated Results of B-B Portion under Earthquake Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-60.03		1.63		-98.04
2		17.31		0.88		15.18
3						
4						
5						
$\Sigma$		-42.72				-82.86

$$Y = \sum H_i * y_i / \sum H_i = 1.94$$

$$c_i (m) = 5.0$$

xi=Distance between centroid and reference axis y;  
 yi=Distance between centroid and reference axis x;  
 ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	72.78	-230.82	16.00	8.933	1164.44	-2061.99
2	25.26	-80.12	16.00	3.850	404.18	-308.46
3	1.04	-3.29	16.00	3.500	16.61	-11.53
4						
5						
$\Sigma$	99.08	-314.23			1585.24	-2381.98

$$X = \sum V_i * x_i / \sum V_i = 16.00$$

$$Y = \sum H_i * y_i / \sum H_i = 7.58$$

$$c_i (m) = 5.0$$

xi=Distance between centroid and reference axis y;  
 yi=Distance between centroid and reference axis x;  
 ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-65.78		2.50		-164.44	
2	-28.36		3.33		-94.54	
3	-5.88		5.28		-31.05	
4	-124.32		10.92		-1357.57	
5						
$\Sigma$	-224.34				-1647.60	

$$X = \sum V_i * x_i / \sum V_i = 7.34$$

$$|ci|(m) = 5.0$$

$xi$ =Distance between centroid and reference axis y;  
 $yi$ =Distance between centroid and reference axis x;  
 $ci$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	2566.89		9.15	11.77	23483.61	
Hydrostatic pressure		-42.72		1.94		-82.86
Earth pressure	99.08	-314.23	16.00	7.58	1585.24	-2381.98
Uplift pressure	-224.34		7.34		-1647.60	
Seismic inertia		-410.70		11.77		-4835.90
Total	2441.62	-767.65			23421.25	-7300.74

$X = \sum Vi * xi / \sum V = 9.59$  X=Distance between centroid and reference axis y;  
 $Y = \sum Hi * yi / \sum H = 9.51$  Y=Distance between centroid and reference axis x;

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V = 6.60$$

#### 3) Against overturning (B=16)

$$e = |B/2 - d|$$

$$e = |16/2 - 6.60| = 1.40 < B/3 = 5.33 \quad \text{OK}$$

$$B = 16.00 \quad (\text{m})$$

#### 4) Against sliding

$$Fs = (\tau_0 * B + c * \sum V) / |\sum H| = 7.76 > 1.2 \quad \text{OK}$$

$$\tau_0 = 50 \quad (\text{tf/m}^2)$$

$$c = 0.8$$

#### 5) Bearing capacity (B=16)

$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{\max} = 232.6 < 1.5Q_a * ci = 750 \quad \text{OK}$$

$$Q_{\min} = 72.6 < 1.5Q_a * ci = 750 \quad \text{OK}$$

$$Q_a = 100 \quad (\text{tf/m}^2)$$

**Table 3.7.2(3/3) Calculated Results of B-B Portion under Flood Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-57.60		1.60		-92.16
2		364.82		4.03		1468.99
3						
4						
5						
$\Sigma$		307.22				1376.83

$$Y = \sum H_i * y_i / \sum H_i = 4.48$$

$$c_i(m) = 5.0$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	101.26	-144.62	16.00	8.867	1620.23	-1282.30
2	33.20	-47.42	16.00	3.800	531.22	-180.18
3	1.29	-1.84	16.00	3.467	20.63	-6.38
4						
5						
$\Sigma$	135.75	-193.88			2172.07	-1468.86

$$X = \sum V_i * x_i / \sum V_i = 16.00$$

$$Y = \sum H_i * y_i / \sum H_i = 7.58$$

$$c_i(m) = 5.0$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-224.78		2.50		-561.96	
2	-170.46		1.67		-284.10	
3	-206.05		10.50		-2163.55	
4	-11.01		5.28		-58.16	
5						
6						
$\Sigma$	-612.31				-3067.76	

$$X = \sum V_i * x_i / \sum V_i = 5.01$$

$|ci| (m) = \boxed{5.0}$

$xi$ =Distance between centroid and reference axis y;  
 $yi$ =Distance between centroid and reference axis x;  
 $ci$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	2708.62		8.75	11.54	23696.21	
Hydrostatic pressure		307.22		4.48		1376.83
Earth pressure	135.75	-193.88	16.00	7.58	2172.07	-1468.86
Uplift pressure	-612.31		5.01		-3067.76	
Total	2232.06	113.34			22800.52	-92.03

$$X = \sum Vi * xi / \sum V =$$

10.22 X=Distance between centroid and reference axis y;

$$Y = \sum Hi * yi / \sum H =$$

-0.81 Y=Distance between centroid and reference axis x;

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V$$

$$= 10.17 \text{ (m)}$$

#### 3) Against overturning (B=16)

$$e = |B/2 - d|$$

$$= 2.17 < B/6 = 2.67 \text{ OK}$$

$$B = 16.00 \text{ (m)}$$

#### 4) Against sliding

$$Fs = (\tau_0 * B * c_i + f * \sum V) / |\sum H| =$$

$$= 51.05 > 1.5 \text{ OK}$$

$$\tau_0 = 50 \text{ (tf/m}^2\text{)}$$

$$f = 0.8$$

#### 5) Bearing capacity (B=16)

$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{max} = 253.2 < Q_a * c_i = 500 \text{ OK}$$

$$Q_{min} = 25.8 < Q_a * c_i = 500 \text{ OK}$$

$$Q_a = 100 \text{ (tf/m}^2\text{)}$$

**Table 3.7.3(1/3) Calculated Results of C-C Portion under Normal Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-112.44		1.63		-183.65
2		32.42		0.88		28.43
3						
4						
5						
$\Sigma$		-80.02				-155.22

$$Y = \sum H_i * y_i / \sum H_i = 1.94$$

$$ci(m) = 9.366$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	66.08	-320.03	16.00	8.933	1057.30	-2858.96
2	22.94	-111.09	16.00	3.850	367.00	-427.68
3	0.94	-4.57	16.00	3.500	15.09	-15.98
4						
5						
$\Sigma$	89.96	-435.68			1439.39	-3302.62

$$X = \sum V_i * x_i / \sum V_i = 16.00$$

$$Y = \sum H_i * y_i / \sum H_i = 7.58$$

$$ci(m) = 9.366$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-123.21		2.50		-308.02	
2	-53.13		3.33		-177.10	
3	-11.01		5.28		-58.16	
4	-232.88		10.92		-2543.01	
5						
$\Sigma$	-420.23				-3086.28	

$$X = \sum V_i * x_i / \sum V_i = 7.34$$

$$ci \text{ (m)} = 9.366$$

$xi$ =Distance between centroid and reference axis y;  
 $yi$ =Distance between centroid and reference axis x;  
 $ci$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	3430.96		8.80	11.57	30191.14	
Hydrostatic pressure		-80.02		1.94		-155.22
Earth press.	89.96	-435.68	16.00	7.58	1439.39	-3302.62
Uplift press.	-420.23		7.34		-3086.28	
Total	3100.70	-515.71			28544.24	-3457.84

$$X = \sum V_i * x_i / \sum V_i =$$

9.21 X=Distance between centroid and reference axis y;

$$Y = \sum H_i * y_i / \sum H_i =$$

6.71 Y=Distance between centroid and reference axis x;

#### 2) Acting point of resultant force

$$d = (\sum V_i * x_i + \sum H_i * y_i) / \sum V_i = 8.09 \text{ (m)}$$

#### 3) Against overturning (B=16)

$$e = |B/2 - d| = 0.09 < B/6 = 2.67 \text{ OK}$$

$$B = 16.00 \text{ (m)}$$

#### 4) Against sliding

$$Fs = (\tau_0 * B * ci + f * \sum V_i) / |\sum H_i| = 19.34 > 1.5 \text{ OK}$$

$$\tau_0 = 50 \text{ (tf/m2)}$$

$$f = 0.8$$

#### 5) Bearing capacity (B=16)

$$Q = \sum V_i / B * (1 \pm 6e/B) =$$

Qmax =	200.4	$\langle Q_a * ci =$	936.6	OK
Qmin =	187.2	$\langle Q_a * ci =$	936.6	OK
Qa =	100	(tf/m <sup>2</sup> )		

**Table 3.7.3(2/3) Calculated Results of C-C Portion under Earthquake Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-112.44		1.63		-183.65
2		32.42		0.88		28.43
3						
4						
5						
$\Sigma$		-80.02				-155.22

$$Y = \sum H_i * y_i / \sum H_i = 1.94$$

$$ci(m) = 9.366$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	0.00	-478.01	16.00	8.933	0.00	-4270.18
2	0.00	-165.92	16.00	3.850	0.00	-638.79
3	0.00	-6.82	16.00	3.500	0.00	-23.87
4						
5						
$\Sigma$	0.00	-650.74			0.00	-4932.84

$$X = \sum V_i * x_i / \sum V_i = 0.00$$

$$Y = \sum H_i * y_i / \sum H_i = 7.58$$

$$ci(m) = 9.366$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-123.21		2.50		-308.02	
2	-53.13		3.33		-177.10	
3	-11.01		5.28		-58.16	
4	-232.88		10.92		-2543.01	
5						
$\Sigma$	-420.23				-3086.28	

$$X = \sum V_i * x_i / \sum V_i = 7.34$$

$$|ci| (m) = 9.366$$

$xi$ =Distance between centroid and reference axis y;  
 $yi$ =Distance between centroid and reference axis x;  
 $ci$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component $V(tf)$	Horizontal component $H(tf)$	X (m)	Y (m)	Moment about y axis $V*X(tfm)$	Moment about x axis $H*Y(tfm)$
Self weight	3430.96		8.80	11.57	30191.14	
Hydrostatic pressure		-80.02		1.94		-155.22
Earth pressure	0.00	-650.74	0.00	7.58	0.00	-4932.84
Uplift pressure	-420.23		7.34		-3086.28	
Seismic inertia		-548.95		11.57		-6352.55
Total	3010.73	-1279.72			27104.86	-11440.61

$$X = \sum V_i * x_i / \sum V = 9.00$$

$$Y = \sum H_i * y_i / \sum H = 8.94$$

X=Distance between centroid and reference axis y;  
Y=Distance between centroid and reference axis x;

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V = 5.20$$

#### 3) Against overturning ( $B=16$ )

$$e = |B/2 - d| = 2.80 < B/3 = 5.33 \quad \text{OK}$$

$$B = 16.00 \quad (\text{m})$$

#### 4) Against sliding

$$F_s = (\tau_0 * B * c_i + f * \sum V) / |\sum H| = 7.74 > 1.2 \quad \text{OK}$$

$$\tau_0 = 50 \quad (\text{tf/m}^2)$$

$$f = 0.8$$

#### 5) Bearing capacity ( $B=16$ )

$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{\max} = 385.6 < 1.5Q_a * c_i = 1404.9 \quad \text{OK}$$

$$Q_{\min} = -9.2 < 1.5Q_a * c_i = 1404.9 \quad \text{OK}$$

$$Q_a = 100 \quad (\text{tf/m}^2)$$

**Table 3.7.3(3/3) Calculated Results of C-C Portion under Flood Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-107.90		1.60	0.00	-172.63
2		683.37		4.03	0.00	2751.72
3						
4						
5						
$\Sigma$		575.48				2579.08

$$Y = \sum H_i * y_i / \sum H_i =$$

$$4.48$$

$$ci(m) = 9.366$$

x<sub>i</sub>=Distance between centroid and reference axis y;  
y<sub>i</sub>=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	67.18	-325.34	16.00	8.867	1074.85	-2884.72
2	22.03	-106.67	16.00	3.800	352.41	-405.35
3	0.86	-4.14	16.00	3.467	13.68	-14.36
4						
5						
$\Sigma$	90.06	-436.16			1440.94	-3304.42

$$X = \sum V_i * x_i / \sum V_i =$$

$$16.00$$

$$Y = \sum H_i * y_i / \sum H_i =$$

$$7.58$$

$$ci(m) = 9.366$$

x<sub>i</sub>=Distance between centroid and reference axis y;  
y<sub>i</sub>=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-224.78		2.50		-561.96	
2	-170.46		1.67		-284.10	
3	-206.05		10.50		-2163.55	
4	-11.01		5.28		-58.16	
5						
6						
$\Sigma$	-612.31				-3067.76	

$$X = \sum V_i * x_i / \sum V_i =$$

$$5.01$$

$$c_i \text{ (m)} = 9.366$$

$x_i$ =Distance between centroid and reference axis y;  
 $y_i$ =Distance between centroid and reference axis x;  
 $c_i$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	3696.46		8.28	11.27	30589.39	
Hydrostatic pressure		575.48		4.48		2579.08
Earth pressure	90.06	-436.16	16.00	7.58	1440.94	-3304.42
Uplift pressure	-612.31		5.01		-3067.76	
Total	3174.21	139.32			28962.57	-725.34

$$X = \sum V_i * x_i / \sum V_i =$$

9.12 X=Distance between centroid and reference axis y;

$$Y = \sum H_i * y_i / \sum H_i =$$

-5.21 Y=Distance between centroid and reference axis x;

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V$$

$$= 8.90 \text{ (m)}$$

#### 3) Against overturning (B=16)

$$e = |B/2 - d|$$

$$= 0.90 < B/6 = 2.67 \text{ OK}$$

$$B = 16.00 \text{ (m)}$$

#### 4) Against sliding

$$F_s = (\tau_0 * B * c_i + f * \sum V) / |\sum H| =$$

$$= 72.01 > 1.5 \text{ OK}$$

$$\tau_0 = 50 \text{ (tf/m}^2\text{)}$$

$$f = 0.8$$

#### 5) Bearing capacity (B=16)

$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{max} = 265.0 < Q_a * c_i = 936.6 \text{ OK}$$

$$Q_{min} = 131.7 < Q_a * c_i = 936.6 \text{ OK}$$

$$Q_a = 100 \text{ (tf/m}^2\text{)}$$

**Table 3.7.4(1/3) Calculated Results of D-D Portion under Normal Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-197.87		0.10		-19.79
2		92.81		-0.66		-60.91
3						
4						
5						
$\Sigma$		-105.06				-80.70

$$Y = \sum H_i * y_i / \sum H_i = 0.77$$

$$ci(m) = 7.634$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	53.86	-260.85	16.00	8.933	861.78	-2330.27
2	18.70	-90.54	16.00	3.850	299.13	-348.59
3	0.77	-3.72	16.00	3.500	12.30	-13.03
4						
5						
$\Sigma$	73.33	-355.12			1173.21	-2691.89

$$X = \sum V_i * x_i / \sum V_i = 16.00$$

$$Y = \sum H_i * y_i / \sum H_i = 7.58$$

$$ci(m) = 7.634$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-60.26		1.50			-90.38
2	-5.27		2.77			-14.59
3	-432.90		8.75			-3787.85
4	-99.60		10.67			-1062.39
5	-56.11		14.73			-826.50
6	-56.11		15.25			-855.68
$\Sigma$	-710.24				-6637.39	0.00

$$X = \sum V_i * x_i / \sum V_i = 9.35$$

$|ci| \text{ (m)} = 7.634$

$x_i$ =Distance between centroid and reference axis y;  
 $y_i$ =Distance between centroid and reference axis x;  
 $ci$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component $V(\text{tf})$	Horizontal component $H(\text{tf})$	X (m)	Y (m)	Moment about y axis $V*X(\text{tfm})$	Moment about x axis $H*Y(\text{tfm})$
Self weight	3153.00		8.93	8.68	28160.44	
Hydrostatic pressure		-105.06		0.77		-80.70
Earth pressure	73.33	-355.12	16.00	7.58	1173.21	-2691.89
Uplift pressure	-710.24		9.35		-6637.39	
Total	2516.09	-460.18			22696.26	-2772.59

$$X = \sum V_i * x_i / \sum V =$$

9.02 X=Distance between centroid and reference axis y;

$$Y = \sum H_i * y_i / \sum H =$$

6.03 Y=Distance between centroid and reference axis x;

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V \\ = 7.92 \text{ (m)}$$

#### 3) Against overturning ( $B=16$ )

$$e = |B/2 - d| \\ = 0.08 < B/6 = 2.67 \text{ OK} \\ B = 16.00 \text{ (m)}$$

#### 4) Against sliding

$$F_s = (\tau_0 * B + c_i + f * \sum V) / |\sum H| \\ = 17.65 > 1.5 \text{ OK} \\ \tau_0 = 50 \text{ (tf/m2)} \\ f = 0.8$$

#### 5) Bearing capacity ( $B=16$ )

$$Q = \sum V / B * (1 \pm 6e/B) \\ Q_{\max} = 162.1 < Q_a * ci = 763.4 \text{ OK} \\ Q_{\min} = 152.5 < Q_a * ci = 763.4 \text{ OK} \\ Q_a = 100 \text{ (tf/m2)}$$

**Table 3.7.4(2/3) Calculated Results of D-D Portion  
under Earthquake Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-197.87		0.10		-19.79
2		92.81		-0.66		-60.91
3						
4						
5						
$\Sigma$		-105.06				-80.70

$$Y = \sum H_i * y_i / \sum H_i = 0.77$$

$$ci (m) = 7.634$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction (flow direction)

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	0.00	-389.61	16.00	8.933	0.00	-3480.52
2	0.00	-135.24	16.00	3.850	0.00	-520.66
3	0.00	-5.56	16.00	3.500	0.00	-19.46
4						
5						
$\Sigma$	0.00	-530.41			0.00	-4020.64

$$X = \sum V_i * x_i / \sum V_i = 0.00$$

$$Y = \sum H_i * y_i / \sum H_i = 7.58$$

$$ci (m) = 7.634$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction (flow direction)

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-60.26		1.50		-90.38	
2	-5.27		2.77		-14.59	
3	-432.90		8.75		-3787.85	
4	-99.60		10.67		-1062.39	
5	-56.11		14.73		-826.50	
6	-56.11		15.25		-855.68	
$\Sigma$	-710.24	0.00			-6637.39	

$$X = \sum V_i * x_i / \sum V_i = 9.35$$

$$ci \text{ (m)} = 7.634$$

$xi$ =Distance between centroid and reference axis y;  
 $yi$ =Distance between centroid and reference axis x;  
 $ci$ =Length in z-direction (flow direction)

### Stability computation

#### 1) Load combination

(Design seismic factor=0.16)

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	3153.00	-504.48	8.93		28160.44	
Hydrostatic pressure		-105.06		0.77		-80.70
Earth pressure	0.00	-530.41	0.00	7.58	0.00	-4020.64
Uplift pressure	-710.24		9.35		-6637.39	
Seismic inertia		-504.48		8.68		-4380.76
Total	2442.76	-1644.43			21523.05	-8482.11

$$X = \sum V_i * x_i / \sum V_i =$$

8.81 X=Distance between centroid and reference axis y;

$$Y = \sum H_i * y_i / \sum H_i =$$

5.16 Y=Distance between centroid and reference axis x;

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V = 5.34$$

#### 3) Against overturning (B=16)

$$e = |B/2 - d|$$

$$= 2.66 < B/3 = 5.33 \text{ OK}$$

$$B = 16.00 \text{ (m)}$$

#### 4) Against sliding

$$F_s = (\tau_0 * B * c_i + f * \sum V) / |\sum H| =$$

$$= 4.90 > 1.2 \text{ OK}$$

$$\tau_0 = 50 \text{ (tf/m}^2\text{)}$$

$$f = 0.8$$

#### 5) Bearing capacity (B=16)

$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{max} = 305.0 < 1.5Q_a * ci = 1145.1 \text{ OK}$$

$$Q_{min} = 0.3 < 1.5Q_a * ci = 1145.1 \text{ OK}$$

$$Q_a = 100 \text{ (tf/m}^2\text{)}$$

**Table 3.7.4(3/3) Calculated Results of D-D Portion under Flood Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-192.41		0.07		-12.83
2		789.30		2.49		1967.98
3						
4						
5						
$\Sigma$		596.88				1955.15

$$Y = \sum H_i * y_i / \sum H_i$$

$$ci(m) = 7.634$$

$$3.28$$

xi=Distance between centroid and reference axis y;

yi=Distance between centroid and reference axis x;

ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	54.76	-265.18	16.00	8.867	876.09	-2351.27
2	17.95	-86.94	16.00	3.800	287.24	-330.39
3	0.70	-3.38	16.00	3.467	11.15	-11.70
4						
5						
$\Sigma$	73.40	-355.50			1174.48	-2693.36

$$X = \sum V_i * x_i / \sum V_i$$

$$16.00$$

$$Y = \sum H_i * y_i / \sum H_i$$

$$7.58$$

$$ci(m) = 7.634$$

xi=Distance between centroid and reference axis y;

yi=Distance between centroid and reference axis x;

ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-276.66		1.50		-414.98	
2	-5.27		2.80		-14.75	
3	-623.32		8.75		-5454.02	
4	-319.56		6.83		-2183.65	
5	-5.27		14.73		-77.59	
6	-58.40		15.25		-890.60	
$\Sigma$		-1288.47				-9035.60

$$X = \sum V_i * x_i / \sum V_i$$

$$7.01$$

$$|ci| (m) = 7.634$$

$xi$ =Distance between centroid and reference axis y;  
 $yi$ =Distance between centroid and reference axis x;  
 $ci$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	3369.40		8.45	8.60	28485.04	
Hydrostatic pressure		596.88		3.28		1955.15
Earth pressure	73.40	-355.50	16.00	7.58	1174.48	-2693.36
Uplift pressure	-1288.47			7.01		-9035.60
Total	2154.34	241.38			20623.92	-738.21

$$X = \sum Vi * xi / \sum V =$$

9.57 X=Distance between centroid and reference axis y;

$$Y = \sum Hi * yi / \sum H =$$

-3.06 Y=Distance between centroid and reference axis x;

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V \\ = 9.23 \text{ (m)}$$

#### 3) Against overturning (B=16)

$$e = [B/2 - d] \\ = 1.23 < B/6 = 2.67 \text{ OK} \\ B = 16.00 \text{ (m)}$$

#### 4) Against sliding

$$Fs = (\tau_0 * B * ci + f * \sum V) / |\sum H| \\ = 32.44 > 1.5 \text{ OK} \\ \tau_0 = 50 \text{ (tf/m2)} \\ f = 0.8$$

#### 5) Bearing capacity (B=16)

$$Q = \sum V / B * (1 \pm 6e/B) = \\ Q_{max} = 196.8 < Qa * ci = 763.4 \text{ OK} \\ Q_{min} = 72.5 < Qa * ci = 763.4 \text{ OK} \\ Qa = 100 \text{ (tf/m2)}$$

**Table 3.7.5(1/3) Calculated Results of E-E Portion under Normal Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-148.84		0.83		-124.03
2		58.71		0.08		4.52
3						
4						
5						
$\Sigma$		-90.13				-119.51

$$Y = \sum H_i * y_i / \sum H_i =$$

$$ci(m) = 8.0$$

$$1.33$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	56.44	-273.36	16.00	8.933	903.10	-2441.99
2	19.59	-94.88	16.00	3.850	313.47	-365.30
3	0.81	-3.90	16.00	3.500	12.89	-13.65
4						
5						
$\Sigma$	76.84	-372.14			1229.46	-2820.94

$$X = \sum V_i * x_i / \sum V_i = 16.00$$

$$Y = \sum H_i * y_i / \sum H_i = 7.58$$

$$ci(m) = 8.0$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-63.14		1.50		-94.72	
2	-1.73		2.88		-4.98	
3	-183.89		6.00		-1103.33	
4	-54.46		7.00		-381.19	
5	-19.20		9.40		-180.48	
6	-122.64		13.85		-1698.56	
$\Sigma$	-445.06					-3463.26

$$X = \sum V_i * x_i / \sum V_i = 7.78$$

$$ci \text{ (m)} = 8.0$$

$x_i$ =Distance between centroid and reference axis y;  
 $y_i$ =Distance between centroid and reference axis x;  
 $ci$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	3747.39		8.72	10.77	32684.77	
Hydrostatic pressure		-90.13		1.33		-119.51
Earth pressure	76.84	-372.14	16.00	7.58	1229.46	-2820.94
Uplift pressure	-445.06		7.78		-3463.26	
Total	3379.17	-462.28			30450.97	-2940.46

$$X = \sum V_i * x_i / \sum V_i = 9.01 \quad X=\text{Distance between centroid and reference axis y};$$

$$Y = \sum H_i * y_i / \sum H_i = 6.36 \quad Y=\text{Distance between centroid and reference axis x};$$

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V = 8.14 \text{ (m)}$$

#### 3) Against overturning ( $B=16$ )

$$e = |B/2 - d| = 0.14 < B/6 = 2.67 \quad \text{OK}$$

$$B = 16.00 \text{ (m)}$$

#### 4) Against sliding

$$Fs = (\tau_0 * B * ci + f * \sum V) / |\sum H| = 5.85 > 1.5 \quad \text{OK}$$

$$\tau_0 = 0 \text{ (tf/m}^2\text{)}$$

$$f = 0.8$$

#### 5) Bearing capacity ( $B=16$ )

$$Q = \sum V / B * (1 \pm 6e/B) =$$

Qmax=	222.4	$\leq Q_a * ci =$	800	OK
Qmin=	200.0	$\leq Q_a * ci =$	800	OK
Qa=	100	(tf/m <sup>2</sup> )		

**Table 3.7.5(2/3) Calculated Results of E-E Portion under Earthquake Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-148.84		0.83		-124.03
2		58.71		0.08		4.52
3						
4						
5						
$\Sigma$		-90.13				-119.51

$$Y = \sum H_i * y_i / \sum H_i = 1.33$$

ci (m)= 8.0

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	0.00	-408.29	16.00	8.933	0.00	-3647.39
2	0.00	-141.72	16.00	3.850	0.00	-545.62
3	0.00	-5.83	16.00	3.500	0.00	-20.39
4						
5						
$\Sigma$	0.00	-555.84			0.00	-4213.40

$$X = \sum V_i * x_i / \sum V_i = 0.00$$

$$Y = \sum H_i * y_i / \sum H_i = 7.58$$

ci (m)= 8.0

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-63.14		1.50		-94.72	
2	-1.73		2.88		-4.98	
3	-183.89		6.00		-1103.33	
4	-54.46		7.00		-381.19	
5	-19.20		9.40		-180.48	
6	-122.64		13.85		-1698.56	
$\Sigma$	-445.06				-3463.26	

$$X = \sum V_i * x_i / \sum V_i = 7.78$$

$$|c_i|(m) = 8.0$$

$x_i$ =Distance between centroid and reference axis y;  
 $y_i$ =Distance between centroid and reference axis x;  
 $c_i$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	3747.39		8.72	10.77	32684.77	
Hydrostatic pressure		-90.13		1.33		-119.51
Earth pressure	0.00	-555.84	0.00	7.58	0.00	-4213.40
Uplift pressure	-445.06		7.78		-3463.26	
Seismic inertia		-599.58		10.77		-6454.74
Total	3302.33	-1245.55			29221.52	-10787.65

$$X = \sum V_i * x_i / \sum V_i = 8.85$$

$$Y = \sum H_i * y_i / \sum H_i = 8.66$$

X=Distance between centroid and reference axis y;  
Y=Distance between centroid and reference axis x;

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V$$

$$= 5.58$$

#### 3) Against overturning (B=16)

$$e = |B/2 - d|$$

$$= 2.42 < B/3 = 5.33 \quad \text{OK}$$

$$B = 16.00 \quad (\text{m})$$

#### 4) Against sliding

$$F_s = (\tau_0 * B * c_i + f * \sum V) / |\sum H| =$$

$$= 7.26 > 1.2 \quad \text{OK}$$

$$\tau_0 = 50 \quad (\text{tf/m}^2)$$

$$f = 0.8$$

#### 5) Bearing capacity (B=16)

$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{\max} = 393.5 < 1.5 Q_a * c_i = 1200 \quad \text{OK}$$

$$Q_{\min} = 19.3 < 1.5 Q_a * c_i = 1200 \quad \text{OK}$$

$$Q_a = 100 \quad (\text{tf/m}^2)$$

**Table 3.7.5(3/3) Calculated Results of E-E Portion under Flood Condition**

**Hydrostatic pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1		-144.00		0.80		-115.20
2		705.43		3.23		2276.20
3						
4						
5						
$\Sigma$		561.43				2161.00

$$Y = \sum H_i * y_i / \sum H_i =$$

$$3.85$$

$$ci(m) = 8.0$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Earth pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	57.38	-277.89	16.00	8.867	918.09	-2463.99
2	18.81	-91.11	16.00	3.800	301.01	-346.23
3	0.73	-3.54	16.00	3.467	11.69	-12.26
4						
5						
$\Sigma$	76.92	-372.54			1230.79	-2822.48

$$X = \sum V_i * x_i / \sum V_i =$$

$$16.00$$

$$Y = \sum H_i * y_i / \sum H_i =$$

$$7.58$$

$$ci(m) = 8.0$$

xi=Distance between centroid and reference axis y;  
yi=Distance between centroid and reference axis x;  
ci=Length in z-direction

**Uplift pressure**

Part ID	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
1	-289.92		1.50		-434.88	
2	-1.73		2.88		-4.98	
3	-288.00		6.00		-1728.00	
4	-174.72		5.00		-873.60	
5	-19.20		9.40		-180.48	
6	-92.80		13.10		-1215.68	
$\Sigma$	-866.37				-4437.62	

$$X = \sum V_i * x_i / \sum V_i =$$

$$5.12$$

$$|ci|(m) = 8.0$$

$xi$ =Distance between centroid and reference axis y;  
 $yi$ =Distance between centroid and reference axis x;  
 $ci$ =Length in z-direction

### Stability computation

#### 1) Load combination

Load	Vertical component $V(tf)$	Horizontal component $H(tf)$	X (m)	Y (m)	Moment about y axis $V*X(tfm)$	Moment about x axis $H*Y(tfm)$
Self weight	3974.17		8.31	10.57	33024.94	
Hydrostatic pressure		561.43		3.85		2161.00
Earth pressure	76.92	-372.54	16.00	7.58	1230.79	-2822.48
Uplift pressure	-866.37		5.12		-4437.62	
Total	3184.72	188.89			29818.11	-661.49

$$X = \sum V_i * x_i / \sum V = 9.36 \quad X = \text{Distance between centroid and reference axis y};$$

$$Y = \sum H_i * y_i / \sum H = -3.50 \quad Y = \text{Distance between centroid and reference axis x};$$

#### 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V$$

$$= 9.16 \quad (\text{m})$$

#### 3) Against overturning ( $B=16$ )

$$e = |B/2 - d|$$

$$= 1.16 < B/6 = 2.67 \quad \text{OK}$$

$$B = 16.00 \quad (\text{m})$$

#### 4) Against sliding

$$F_s = (\tau_0 * B * c_i + f * \sum V) / |\sum H|$$

$$= 47.37 > 1.5 \quad \text{OK}$$

$$\tau_0 = 50 \quad (\text{tf/m}^2)$$

$$f = 0.8$$

#### 5) Bearing capacity ( $B=16$ )

$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{\max} = 285.3 < Q_a * c_i = 800 \quad \text{OK}$$

$$Q_{\min} = 112.8 < Q_a * c_i = 800 \quad \text{OK}$$

$$Q_a = 100 \quad (\text{tf/m}^2)$$

**Table 3.7.6 Calculated Results of the Whole Powerhouse under Normal Condition**

**Hydrostatic pressure**

Section	Vertical component $V_i(\text{tf})$	Horizontal component $H_i(\text{tf})$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(\text{tfm})$	Moment about x axis $H_i \cdot y_i(\text{tfm})$
B-B		-42.72				-82.86
C-C		-80.02				-155.22
D-D		-105.06				-80.70
E-E		-90.13				-119.51
$\Sigma$		-317.94				-438.30

**Earth pressure**

Section	Vertical component $V_i(\text{tf})$	Horizontal component $H_i(\text{tf})$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(\text{tfm})$	Moment about x axis $H_i \cdot y_i(\text{tfm})$
B-B	135.61	-193.67			2169.72	-1468.06
C-C	89.96	-435.68			1439.39	-3302.62
D-D	73.33	-355.12			1173.21	-2691.89
E-E	76.84	-372.14			1229.46	-2820.94
$\Sigma$	375.74	-1356.61			6011.77	-10283.51

**Uplift pressure**

Section	Vertical component $V_i(\text{tf})$	Horizontal component $H_i(\text{tf})$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(\text{tfm})$	Moment about x axis $H_i \cdot y_i(\text{tfm})$
B-B	-224.34				-1647.60	
C-C	-420.23				-3086.28	
D-D	-710.24				-6637.39	
E-E	-445.06				-3463.26	
$\Sigma$	-1799.86				-14834.53	

**Self weight**

Section	Vertical component $V_i(\text{tf})$	Horizontal component $H_i(\text{tf})$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(\text{tfm})$	Moment about x axis $H_i \cdot y_i(\text{tfm})$
B-B	2566.89				23483.61	
C-C	3430.96				30191.14	
D-D	3153.00				28160.44	
E-E	3747.39				32684.77	
$\Sigma$	12898.24				114519.97	

## 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	12898.24				114519.97	
Hydrostatic pressure		-317.94				-438.30
Earth pressure	375.74	-1356.61			6011.77	-10283.51
Uplift pressure	-1799.86				-14834.53	
Total	11474.11	-1674.55			105697.21	-10721.81

$$X = \sum V_i * x_i / \sum V =$$

$$9.21$$

X=Distance between centroid and reference axis y;

$$Y = \sum H_i * y_i / \sum H =$$

$$6.40$$

Y=Distance between centroid and reference axis x;

## 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V$$

$$= 8.28$$

## 3) Against overturning (B=16)

$$e = |B/2 - d|$$

$$= 0.28$$

$$< B/6 =$$

$$2.67 \quad OK$$

$$B = 16.00 \quad (m)$$

## 4) Against sliding

$$F_s = (\tau_0 * B * L + f * \sum V) / |\sum H| =$$

$$= 19.81 > 1.5 \quad OK$$

$$\tau_0 = 50 \quad (tf/m^2)$$

$$f = 0.8$$

## 5) Bearing capacity (B=16)

$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{max} = 791.7 \quad < Q_a * L = 3000 \quad OK$$

$$Q_{min} = 642.5 \quad < Q_a * L = 3000 \quad OK$$

$$Q_a = 100 \quad (tf/m^2)$$

$$Length = 30 \quad (m)$$

**Table 3.7.7 Calculated Results of the Whole Powerhouse under Earthquake Condition**

**Hydrostatic pressure**

Section	Vertical component $V_i(t_f)$	Horizontal component $H_i(t_f)$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(t_f m)$	Moment about x axis $H_i \cdot y_i(t_f m)$
B-B		-42.72				-82.86
C-C		-80.02				-155.22
D-D		-105.06				-80.70
E-E		-90.13				-119.51
$\Sigma$		-317.94				-438.30

**Earth pressure**

Section	Vertical component $V_i(t_f)$	Horizontal component $H_i(t_f)$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(t_f m)$	Moment about x axis $H_i \cdot y_i(t_f m)$
B-B	99.08	-314.23			1585.24	-2381.98
C-C		-650.74				-4932.84
D-D		-530.41				-4020.64
E-E		-555.84				-4213.40
$\Sigma$	99.08	-2051.22			1585.24	-15548.86

**Uplift pressure**

Section	Vertical component $V_i(t_f)$	Horizontal component $H_i(t_f)$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(t_f m)$	Moment about x axis $H_i \cdot y_i(t_f m)$
B-B	-224.34				-1647.60	
C-C	-420.23				-3086.28	
D-D	-710.24				-6637.39	
E-E	-445.06				-3463.26	
$\Sigma$	-1799.86				-14834.53	

**Self weight**

Section	Vertical component $V_i(t_f)$	Horizontal component $H_i(t_f)$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(t_f m)$	Moment about x axis $H_i \cdot y_i(t_f m)$
B-B	2566.89				23483.61	
C-C	3430.96				30191.14	
D-D	3153.00				28160.44	
E-E	3747.39				32684.77	
$\Sigma$	12898.24				114519.97	

## Seismic inertia

Section	Vertical component Vi(tf)	Horizontal component Hi(tf)	xi (m)	yi (m)	Moment about y axis Vi*xi(tfm)	Moment about x axis Hi*yi(tfm)
B-B		-410.70				-4835.90
C-C		-548.95				-6352.55
D-D		-504.48				-4380.76
E-E		-599.58				-6454.74
$\Sigma$		-2063.72				-22023.94

## 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	12898.24				114519.97	
Hydrostatic pressure		-317.94				-438.30
Earth pressure	99.08	-2051.22			1585.24	-15548.86
Uplift pressure	-1799.86				-14834.53	
Total	11197.45	-4432.88			101270.67	-38011.11

$$X = \sum V_i * x_i / \sum V_i =$$

$$9.04$$

X=Distance between centroid and reference axis y;

$$Y = \sum H_i * y_i / \sum H_i =$$

$$8.57$$

Y=Distance between centroid and reference axis x;

## 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V \\ = 5.65$$

## 3) Against overturning (B=16)

$$e = |B/2 - d| \\ = 2.35 < B/3 = 5.33 \quad \text{OK} \\ B = 16.00 \quad (\text{m})$$

## 4) Against sliding

$$F_s = (\tau_0 * B * L + f * \sum V) / |\sum H| \\ = 7.43 > 1.2 \quad \text{OK} \\ \tau_0 = 50 \quad (\text{tf/m}^2) \\ f = 0.8$$

## 5) Bearing capacity (B=16)

$$Q = \sum V / B * (1 \pm 6e/B) \\ Q_{max} = 1316.7 < Q_a * L = 4500 \quad \text{OK} \\ Q_{min} = 83.0 < Q_a * L = 4500 \quad \text{OK} \\ Q_a = 100 \quad (\text{tf/m}^2) \\ \text{Length} = 30 \quad (\text{m})$$

**Table 3.7.8 Calculated Results of the Whole Powerhouse under Flood Condition**

**Hydrostatic pressure**

Section	Vertical component $V_i(t_f)$	Horizontal component $H_i(t_f)$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(t_f m)$	Moment about x axis $H_i \cdot y_i(t_f m)$
B-B		307.22				1376.83
C-C		575.48				2579.08
D-D		596.88				1955.15
E-E		561.43				2161.00
$\Sigma$		2041.01				8072.06

**Earth pressure**

Section	Vertical component $V_i(t_f)$	Horizontal component $H_i(t_f)$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(t_f m)$	Moment about x axis $H_i \cdot y_i(t_f m)$
B-B	135.75	-193.88			2172.07	-1468.86
C-C	90.06	-436.16			1440.94	-3304.42
D-D	73.40	-355.50			1174.48	-2693.36
E-E	76.92	-372.54			1230.79	-2822.48
$\Sigma$	376.14	-1358.08			6018.28	-10289.13

**Uplift pressure**

Section	Vertical component $V_i(t_f)$	Horizontal component $H_i(t_f)$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(t_f m)$	Moment about x axis $H_i \cdot y_i(t_f m)$
B-B	-612.31				-3067.76	
C-C	-612.31				-3067.76	
D-D	-1288.47				-9035.60	
E-E	-866.37				-4437.62	
$\Sigma$		-3379.46			-19608.74	

**Self weight**

Section	Vertical component $V_i(t_f)$	Horizontal component $H_i(t_f)$	$x_i$ (m)	$y_i$ (m)	Moment about y axis $V_i \cdot x_i(t_f m)$	Moment about x axis $H_i \cdot y_i(t_f m)$
B-B	2708.62				23696.21	
C-C	3696.46				30589.39	
D-D	3369.40				28485.04	
E-E	3974.17				33024.94	
$\Sigma$	13748.65				115795.58	

## 1) Load combination

Load	Vertical component V(tf)	Horizontal component H(tf)	X (m)	Y (m)	Moment about y axis V*X(tfm)	Moment about x axis H*Y(tfm)
Self weight	13748.65				115795.58	
Hydrostatic pressure	0.00	2041.01			0.00	8072.06
Earth pressure	376.14	-1358.08			6018.28	-10289.13
Uplift pressure	-3379.46				-19608.74	
Total	10745.33	682.93			102205.13	-2217.06

$$X = \sum V_i * x_i / \sum V =$$

$$9.51$$

X=Distance between centroid and reference axis y;

$$Y = \sum H_i * y_i / \sum H =$$

$$-3.25$$

Y=Distance between centroid and reference axis x;

## 2) Acting point of resultant force

$$d = (\sum V * X + \sum H * Y) / \sum V$$

$$= 9.31$$

## 3) Against overturning (B=16)

$$e = [B/2 - d]$$

$$= 1.31 < B/6 = 2.67 \quad \text{OK}$$

$$B = 16.00 \quad (\text{m})$$

## 4) Against sliding

$$F_s = (t_0 * B * L + f * \sum V) / |\sum H| =$$

$$= 47.73 > 1.5 \quad \text{OK}$$

$$t_0 = 50 \quad (\text{tf/m}^2)$$

$$f = 0.8$$

## 5) Bearing capacity (B=16)

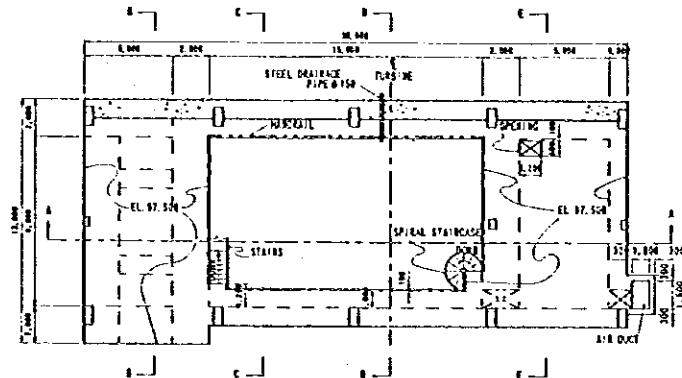
$$Q = \sum V / B * (1 \pm 6e/B) =$$

$$Q_{\max} = 1000.3 < Q_a * L = 3000 \quad \text{OK}$$

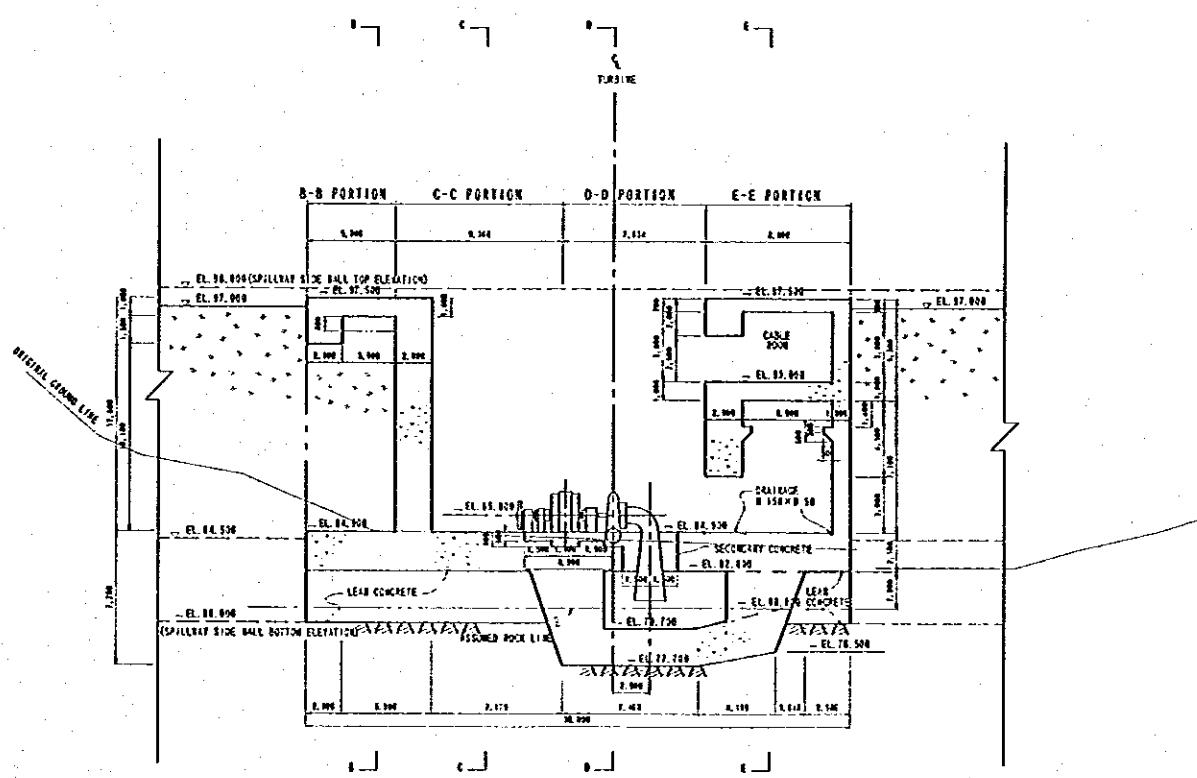
$$Q_{\min} = 342.9 < Q_a * L = 3000 \quad \text{OK}$$

$$Q_a = 100 \quad (\text{tf/m}^2)$$

$$\text{Length} = 30 \quad (\text{m})$$



EL. 97.500 FLOOR



SECTION A-A

SCALE 1 : 1000 10 m

Fig. 3.7.1

### PORTIONS FOR LOAD COMPUTATION

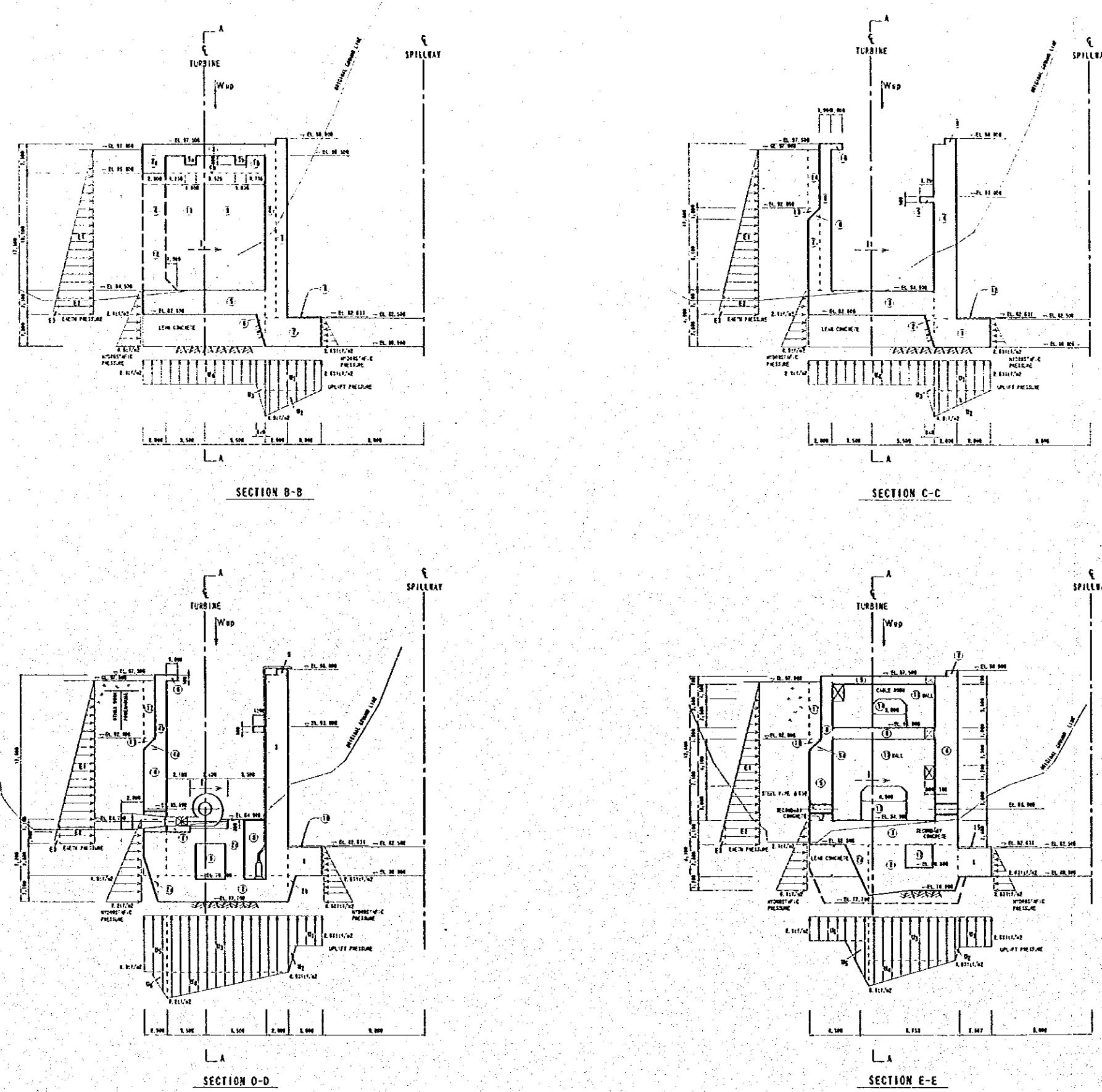
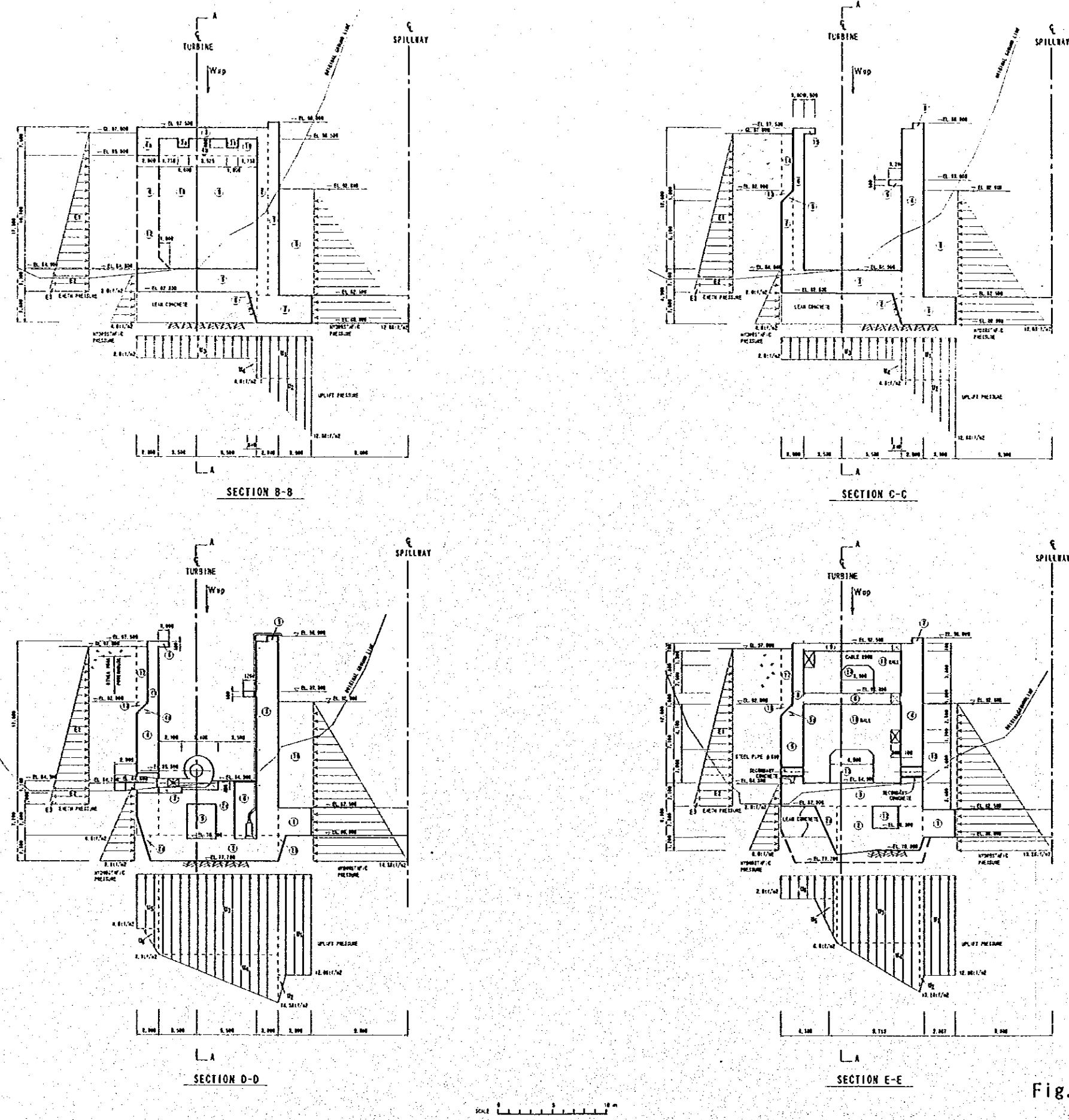


Fig. 3.7.2  
LOADS ACTING ON POWERHOUSE UNDER  
NORMAL AND SEISMIC CONDITIONS



**Fig. 3.7.3**  
LOADS ACTING ON POWERHOUSE UNDER  
FLOOD CONDITION