3.1 Baru Pumping Station

3.1.6 Structural Calculation of Pumping Station

CONTENTS

1. General Layout

The dimension of pump house is determined by layout of machine. The general layout is shown in Fig.1.

(1) Up/down stream direction

L1: space for stop log

L2: space for inspection road for stop log

L3: space for screen belt conveyor (in future)

L4: space for inspection road for screw and gates

L5: space for screw

L6: space for gear and engine

L7: space for pump control building

(2) Design water level

WL1: design high water level Semarang River Side

WL2: design high water level behind the screen

WL3: design low water level behind the screen

WL4: design high water in the pump pond

WL5: design low water level in the pump pond

(3) Design structure elevation

EL1: pumping station ground level

EL2: pump pond bottom elevation

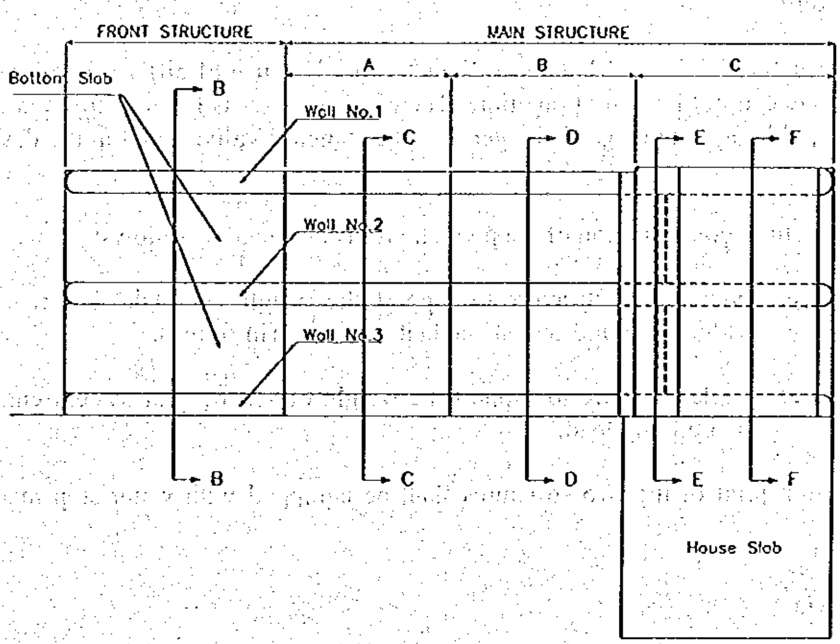
EL3: screen bottom elevation

(4) Right/left bank direction

W1: space for inspection road

W2: space for screw/engine system

Figure 1 General Layout



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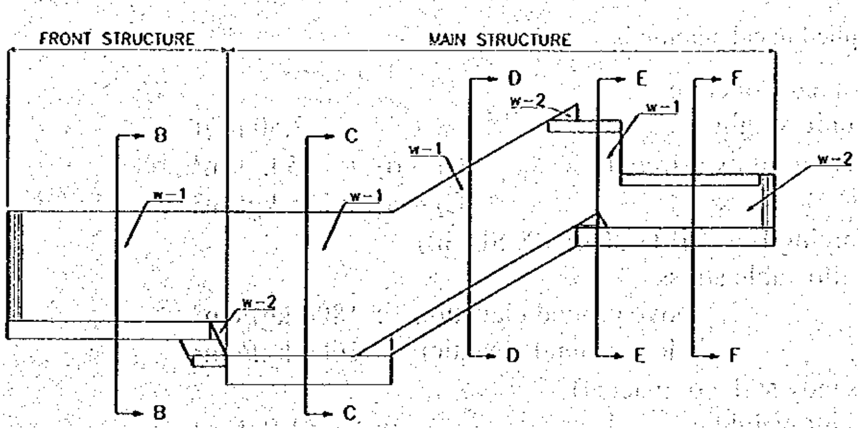


LONGITUDINAL PROFILE

(5) Structure configuration

The total length of the pump house including the intake basin is 35 m and it is too long to construct in one piece of concrete structure, considering the development of cracks caused by contraction of concrete.

Looking at the location of machines and the force distribution, it is reasonable to make a contraction joint between the screen floor and the screw floor. As the screw is supported by both top slab and the bottom slab of the pump house, it is necessary to make the two slabs act as one structure.

This main structure has a total length of 25 meter, but because of difference of elevation, the whole concrete can not be cast at one time. Therefore, no excess thermal stress is expected in the structure, although the length is longer than the standard value stated in the design criteria (15m).

Thus, the structural configuration of the pump house is designed as follows;

<u>Front Structure</u>: independent structure to support the weight of intake basin, maintenance bridge No.2 and screen and belt conveyor (in future).

<u>Main Structure</u>: single structure to support the weight of screw, gear system engine and all the building load.

The contraction joint of the two structures shall be equipped with water stop made of vinyl chloride

2. Design Criteria

Design Criteria is described in "Design Criteria", Vol. III, Interim Report(4).

2.1 Materials

Materials applied in calculation is as follows;

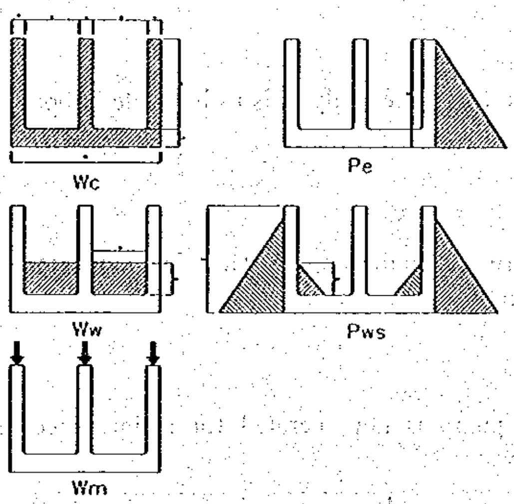
- Reinforced Concrete
  - unit weight: 2.50 m²/t
  - compressive strength: $C_1 = \sigma_{28} = 225$ kgf/m²
    $C_2 = \sigma_{28} = 225$ kgf/m²
- Reinforcing Bar (SII U-30 or JIS SD-30)
  - allowable stress
    - above ground elevation : 1800 kgf/cm²
    - below ground elevation : 1600 kgf/cm²
- Soil (sandy soil, compacted)
  - unit weight: wet $\gamma = 1.9$ tf/m³
    submerged $\gamma = 0.9$ tf/m³
  - internal friction angle: $\phi = 25.6°$ (N=7.5)

2.2 Loads

Loads to be considered are listed below.

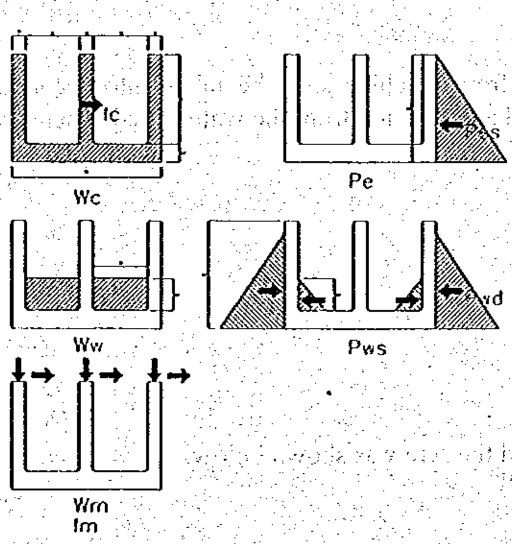
Normal condition

Wc: weight of concrete slab including inspection path no.1 and no.2
Ww: weight of water
Wm: weight of machine and other structures
Pe: earth pressure
Pws: hydro-static pressure



Seismic condition

Wc: weight of concrete slab including inspection path no.1 and no.2
Ww: weight of water
Wm: weight of machine and other structures
Ic, Im: seismic inertia of above all items except water
Pes: seismic earth pressure
Pws: hydro-static pressure
Pwd: hydro-dynamic pressure



2.3 Cases of Analysis

(1) Seismic status

Structural analysis is to be made in both normal condition (without earthquake) and seismic condition (with earthquake).

(2) Operation status

Since an operated screw generates dynamic force, the analysis is to be made in both cases of with pump operation and without pump operation.

(3) Stoplog status

When stop log is closed, hydrostatic pressure acts on the stoplog. Therefore, both stoplog-open and stoplog-closed status should be considered.

(4) Combination of status

When the stop log is closed, the screw pump is not operated for maintenance purpose. Therefore, combination of status is as follows;

Case	Seismic status	Pump operation status
1	Normal	Not operated
2	Normal	Operated
3	Earthquake	Operated
4	Earthquake	Not operated

3. Stability Analysis

3.1 Weight of Screw

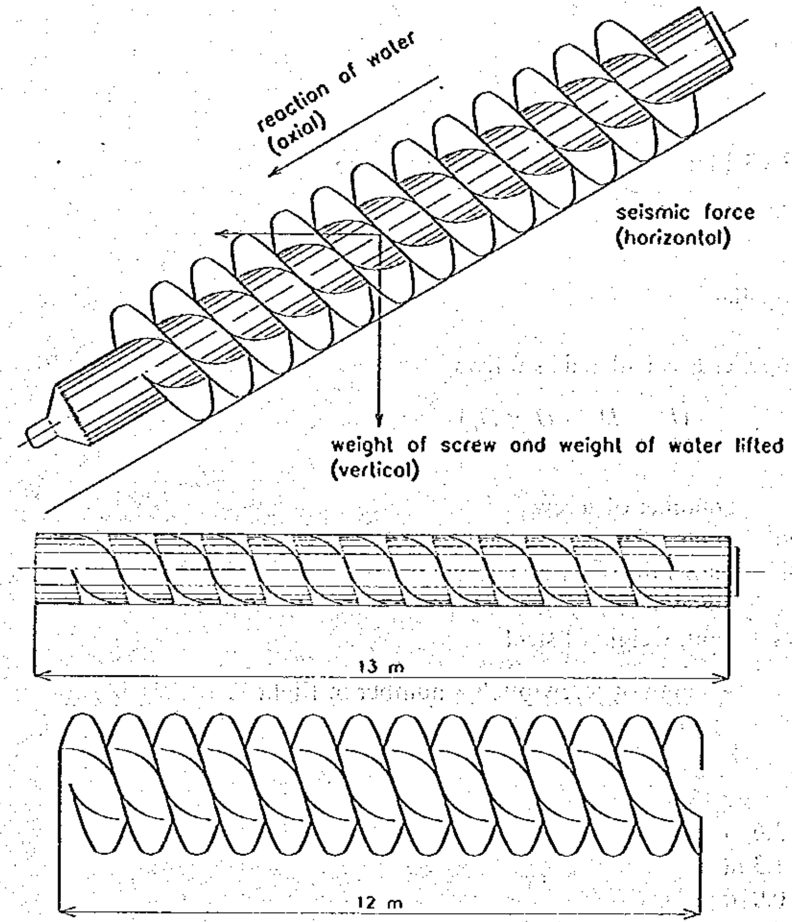
3.1.1 General

In the design of civil structure, all forces acting from machine shall be taken into account. They include weight of screw itself, weight of water lifted and reaction from the water lifted. There are three calculation cases as follows;

- (case 1) normal condition without operation
- (case 2) normal condition with operation
- (case 3) seismic condition with operation
- (case 4) seismic condition without operation

3.1.2 Weight of screw

Calculation of screw weight is done for the shaft and the screw as shown below.



(1) Weight of the shaft

Weight of the shaft is calculated as follows;

$$W = 1 \times 3.14 \times \frac{(D_o + D_i)}{2} \times t \times W_S$$

where
- l ; length of shaft
- Do ; outer diameter
- Di ; inner diameter
- t ; thickness of plate
- ws ; unit weight of steel

here for Asin Pumping station
- l = 13 m
- Do = 1.300 m
- Di = 1.288 m
- t = 0.012 m

Ws = 7.85 t/m³

therefore

$$W = 13 \times 3.14 \times \frac{(1.300 + 1.288)}{2} \times 0.0012 \times 7.85$$
$$= 4.98\ t$$

(2) Weight of propeller

Weight of propeller is calculated as follws;

$$W = n \times 3.14 \times \frac{(D_o \times D_o - D_i \times D_i)}{4} \times t \times W_S$$

where
- n : number of screw
- Do : outer diameter of screw
- Di : inner diameter of screw
- t : thickness of plate
- Ws : unit weight of steel

here n = length of screw/pitch × number of flight

$$= \frac{12}{2.6} \times 3$$
$$= 13.8$$

Do = 2.6 m
Di = 1.3 m
t = 0.010 m
Ws = 7.85 t/m³

therefore

$$W = 13.8 \times 3.14 \times \frac{(2.6 \times 2.6 - 1.3 \times 1.3)}{4} \times 4 \times 0.010 \times 7.85$$
$$= 4.31\ t$$

(3) Total weight of screw

Total weight of screw = weight of shaft + weight of propeller
= 4.98 + 4.31
= 9.29 t

By adding 10% for other parts
total weight of screw system = 9.29 × 1.1 = 10.22 t
The direction of the force is vertical and it is divided into axial and radial components.

Axial component	=	10.22 × SIN 30°	=	5.11 t
Radial component	=	10.22 × COS 30°	=	8.85 t

3.1.3 Weight of water lifted

The weight of water lifted is calculated as follows;

$$W = 12 \times 3.14 \times \frac{\frac{1}{2}(Dp^2 - Ds^2)}{4} \times Ww$$

where

W : weight of water lifted (t)

l : length of shaft (m)

Dp : diameter of propeller (m)

Ds : diameter of shaft (m)

Ww : unit weight of water (t/m^3)

$$W = 12 \times 3.14 \times \frac{½(1.3 \times 1.3 - 0.65 \times 1.5)}{4} \times 1$$

$= 5.97$ t

The weight is divided into axial component and radial component

Axial component = 5.7 × SIN30° = 2.99 t (supported by the propeller)

Radial component = 5.97 × COS30° = 5.17 t (supported by the concrete bed)

3.1.4 Reaction of water lifted

The reaction of water lifter is calculated as follows;

$Fr = Q \times v \times W_w$

where
Fr : reaction of water lifted (t)
Q : discharge (m^3/s)
v : velocity of water (m/s)
W_w : unit mass of water (t/m^3)

here Q = 3 m^3/s

v = Q/A
A = section area of flow
= $1/2 \times 3.14 \times (1.3^2 - 0.65^2)$
= 1.99 m^2
v = 2.2/1.99 = 1.11 m/s
Ww = 1.0 t/m^3

therefore
Fr = 2.2 × 1.11 × 1
= 2.44 t

The direction of the force is axial.

3.1.5 Combination of force

(case-1) normal condition without operation
weight of screw : axial component = 5.11 → 6 t
radial component = 8.85 → 9 t

(case-2) normal condition with operation
weight of screw : axial component = 5.11 t
radial component = 8.85 t

weight of water lifted	axial component	= 2.99 t
	radial component	= 5.17 t
reaction from water lifted	axial component	= 0
	radial component	= 2.44 t
combined force	axial component	= 5.11 + 2.99 + 0 = 8.1 → 9 t
	radial component	= 8.85 + 5.17 + 2.44 = 16.46 → 17 t

(case-3) seismic condition with operation

weight of screw	axial component	= 5.11 t
	radial component	= 8.85 t
weight of water lifted	axial component	= 2.99 t
	radial component	= 5.17 t

seismic force acting on the screw

seismic force (horizontal)= 14.96(weight)×0.11(seismic coefficient) =1.65 t

	axial component	= 1.65×COS30° = 1.43 t
	radial component	= 1.65 × SIN30° = 0.83 t

seismic force acting on water

seismic force (horizontal) = 5.97(weight)×0.11(seismic coefficient) = 0.66 t

	axial component	= 0.66 × COS30° = 0.57 t
	radial component	= 0.66 × SIN30° = 0.33 t
reaction from water lifted	axial component	= 0
	radial component	= 2.44 t
combined force	axial component	= 5.11+2.99+1.43+0.57 = 10.1 → 11 t
	radial component	= 8.85+5.17+0.83+0.33+2.44 = 17.62 → 18 t

(case-4) seismic condition without operation

weight of screw	axial component	= 5.11 → 6 t
	radial component	= 8.85 → 9 t
seismic force acting on the screw		
	axial component	= 1.65×COS30° = 1.43 t
	radial component	= 1.65 × SIN30° = 0.83 t
combined force	axial component	= 5.11 + 1.43 = 6.54 → 7 t
	radial component	= 8.85 + 0.83 = 9.68 → 10 t

The conclusion is

case(1) normal without operation	axial force	= 6 t
	radial force	= 9 t
case(2) normal with operation	axial force	= 9 t
	radial force	= 17 t
case(3) seismic with operation	axial force	= 11 t
	radial force	= 18 t
case(4) seismic without operation	axial force	= 7 t
	radial force	= 10 t

All cases and acting points are shown in Table-1.

In structural analysis of concrete slab, the axial forces shall be applied on both ends of the screw shaft as the full force, considering the uncertainity of force distribution. However, the radial forces shall be applied on both ends of the screw as the half of the forces as it is certainly distributed evenly.

Table 1 Forces Acting from Screw System

Y_0= -6.1 m

	axial	radial	Fx	Fy	Fz	acting point (Fx) x		y		z		direction	acting point(Fy) x	Mx	y	My	z	Mz	direction	acting point(Fz) x	Mx	y	My	z	Mz	direction
(normal without operation condition)																										
main structure-A no-1	6	4.5	-7.45	-6.90	0	14.45	-107.6	1.79	-13.306	3.00	-22.338	-x	14.45	-99.65	5.41	-37.3229	3.00	-20.69	-y							
main structure-A no-2	6	4.5	-7.45	-6.90	0	14.45	-107.6	1.79	-13.306	8.00	-59.567	-x	14.45	-99.65	5.41	-37.3229	8.00	-55.17	-y							
total			-14.89	-13.79	0	14.45	-215.2	1.79	-26.612	5.50	-81.905															
main structure-C no-1	6	4.5	-7.45	-6.90	0	27.00	-201.04	9.04	-67.289	3.00	-22.338	-x	27.00	-186.2	5.41	-37.3229	3.00	-20.69	-y							
main structure-C no-2	6	4.5	-7.45	-6.90	0	27.00	-201.04	9.04	-67.289	8.00	-59.567	-x	27.00	-186.2	5.41	-37.3229	8.00	-55.17	-y							
total			-14.89	-13.79	0	27.00	-402.08	9.04	-134.58	5.50	-81.905	-x	27.00	-372.4	10.82	-149.292	11.00	-151.7	-y							
(normal with operation condition)																										
main structure-A no-1	9	8.5	-12.04	-11.86	0	14.45	-174.04	1.79	-21.522	3.00	-36.13	-x	14.45	-171.4	1.79	-21.1943	3.00	-35.58	-y							
main structure-A no-2	9	8.5	-12.04	-11.86	0	14.45	-174.04	1.79	-21.522	8.00	-96.348	-x	14.45	-171.4	1.79	-21.1943	8.00	-94.88	-y							
total			-24.09	-23.72	0	14.45	-348.08	1.79	-43.043	5.50	-132.48		14.45	-342.8	1.79	-42.3886	5.50	-130.5	-y							
main structure-C no-1	9	8.5	-12.04	-11.86	0	27.00	-325.17	9.04	-108.84	3.00	-36.13	-x	27.00	-320.2	9.04	-107.181	3.00	-35.58	-y							
main structure-C no-2	9	8.5	-12.04	-11.86	0	27.00	-325.17	9.04	-108.84	8.00	-96.348	-x	27.00	-320.2	9.04	-107.181	8.00	-94.88	-y							
total			-24.09	-23.72	0	27.00	-650.35	9.04	-217.67	5.50	-132.48	-x	27.00	-640.5	9.04	-214.363	5.50	-130.5	-y							
(earthquake with operation condition)																										
main structure-A no-1	11	9	-14.03	-13.29	0	14.45	-202.68	1.79	-25.064	3.00	-42.077	-x	14.45	-192.1	1.79	-23.7544	3.00	-39.88	-y							
main structure-A no-2	11	9	-14.03	-13.29	0	14.45	-202.68	1.79	-25.064	8.00	-112.21	-x	14.45	-192.1	1.79	-23.7544	8.00	-106.3	-y							
total			-28.05	-26.59	0	14.45	-405.37	1.79	-50.128	5.50	-154.28		14.45	-384.2	1.79	-47.5088	5.50	-146.2								
main structure-C no-1	11	9	-14.03	-13.29	0	27.00	-378.69	9.04	-126.75	3.00	-42.077	-x	27.00	-358.9	9.04	-120.128	3.00	-39.88	-y							
main structure-C no-2	11	9	-14.03	-13.29	0	27.00	-378.69	9.04	-126.75	8.00	-112.21	-x	27.00	-358.9	9.04	-120.128	8.00	-106.3	-y							
tota			-28.05	-26.59	0	27.00	-757.39	9.04	-253.5	5.50	-154.28	-x	27.00	-717.8	9.04	-240.256	5.50	-146.2	-y							
(earthquake without operation condition)																										
main structure-A no-1	7	5	-8.56	-7.83	0.9	14.45	-123.73	1.79	-15.3	3.00	-25.686	-x	14.45	-113.1	1.79	-13.9907	3.00	-23.49	-y	14.45	12.4453	1.79	1.53898	3.00	2.5836298	z
main structure-A no-2	7	5	-8.56	-7.83	0.9	14.45	-123.73	1.79	-15.3	8.00	-68.496	-x	14.45	-113.1	1.79	-13.9907	8.00	-62.63	-y	14.45	12.4453	1.79	1.53898	8.00	6.8896794	z
total			-17.12	-15.66	1.7	14.45	-247.46	1.79	-30.6	5.50	-94.182		14.45	-226.3	1.79	-27.9815	5.50	-86.12		14.45	24.8907	1.79	3.07796	5.50	9.4733092	z
main structure-C no-1	7	5	-8.56	-7.83	0.9	27.00	-231.17	9.04	-77.374	3.00	-25.686	-x	27.00	-211.4	9.04	-70.7523	3.00	-23.49	-y	20.73	17.849	5.41	4.66087	3.00	2.5836298	z
main structure-C no-2	7	5	-8.56	-7.83	0.9	27.00	-231.17	9.04	-77.374	8.00	-68.496	-x	27.00	-211.4	9.04	-70.7523	8.00	-62.63	-y	20.73	17.849	5.41	4.66087	8.00	6.8896794	z
total			-17.12	-15.66	1.7	27.00	-462.35	9.04	-154.75	5.50	-94.182	-x	27.00	-422.8	9.04	-141.505	5.50	-86.12	-y	20.73	35.698	5.41	9.32174	5.50	9.4733092	z

3.2 Weight of Machine and Other Structures

3.2.1 General

Fig. 2 shows the location of machines and other structures.

The machines to be considered are screw, gear box, engine and screen. For gear box, engine and screen, estimation by factories are adopted. For screen system, future installation is taken into account.

Stop log	3 t
Embedded material	3 t
Inspection bridge	12 t
Screen	8 t
Belt conveyor	50 t
Secondary concrete	91 t
Gear box	2 t
Engine	17 t
Bridge	47 t

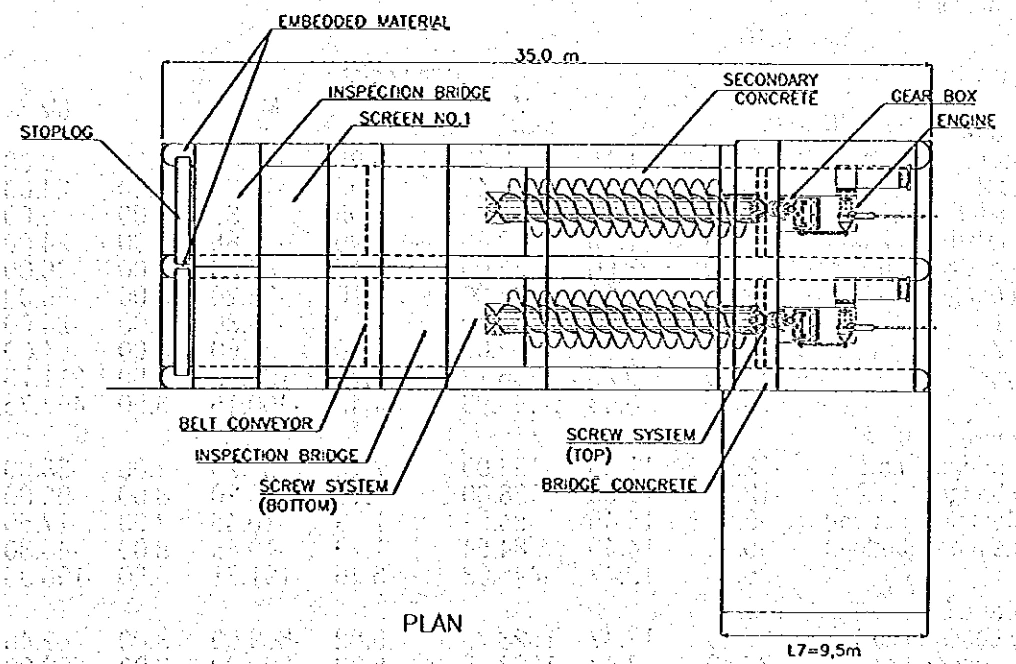
The seismic force acting on each machine can be calculated by multiplying seismic coefficient Kh = 0.11 to the weight of machine.

The forces acting from machine and other structures are shown in Table 2.

3.3 Weight of Pump Control Building

The weight of the Pump Control Building (architectural design) is assumed as 2.5 t/m².

Fig. 2 Location of Machines and Other Structures



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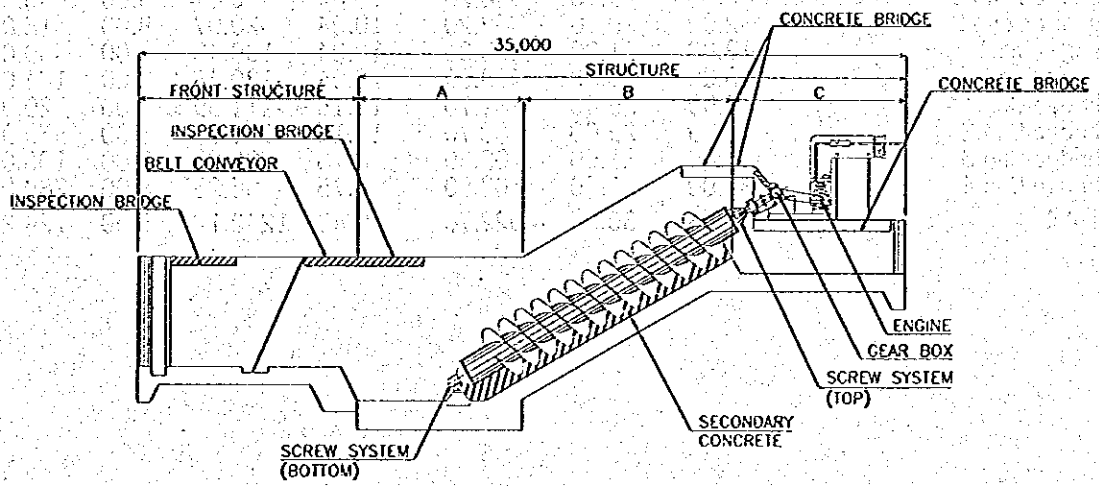


LONGITUDINAL PROFILE

Table 2(1/2) Force Acting from Machine and Other Structures

Weight of machine

Y_0= -6.10

name	weight	acting point					
		x	Mx	y	My	z	Mz
front structure							
stop log no.1	-3.00	1.15	-3.45	3.95	-11.85	3.00	-9.00
stop log no.2	-3.00	1.15	-3.45	3.95	-11.85	8.00	-24.00
imbeded material no.1	-3.00	1.15	-3.45	3.95	-11.85	3.00	-9.00
imbeded material no.2	-3.00	1.15	-3.45	3.95	-11.85	8.00	-24.00
inspection bridge-A no.1	-12.00	3.00	-36.00	7.10	-85.20	3.00	-36.00
inspection bridge-A no.2	-12.00	3.00	-36.00	7.10	-85.20	8.00	-96.00
screen no.1	-8.00	6.50	-52.00	7.10	-56.80	3.00	-24.00
screen no.2	-8.00	6.50	-52.00	2.70	-21.60	8.00	-64.00
beltconbeyor	-38.50	9.25	-356.13	2.70	-103.95	5.50	-211.75
total	-90.50	6.03	-545.93	4.42	-400.15	5.50	-497.75
main structure A							
inspection bridge-B no.1	-12.00	11.50	-138.00	7.10	-85.20	3.00	-36.00
inspection bridge-B no.2	-12.00	11.50	-138.00	7.10	-85.20	8.00	-96.00
screw system no.1(bottom)	-5.85	14.45	-84.54	1.79	-10.45	3.00	-17.55
screw system no.2(bottom)	-5.85	14.45	-84.54	1.79	-10.45	8.00	-46.80
total	-35.70	12.47	-445.08	5.36	-191.31	5.50	-196.35
main structure B							
secondary concrete no.1	-87.49	17.47	-1528.75	5.82	-509.00	3.00	-262.46
secondary concrete no.2	-87.49	17.47	-1528.75	5.82	-509.00	8.00	-699.90
bridge-Cno.1	-3.47	27.65	-95.82	11.15	-38.63	3.00	-10.40
bridge-Cno.2	-3.47	27.65	-95.82	11.15	-38.63	8.00	-27.72
total	-181.90	17.86	-3249.14	6.02	-1095.27	5.50	-1000.48
main structure C							
screw system no1.(top)	-5.85	27.00	-157.95	9.04	-52.87	3.00	-17.55
screw system no.2(top)	-5.85	27.00	-157.95	9.04	-52.87	8.00	-46.80
gear box no.1	-2.00	29.10	-58.20	10.04	-20.07	3.00	-6.00
gear box no.2	-2.00	29.10	-58.20	10.04	-20.07	8.00	-16.00
engine no.1	-13.00	31.00	-403.00	10.04	-130.48	3.00	-39.00
engine no.2	-13.00	31.00	-403.00	10.04	-130.48	8.00	-104.00
bridge-Cno.1	-9.99	29.00	-289.70	11.15	-111.39	3.00	-29.97
bridge-Cno.2	-9.99	29.00	-289.70	11.15	-111.39	8.00	-79.92
bridge-Cno.3	-35.00	31.50	-1102.50	8.75	-306.25	3.00	-105.00
bridge-Cno.4	-35.00	31.50	-1102.50	8.75	-306.25	8.00	-280.00
Total	-131.68	30.55	-4022.70	9.43	-1242.12	5.50	-724.24

Table 2(2/2) Force Acting from Machine

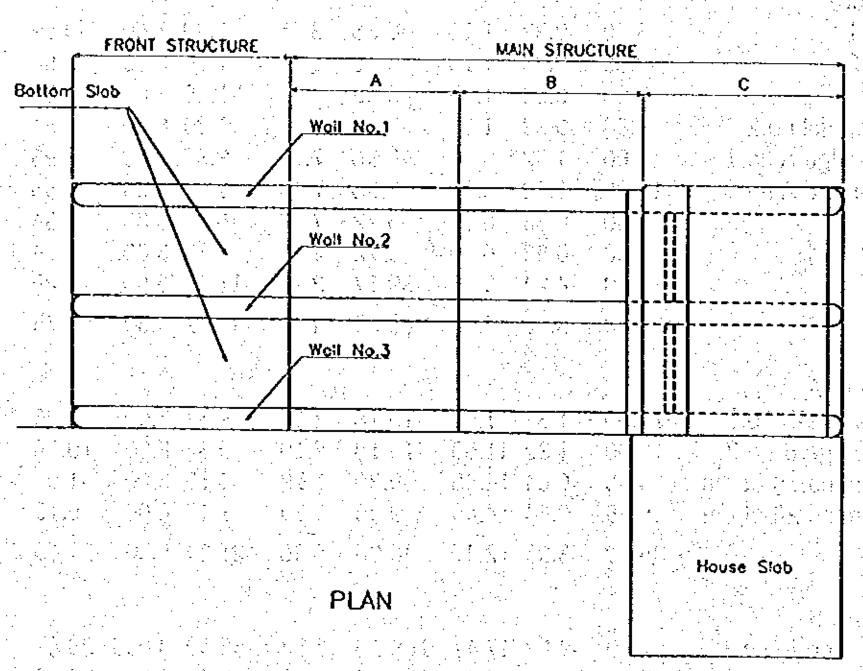
Inertia of Machine

Y_0= -6.1

name	weight	inertia	acting point x	Mx	y	My	z	Mz	direction
front structure									
stop log no.1	-3.00	-0.33	1.15	-0.38	3.95	-1.30	3.00	-0.99	-z
stop log no.2	-3.00	-0.33	1.15	-0.38	3.95	-1.30	8.00	-2.64	-z
imbeded material no.1	-3.00	-0.33	1.15	-0.38	3.95	-1.30	3.00	-0.99	-z
imbeded material no.2	-3.00	-0.33	1.15	-0.38	3.95	-1.30	8.00	-2.64	-z
inspection bridge-A no.1	-12.00	-1.32	3.00	-3.96	7.10	-9.37	3.00	-3.96	-z
inspection bridge-A no.2	-12.00	-1.32	3.00	-3.96	7.10	-9.37	8.00	-10.56	-z
screen no.1	-8.00	-0.88	6.50	-5.72	7.10	-6.25	3.00	-2.64	-z
screen no.2	-8.00	-0.88	6.50	-5.72	2.70	-2.38	8.00	-7.04	-z
belt conveyor	-38.50	-4.24	9.25	-39.17	2.70	-11.43	5.50	-23.29	-z
total	-90.50	-9.96	6.03	-60.05	4.42	-44.02	5.50	-54.75	
main structure A									
inspection bridge-B no.1	-12.00	-1.32	11.50	-15.18	7.10	-9.37	3.00	-3.96	-z
inspection bridge-B no.2	-12.00	-1.32	11.50	-15.18	7.10	-9.37	8.00	-10.56	-z
screw system no.1(bottom	-5.85	-0.64	14.45	-9.30	1.79	-1.15	3.00	-1.93	-z
screw system no.2(bottom	-5.85	-0.64	14.45	-9.30	1.79	-1.15	8.00	-5.15	-z
total	-35.70	-3.93	12.47	-48.96	5.36	-21.04	5.50	-21.60	
main structure B									
secondary concrete no.1	-87.49	-9.62	17.47	-168.16	5.82	-55.99	3.00	-28.87	-z
secondary concrete no.2	-87.49	-9.62	17.47	-168.16	5.82	-55.99	8.00	-76.99	-z
bridge-Cno.1	-3.47	-0.38	27.65	-10.54	11.15	-4.25	3.00	-1.14	
bridge-Cno.2	-3.47	-0.38	27.65	-10.54	11.15	-4.25	8.00	-3.05	
total	-181.90	-20.01	17.05	-357.41	5.60	-120.48	5.50	-110.05	
main structure C									
screw system no1.(top)	-5.85	-0.64	27.00	-17.37	9.04	-5.82	3.00	-1.93	-z
screw system no.2(top)	-5.85	-0.64	27.00	-17.37	9.04	-5.82	8.00	-5.15	-z
gear box no.1	-2	-0.22	29.10	-6.40	10.04	-2.21	3.00	-0.66	-z
gear box no.2	-2	-0.22	29.10	-6.40	10.04	-2.21	8.00	-1.76	-z
engine no.1	-13	-1.43	31.00	-44.33	10.04	-14.35	3.00	-4.29	-z
engine no.2	-13	-1.43	31.00	-44.33	10.04	-14.35	8.00	-11.44	-z
bridge-Cno.1	-9.99	-1.10	29.00	-31.87	11.15	-12.25	3.00	-3.30	
bridge-Cno.2	-9.99	-1.10	29.00	-31.87	11.15	-12.25	8.00	-8.79	
bridge-Cno.3	-35.00	-3.85	31.50	-121.28	8.75	-33.69	3.00	-11.55	
bridge-Cno.4	-35.00	-3.85	31.50	-121.28	8.75	-33.69	8.00	-30.80	
Total	-131.68	-14.48	30.55	-442.50	9.43	-136.63	5.50	-79.67	

3.4 Weight of Civil Structure

Weight of civil structure is calculated by dividing it into small parts as show in the figure below.



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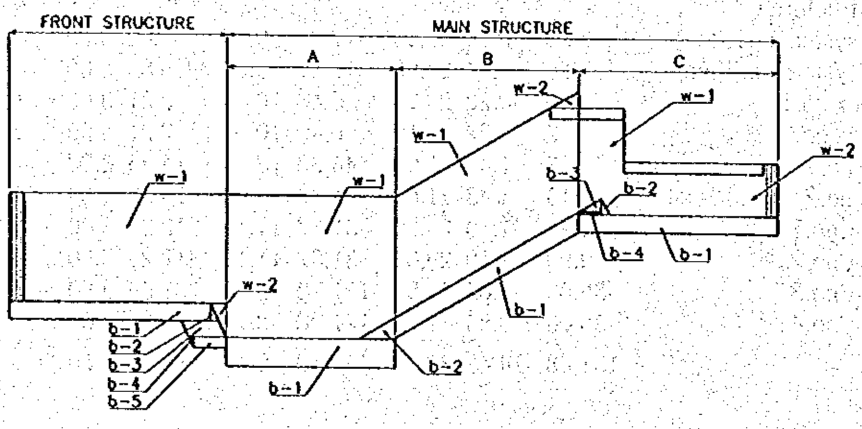

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Table 3 Force Acting from Concrete

Weight of concrete

Y0= -6.1

slab name	name	weight	acting point x	Mx	y	My	z	Mz	direction
front structure	wall no.1-1	-122.50	5.00	-612.50	4.85	-594.13	0.50	-61.25	-y
	wall no.1-2	-0.76	9.63	-7.29	2.03	-1.54	0.50	-0.38	-y
	wall no.2-1	-122.50	5.00	-612.50	4.85	-594.13	5.50	-673.75	-y
	wall no.2-2	-0.76	9.63	-7.29	2.03	-1.54	5.50	-4.16	-y
	wall no.3-1	-122.50	5.00	-612.50	4.85	-594.13	10.50	-1286.25	-y
	wall no.3-2	-0.76	9.63	-7.29	2.03	-1.54	10.50	-7.94	-y
	bottom slab 1	-207.90	4.73	-982.33	2.00	-415.80	5.50	-1143.45	-y
	bottom slab 2	-4.40	9.58	-42.17	1.87	-8.21	5.50	-24.20	-y
	bottom slab 3	-17.19	9.30	-159.84	1.45	-24.92	5.50	-94.53	-y
	bottom slab 4	-1.72	9.08	-15.61	1.13	-1.95	5.50	-9.45	-y
	bottom slab 5	-13.75	9.50	-130.63	1.05	-14.44	5.50	-75.63	-y
	total	-614.73	5.19	-3189.93	3.66	-2252.31	5.50	-3380.99	-y
main structure-A	wall no.1-1	-123.12	14.10	-1736.48	4.30	-529.42	0.50	-61.56	-y
	wall no.2-1	-123.12	14.10	-1736.48	4.30	-529.42	5.50	-677.16	-y
	wall no.3-1	-123.12	14.10	-1736.48	4.30	-529.42	10.50	-1292.76	-y
	bottom slab-1	-293.44	14.10	-4138.62	0.65	-190.73	5.50	-1613.90	-y
	total	-662.80	14.10	-9348.07	2.68	-1778.98	5.50	-3645.38	
main structure-B	wall no.1-1	-116.91	21.13	-2470.78	0.88	-103.33	0.50	-58.46	-y
	wall no.1-2	2.88	26.00	74.86	11.78	33.93	0.50	1.44	-y
	wall no2-1	-113.18	21.13	-2391.84	0.88	-100.03	5.50	-622.46	-y
	wall no2-2	2.88	26.00	74.86	11.78	33.93	5.50	15.84	-y
	wall no3-1	-113.18	21.13	-2391.84	0.88	-100.03	10.50	-1188.34	-y
	wall no3-2	2.88	26.00	74.86	11.78	33.93	10.50	30.23	-y
	bottom slab-1	-18.00	22.11	-397.82	13.15	-236.63	5.50	-98.98	-y
	total	-352.62	21.06	-7427.69	1.24	-438.24	5.45	-1920.73	
main structure-C	wall no.1-1	-34.27	27.00	-925.21	8.60	-294.69	0.39	-13.28	-y
	wall no1-2	-51.45	31.50	-1620.68	8.75	-450.19	0.39	-19.94	-y
	wall no.2-1	-27.97	27.00	-755.27	8.60	-240.56	5.50	-153.85	-y
	wall no.2-2	-42.00	31.50	-1323.00	8.75	-367.50	5.50	-231.00	-y
	wall no.3-1	-27.97	27.00	-755.27	8.60	-240.56	10.50	-293.71	-y
	wall no.2-2	-42.00	31.50	-1323.00	8.75	-367.50	10.50	-441.00	-y
	bottom-1	-143.97	30.50	-4391.17	6.20	-892.60	5.39	-775.63	-y
	bottom-2	-2.83	26.14	-73.90	6.83	-19.32	5.50	-15.55	-y
	bottom-3	-2.04	26.40	-53.78	7.07	-14.41	5.50	-11.21	-y
	bottom-4	-4.24	26.30	-111.54	6.78	-28.75	5.50	-23.33	
	total	-378.73	29.92	-11332.81	7.70	-2916.07	5.22	-1978.48	-y
house structure	bottom	-112.38	30.51	-3428.00	8.75	-983.28	16.00	-1798.00	-y

Total Weight -2121.25

total volume 848.50

3.5 Weight of Water

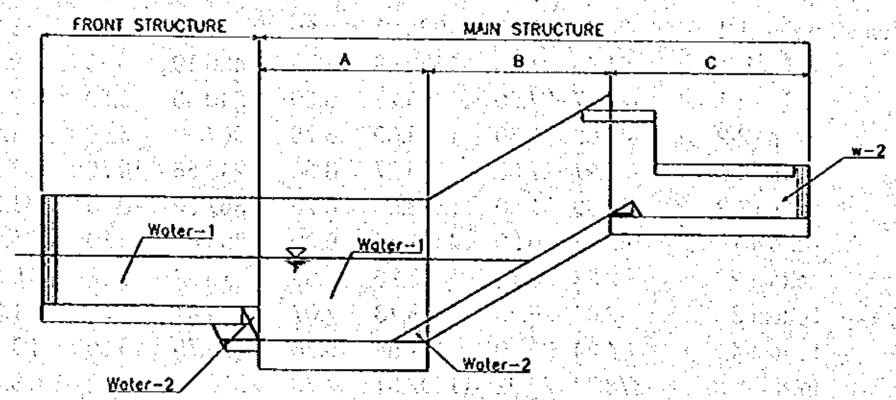
Water weight is calculated as shown in Table – 4.

Table 4 Weight of Water

water level = -2.50 m

Y_0= -6.1

water body name	name	weight	acting point						direction
			x	Mx	y	My	z	Mz	
front structure	water no1-1	-48.00	5.00	-240.00	3.00	-144.00	3.00	-144.00	-y
	water no1-2	-1.40	9.79	-13.67	2.03	-2.84	3.00	-4.19	-y
	water no2-1	-48.00	5.00	-240.00	3.00	-144.00	8.00	-384.00	-y
	water no2-2	-1.40	9.79	-13.67	2.03	-2.84	8.00	-11.17	-y
	total	-98.79	5.14	-507.34	2.97	-293.68	5.50	-543.36	-y
									-y
main structure-A	water no1-1	-47.91	14.10	-675.77	2.45	-117.39	3.00	-143.74	-y
	water no1-2	2.95	17.67	52.21	1.61	4.75	3.00	8.86	-y
	water no2-1	-47.91	14.10	-675.77	2.45	-117.39	8.00	-383.31	-y
	water no2-2	2.95	17.67	52.21	1.61	4.75	8.00	23.63	-y
	total	-89.92	13.87	-1247.12	2.51	-225.28	5.50	-494.55	
main structure-C	wall no.1	-22.40	30.50	-683.22	6.45	-144.48	3.00	-67.20	-y
	wall no.2	-22.40	30.50	-683.22	6.45	-144.48	8.00	-179.20	-y
	total	-44.80	30.50	-1366.44	6.45	-288.96	5.50	-246.40	-y



LONGITUDINAL PROFILE

3.6 Hydrostatic Pressure

Hydrostatic pressure is lateral pressure and uplift. Lateral pressure is calculated in Table - 5 while uplift is calculated in Table - 6.

3.7 Earth Pressure

The earth pressure is calculated in Table – 7. The earth pressure coefficient is calculated in Table - 8.

Table 5 Water Pressure (earthquake condition)

Water level= 0.90

Y_0= -6.1

water pressure	name	height	width	P	acting point						direction
					x	Mx	y	My	z	Mz	
front structure	wp	3.60	11.00	83.16	1.15	95.63	4.10	340.96	5.50	457.38	x
front structure	dwp-1	2.800	10.00	45.73	5.00	228.67	3.52	160.98	5.00	228.67	z
	dwp-2	2.800	10.00	45.73	5.00	228.67	3.52	160.98	10.00	457.33	z
total				91.47	5.00	457.33	3.52	321.96	7.5	686.00	
main structure A	dwp-1	3.9	8.21	72.83	13.68	996.47	2.86	208.28	5.00	364.13	z
	dwp-2	3.9	8.21	72.83	13.68	996.47	2.86	208.28	10.00	728.25	z
total				145.65	13.68	1,992.94	2.86	416.56	7.50	1,092.38	
main structure C	dwp-1	0.7	9.00	2.57	31.00	79.73	6.88	17.69	5.00	12.86	z
	dwp-2	0.7	9.00	2.57	31.00	79.73	6.88	17.69	10.00	25.72	z
				5.14	31	159.46	6.88	35.39	7.50	38.58	

Table 6 Uplift

water level(U/S) = -0.90m   water level(D/S) = -0.47m *

Y_0= -6.10m

water body name	name	uplift	acting point						direction
			x	Mx	y	My	z	Mz	
front structure	uplift	415.36	5.00	2,076.80	1.41	584.00	5.50	2,284.48	y
main structure-A	uplift	508.32	14.10	7,169.37	0.00	0.00	5.50	2,795.77	y
main structure-B	uplift	152.61	18.61	2,839.85	3.55	541.75	5.50	839.34	y
main structure-C	wall no.1	-27.27	30.50	-831.78	5.80	-158.17	5.50	-149.99	y

uplift pressure= the water pressure inside of the steel sheet pile

Table 7 Force Acting from Earth (earthquake condition)

g level = 1.20

g.water level = 0.35   phai = 25.60 (natural soil)   over burden = 0.00 t/m2

Y_0= -6.1

earth pressure	name	height	width	weight of soil	Ka	P	acting point						direction
							x	Mx	y	My	z	Mz	
front structure	ep-1	5.92	10.00	1.90	0.47	-111.54	5.00	-557.70	3.42	-381.47	11.00	-1226.94	-z
main structure-A	ep-1	7.30	8.21	1.90	0.47	-115.05	14.10	-1622.73	2.43	-279.97	11.00	-1265.60	-z
main structure-B	ep-1	3.750	7.79	1.90	0.47	-33.53	22.11	-741.27	4.75	-159.29	11.00	-368.88	-z
main structure-C	ep-1	1.50	9.00	1.90	0.47	-8.15	31.50	-256.60	6.30	-51.32	11.00	-89.61	-z
total													

Table - 8 . Calculation of Earth Pressure Coefficient (ϕ=25.6°)

normal condition				
phai	25.6	conversion(3.14/180)	0.0174444	Kas
delta	8.533			Kp
theta	0	cos(pahi-theta)	0.9019304	
alpha	0	cos(theta)	1	
		cos(theta+delta)	0.9889409	
phai-theta	25.6	sin(pahi+delta)	0.5608706	
theta+delta	8.533	sin(phai-alpha)	0.4318815	
phai+delta	34.13	cos(theta-alpha)	1	
phai-alpha	25.6	cos(phai+theta)	0.9019304	
theta-alpha	0	sin(phai-delta)	0.2933399	
phai+theta	25.6	sin(phai+alpha)	0.4318815	
phai-delta	17.07			
phai+alhpa	25.6			

seismic condition		seismicity(kh)	0.11		
phai	25.6	conversion(3.14/180)	0.0174444	Kea	0.474
delta	0			Kep	2.338
theta	0	cos(pahi-theta0-theta)	0.9437448		
alpha	0	cos(theta0)	0.9940044		
theta0	6.28	cos(theta)	1		
		cos(theta+theta0+delta)	0.9940044		
phai-theta0-theta	19.32	sin(pahi+delta)	0.4318815		
theta+theta0+delta	6.28	sin(phai-alpha-theta0)	0.3306746		
phai+delta	25.6	cos(theta-alpha)	1		
phai-alpha-theta0	19.32	cos(phai-theta0+theta)	0.9437448		
theta-alpha	0	cos(theta-theta0+delta)	0.9940044		
phai-theta0+theta	19.32	sin(phai-delta)	0.4318815		
theta-theta0+delta	-6.28	sin(phai+alpha-theta0)	0.3306746		
phai-delta	25.6				
phai+alpha-theta0	19.32				

3.8 Seismic Forces

3.8.1 Calculation of Seismic Coefficient

According to the Design Criteria of the Project, earthquake load is calculated as follows:

$G = E \times M$

where

G : earthquake load

E : horizontal earthquake factor

M : total dead load

the earthquake factor is calculated using the following equation;

$E = ad/g$

$ad = n(ac \times Z)^m$

where

ad : design shock acceleration (cm/s^2)

ac : basic shock acceleration (cm/s^2)

where

ac : 160 cm/s^2

by taking 100 years for return period

Z : factor depending on geographical position and equal 0.56 taking northern Java Island

n,m : factor determined by soil type and taken as 0.29 and 1.32 respectively, for soft alluvium

Finally, we get $E = 0.11$ for the design.

3.9 Total Forces

Total forces which would act on the structure are shown in Table 9 ~ (1/4 ~ 4/4) and Table 10.

Table 9 (1/4) Total Forces

Z direction forces act only when earthquake is in z direction

(case-1-1) normal condition and stop log open(pump operated)

slab name	Total Force	point of action			direction			Moment footing C.		
		x	y	z	X	Y	Z	Mx	My	Mz
front	-388.66	5.58	6.07	5.50		*		0.00	0.00	225.42
	-74.97	5.00	3.42	11.00			*	106.46	0.00	0.00
main-A	-24.09	14.45	1.79	5.50	*			0.00	0.00	27.46
	-596.41	14.04	5.71	5.50		*		0.00	0.00	38.17
	-96.54	14.13	2.38	10.55			*	167.01	2.51	0.00
main-C	-24.09	27.00	9.04	5.50	*			0.00	0.00	68.42
	-934.56	29.47	8.88	5.50		*		0.00	0.00	962.60
	-14.80	28.65	7.75	8.09			*	22.94	27.38	0.00
house	-337.13	30.51	9.78	16.00		*		0.00	0.00	0.00

Table 9 (2/4) Total Forces

(case-1-2) normal condition and stop log closed(pump not operation)

slab name	Total Force	point of action			direction			Moment footing C.		
		x	y	z	X	Y	Z	Mx	My	Mz
front	71.28	1.15	4.30	5.50	*			0.00	0.00	249.48
	-289.87	5.72	7.12	5.50		*		0.00	0.00	208.71
	-74.97	5.00	3.42	11.00			*	106.46	0.00	0.00
main-A	-15.39	14.45	1.79	5.50	*			0.00	0.00	17.54
	-389.17	14.13	5.97	5.50		*		0.00	0.00	10.12
	-96.54	14.13	2.38	10.55			*	167.01	2.51	0.00
main-C	-866.34	29.48	9.01	5.37		*		112.62	0.00	883.67
	-14.80	28.65	7.75	8.09			*	22.94	27.38	0.00

Table 10 (3/4) Total Forces

(case-2-1) earthquake condition and stop log open(pump operated)

slab name	Total Force	point of action			direction			Moment footing C.		
		x	y	z	X	Y	Z	Mx	My	Mz
front	77.58	5.30	3.76	5.50	*			0.00	0.00	136.54
	-388.66	5.58	6.07	5.50		*		0.00	0.00	225.42
	-280.59	5.08	3.55	8.27			*	434.91	22.45	0.00
main-A	-161.96	14.25	2.28	5.50	*			0.00	0.00	263.99
	-496.65	14.09	5.21	5.50		*		0.00	0.00	6.95
	-383.71	13.97	2.60	7.86			*	748.23	51.42	0.00
main-C	-142.12	28.64	8.59	5.44	*			0.00	8.53	339.67
	-938.90	29.57	6.46	5.50		*		0.00	0.00	873.18
	-139.95	28.99	8.49	5.82			*	320.49	211.32	0.00
house	37.08	30.51	9.78	16.00	*			0.00	0.00	38.19
	-337.13	30.51	9.78	16.00		*		0.00	0.00	0.00
	37.08	30.51	9.78	16.00			*	38.19	0.00	0.00

Table 9 (4/4) Total Forces

(case-2-2) earthquake condition and stop log closed(pump not operated operation)

slab name	Total Force	point of action			direction			Moment footing C.		
		x	y	z	X	Y	Z	Mx	My	Mz
front	160.71	3.15	4.04	5.50	*			0.00	0.00	562.49
	-289.87	5.72	7.12	5.50		*		0.00	0.00	208.71
	-189.12	5.13	3.56	8.66			*	295.03	24.59	0.00
main-A	-151.03	14.23	2.31	5.50	*			0.00	0.00	250.71
	-395.80	14.13	5.90	5.50		*		0.00	0.00	10.29
	-239.67	14.15	2.43	8.06			*	426.61	11.02	0.00
main-C	-157.51	28.48	8.63	5.45	*			0.00	7.88	382.75
	-908.76	29.48	8.94	5.38		*		109.05	0.00	926.94
	-141.41	28.79	8.55	5.44			*	332.31	241.81	0.00

Table 10 Total Forces (Summary)

case no.	slab name	V	H	critical case
		t	t	
normal condition, stop log open	F	339	75	
	A	596	97	*
	C	935	24	*
	H	337	0	*
normal condition, stop log closed	F	290	75	*
	A	389	97	
	C	866	15	
earthquake condition, stop log open	F	389	281	*
	A	497	384	*
	C	939	142	
	H	337	37	*
earthquake condition, stop log closed	F	290	189	
	A	396	240	
	C	909	158	*

normal condition: no earthquake
earthquake condition: earthquake

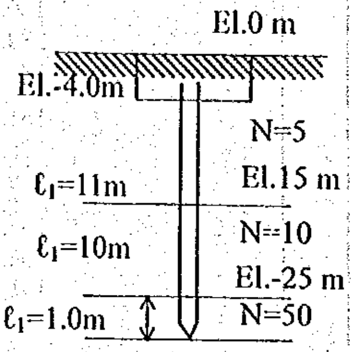
in stop log open condition, water weight is included
in stop log closed condition, water pressure on stop log is included
in earthquake condition, inertia on screw has vertical component
in stop log open condition, driving force of screw is included

3.10 Pile Foundation Analysis

3.10.1 Pile Stress Analysis

(1) N-value for design of pile foundation

Geological condition at the site is assumed as shown in Figure-11.



N-value at pile tip (Nt): 50
average N-value 3.75D above the tip to pile tip (N2):

3.75 D = 3.75 x 0.5 = 1.875
N2 = (0.875 x 10 + 1.0 x 50) / 1.875 = 31.3 → 31

N-value for pile design (N): N = (50+31)/2 = 40.5 → 40

(2) Estimation of internal friction angle

$\phi = 15 + \sqrt{(15 \times N)} = 15 + \sqrt{(15 \times 40)} = 39.5 \rightarrow 40$

(3) Allowable compressive bearing capacity (Ra)

$$Ra = \frac{\{qd \times A + u(li \times fi)\}}{SF}$$

qd : ultimate bearing capacity per unit are at pile tip (tf/m^2)
A : Area of pile tip ($=\pi R^2/4 = 0.196$ m^2)
li : stratum depth (l_1= 11.0 m, l_2= 10 m, l_3= 1 m)
u : circumferential length of pile (= 1.571 m)
fi : maximum skin firiction of stratum
(f_1= 2.5 tf/m^2, f_2= 3 tf/m^2, f_3= 3 tf/m^2)
SF : safety factor (normal: 3, earthquake:2)

- ultimate bearing capacity (qd)

$$qd = 1.3 \times c \times N + 0.3 \times R \times \gamma_1 + N_\gamma \times Df \times Nq$$

c : cohesion (= 0)
Nc, N_γ, Nq : bearing capacity foctors
Nc = 92, N_γ= 110, Nq = 85
γ_1 : unit weight of soil below pile tip (= 0.8 tf/m^3)
γ_2 : unit weight of soil above pile tip (= 0.8 tf/m^3)
R : diameter of pile (= 0.5 m)
Df : Pile length (= 22.0 m)

qd = 0.3 x 0.5 x 0.8 x 110 + 0.8 x 22.0 x 85 = 1509.2 tf/m^2

$$Ra = \frac{\{1509.2 \times 0.196 + 1.571 \times (11.00 \times 2.5 + 10 \times 3 + 1 \times 3)\}}{SF} = \frac{390.8}{SF}$$

- Normal condition: Ra = 130 tf
- Earthquake condition: Ra = 195 tf

(4) Allowable pull-out capacity (Pa)

$$Pa = \frac{Pu}{SF + \overline{w}}$$

Pu: ultimate axial pull-out capacity of pile determined by ground conditions (tf)

Pu = UΣ(li x fi) = 95

w : effective weight of pile (= 1.6 tf/m x 22.0 m = 35.2 tf)

SF: safety factor (normal: 6, earthquake:3)

-Normal condition: Pa = 51.0 tf

-Earthquake condition: Pa = 69.9 tf

(5) Allowable lateral bearing capacity (Ha)

Ha = (k x D /β) x δa

k: coefficient of lateral reaction of foundation ground (kgf/cm^3)

D: pile diameter(= 0.5 m)

β: charactaristic value of pile (cm^{-1})

$$\beta = \sqrt[4]{\frac{k \cdot D}{4 \cdot E \cdot I}}$$

E: coefficient of elasticity of pile body (= 400,000 kgf/cm^2)

I: momet of inertia of corss section of pile body (= 260,604.6 m^4)

δa: allowable displacement of pile (normal: 1.0 cm, earthquake: 1.5 cm)

(5)-1 Estimation of coefficient of lateral reaction of foundation ground (k)

$k = k_0(B_H/30)^{-3/4}$

$$k_0 = \frac{1}{30} \times \alpha \times E_0$$

E0 = 28N = 140, α=1 (normal), α=2 (earthquake)

$$B_H = \sqrt{\frac{D}{\beta}}$$

D = 0.5 m

k = 1.70 (normal condition)

k = 3.40 (earthquake condition)(details see table-5)

(5)-2 Allowable lateral bearing capacity (Ha)

$$Ha = \left(K \times \frac{D}{\beta}\right) \times \delta a$$

K: 1.70 kgf/cm^3 (normal), 3.40 kgf/cm^3 (earthquake)

D: pile diameter(= 50 cm)

β: 0.0038 cm^{-1}, 1/β= 264.5 cm

δa: allowable displacement of pile (normal: 1.0 cm, earthquake: 1.5 cm)

Ha = 22.5 t (normal),

Ha = 67.4 t (earthquake)

6) Load and moment for a pile

6)-1 Load and moment at footing center

	normal(X)			normal(Z)			seismic(ZX)			seismic(ZZ)			seismic(XX)			seismic(XZ)		
Name of Structure	V	H	M	V	H	M	V	H	M	V	H	M	V	H	M	V	H	M
Front Structure	-290	71	458	-290	-75	106	-389	0	225	-389	-273	424	-389	78	362	-389	-75	106
Main Structure-A	-596	-24	65	-596	-97	167	-497	-24	34	-497	-375	732	-497	-162	271	-497	-97	167
Main Structure-C	-935	-24	1031	-935	-15	23	-909	0	84	-909	-130	415	-909	-158	1310	-909	-15	136
House Slab	-337	0	0	-337	0	0	-337	37	9	-337	37	9	-337	0	0	-337	0	0

Displacement of Piles and Load on Piles (Baru Pumping Station)

Front Structure

displacement of pile

		delta H(cm)			alpha H(10-5 radian)		
	delta y	delta x	delta z	delta H	alpha x	alpha z	alphs H
normal	-0.028	0.077	-0.081	0.11	1.41	-1.18	1.84
earthquake: z	-0.037	0.004	-0.176	0.18	0.03	-3.59	3.59
earthquake:x	-0.037	0.050	-0.048	0.07	1.29	-0.99	1.63

load on pile

	Pv(t)				
	Pvmax	Pvmin	Ph(t)	Mo(tm)	Mm(tm)
normal	7.1	6.9	2.46	3.25	-0.7
earthquake: z	12.9	5.5	6.72	7.55	-1.6
earthquake: x	9.3	9.0	2.54	2.85	-0.6

beta(normal)= 0.00378
beta(quake)= 0.004449

Main Structure-A

displacement of pile

		delta H(cm)			alpha H(10-5 radian)		
	delta y	delta x	delta z	delta H	alpha x	alpha z	alphs H
normal	-0.05	-0.023	-0.091	0.094	-0.51	-1.27	1.37
earthquake: z	-0.042	-0.014	-0.211	0.211	-0.43	-4.11	4.13
earthquake:x	-0.042	-0.09	-0.055	0.105	-2.92	-1.07	3.11

load on pile

	Pv(t)				
	Pvmax	Pvmin	Ph(t)	Mo(tm)	Mm(tm)
normal	14.2	10.6	2.08	2.75	-0.572
earthquake: z	15.2	5.6	7.83	8.72	-1.81276
earthquake: x	12.8	8.1	3.93	4.38	-0.90985

beta(normal)= 0.00378
beta(quake)= 0.00449

Main Structure-C

displacement of pile

		delta H(cm)			alpha H(10-5 radian)		
	delta y	delta x	delta z	delta H	alpha x	alpha z	alphs H
normal	-0.236	-0.0680	-0.042	0.080	-1.05	-0.50	1.16
earthquake: z	-0.229	0.0004	-0.218	0.218	0.43	-3.55	3.58
earthquake:x	-0.229	-0.2690	-0.025	0.270	-7.92	-0.39	7.93

load on pile

	Pv(t)				
	Pvmax	Pvmin	Ph(t)	Mo(tm)	Mm(tm)
normal	59.2	57.6	1.77	2.34	-0.48675
earthquake: z	56.9	56.4	9.56	10.65	-2.21328
earthquake: x	62.1	51.3	8.18	9.11	-1.89379

beta(normal)= 0.00378
beta(quake)= 0.00449

Pile Cap Analysis

F-F

normal stress in the footing concrete

P_{Nmax} = 7.1 tf/pile (in case of normal condition)

P_{Nmax} = 12.9 tf/pile (in case of earthquake condition)

$$\delta_{cv} = \frac{P_{N\max}}{\pi D^2/4} = \frac{12900}{\frac{\pi}{4}\times 50^2} = 6.6\,{}^{kgf}/_{cm^2} < \delta_{ca} = 60.0\times 1.5 = 90.0\,{}^{kgf}/_{cm^2}$$

shearing stress in the footing concrete

$$\tau_v = \frac{P_{N\max}}{\pi(D+h)h} = \frac{12900}{\pi(50+70)\times 70} = 0.49\,{}^{kgf}/_{cm^2} < \tau ca = 8.8\,{}^{kgf}/_{cm^2}........O.K.$$

horizontal punching stress in the footing concrete

$$\delta_{ch} = \frac{H}{D\ell}$$

ℓ = inserted pile length (cm)

M = Moment (kgf.cm)

H = Axial Force

P_{Nmax} = 9.3 tf/pile M.x = 2.85 tf.m S.x = 2.54 tf

P_{Nmax} = 12.9 tf/pile M.z = 7.75 tf.m S.z = 6.72 tf

$$\delta_{ch\text{-}X} = \frac{2540}{50\times 10} = 5.1\,{}^{kgf}/_{cm^2} < \delta_{ca} = 60.0\times 1.5 = 90.0\,{}^{kgf}/_{cm^2}.......O.K$$

$$\delta_{ch\text{-}Z} = \frac{67250}{50\times 10} = 13.4\,{}^{kgf}/_{cm^2} < \delta_{ca} = 60.0\times 1.5 = 90.0\,{}^{kgf}/_{cm^2}.......O.K$$

horizontal punching stress in the pile

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

h' = effective thickness of footing concrete against horizontal punching

h' = 45 cm (z direction)

$$\tau_h = \frac{6720}{45\times(2\times 10 + 50 + 2\times 45)} = 0.93\,{}^{kgf}/_{cm^2} < \tau_{a3} = 8.8\,{}^{kgf}/_{cm^2}..........O.K$$

stress in the imaginary concrete section

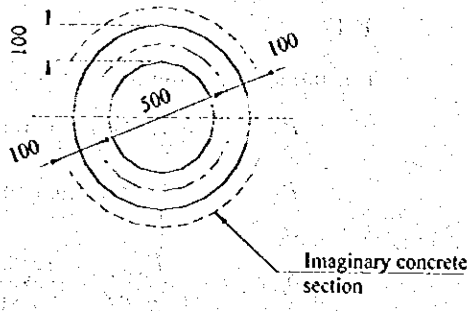
$N = N_{min} =$ 5.5 tf (in case of earthquake condition)

M = 7.75 tf.m

D = 50 + 10 x 2 = 70.0 cm

a = 11.0 cm x 2 = 22.0 cm

d = 24.0 cm



$\delta_C = 83.3^{kgf}/_{cm^2} < \delta_{ca} = 75 \times 15 = 112.5^{kgf}/_{cm^2}$..........O.K

$\delta_S = 2049^{kgf}/_{cm^2} < \delta_{sa} = 2400^{kgf}/_{cm^2}$..........O.K

D16 – 8 bars

reinforcing bar for inserted concrete

$L_1 \geqslant L_0$

bond length in footing L_0 = 35Ø (mm)

Ø = reinforcing bar diameter (mm)

L_1 = 35 x 16 = 560 ≑ 600 mm

bond length in footing L_2 = 50Ø + L_0

Ø = PC cable diameter (mm)

L_2 = 50 x 9.0 + 35 x 16 = 1010 mm

≑ 1050 mm

Stirrup : D13 per 150 mm pitch

height of inserted concrete

$L_2 \geqslant$ 1050 mm

A-A

(a) normal stress in the footing concrete

$P_{N max}$ = 14.2 tf/pile (in case of normal condition)

$P_{N max}$ = 19.2 tf/pile (in case of earthquake condition)

$$\delta_{cv} = \frac{P_{N\max}}{\pi D^2/4} = \frac{15200}{\frac{\pi}{4}\times 50^2} = 7.7\,kgf/cm^2 < \delta_{ca} = 60.0\times 1.5 = 90.0\,kgf/cm^2$$

(b) shearing stress in the footing concrete

$$\tau_v = \frac{P_{N\max}}{\pi(D+h)h} = \frac{15200}{\pi(50+70)\times 70} = 0.58\,kgf/cm^2 < \tau ca = 8.8\,kgf/cm^2 ........O.K.$$

(c) horizontal punching stress in the footing concrete

$$\delta_{ch} = \frac{H}{D\ell}$$

ℓ = inserted pile length (cm)

M = Moment (kgf.cm)

H = Axial Force

$P_{N max}$ = 12.8 tf/pile   M.x = 4.38 tf.m   S.x = 3.93 tf

$P_{N max}$ = 15.2 tf/pile   M.z = 8.72 tf.m   S.z = 7.83 tf

$$\delta_{ch\text{-}X} = \frac{7830}{50\times 10} = 15.7\,kgf/cm^2 < \delta_{ca} = 60.0\times 1.5 = 90.0\,kgf/cm^2 ....O.K$$

$$\delta_{ch\text{-}Z} = \frac{7830}{50\times 10} = 15.7\,kgf/cm^2 < \delta_{ca} = 60.0\times 1.5 = 90.0\,kgf/cm^2 ....O.K$$

(d) horizontal punching stress in the pile

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

h' = effective thickness of footing concrete against horizontal punching

h' = 45 cm (z direction)

$$\tau_h = \frac{7830}{45\times(2\times 10 + 50 + 2\times 45)} = 1.09\,kgf/cm^2 < \tau_{a3} = 8.8\,kgf/cm^2 ....O.K$$

(e) stress in the imaginary concrete section

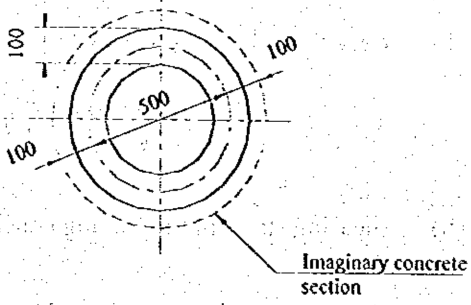
$N = N_{min} =$ 5.6 tf (in case of earthquake condition)

$M =$ 8.72 tf.m

$D =$ 50 + 10 x 2 = 70.0 cm

$a =$ 11.0 cm x 2 = 22.0 cm

d = 14.0 cm



$\delta_C = 94.4 \, {}^{kgf}/_{cm^2} < \delta_{ca} = 75 \times 15 = 112.5 \, {}^{kgf}/_{cm^2}$ ....O.K

$\delta_S = 2350 \, {}^{kgf}/_{cm^2} < \delta_{sa} = 2400 \, {}^{kgf}/_{cm^2}$ ....O.K

D16 – 8 bars

(f) reinforcing bar for inserted concrete

$L_1 \geqslant L_0$

bond length in footing L_0 = 35Ø (mm)

Ø = reinforcing bar diameter (mm)

L_1 = 35 x 16 = 560 ≑ 600 mm

bond length in footing L_2 = 50Ø + L_0

Ø = PC cable diameter (mm)

L_2 = 50 x 9.0 + 35 x 16 = 1010 mm

≑ 1050 mm

Stirrup : D13 per 150 mm pitch

(g) height of inserted concrete

$L_2 \geqslant$ 1050 mm

<u>C-C</u>

(a) normal stress in the footing concrete

$P_{N max}$ = 59.2 tf/pile (in case of normal condition)

$P_{N max}$ = 62.1 tf/pile (in case of earthquake condition)

$$\delta_{cv} = \frac{P_{N\max}}{\pi D^2/4} = \frac{62100}{\frac{\pi}{4}\times 50^2} = 31.6\ ^{kgf}/_{cm^2} < \delta_{ca} = 60.0\times 1.5 = 90.0\ ^{kgf}/_{cm^2}$$

(b) shearing stress in the footing concrete

$$\tau_V = \frac{P_{N\max}}{\pi(D+h)h} = \frac{62100}{\pi(50+70)\times 70} = 2.4\ ^{kgf}/_{cm^2} < \tau ca = 8.8\ ^{kgf}/_{cm^2} \text{........O.K.}$$

(c) horizontal punching stress in the footing concrete

$$\delta_{ch} = \frac{H}{D\ell}$$

ℓ = inserted pile length (cm)

M = Moment (kgf.cm)

H = Axial Force

$P_{N max}$	=	62.1 tf/pile	M.x	=	9.11 tf.m	S.x	=	8.18 tf
$P_{N max}$	=	56.9 tf/pile	M.z	=	10.65 tf.m	S.z	=	9.56 tf

$$\delta_{ch\text{-}x} = \frac{8180}{50\times 10} = 16.4\ ^{kgf}/_{cm^2} < \delta_{ca} = 60.0\times 1.5 = 90.0\ ^{kgf}/_{cm^2} \text{.......O.K}$$

$$\delta_{ch\text{-}z} = \frac{9560}{50\times 10} = 19.1\ ^{kgf}/_{cm^2} < \delta_{ca} = 60.0\times 1.5 = 90.0\ ^{kgf}/_{cm^2} \text{.......O.K}$$

(d) horizontal punching stress in the pile

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

h' = effective thickness of footing concrete against horizontal punching

h' = 45 cm (z direction)

$$\tau_h = \frac{9560}{45\times(2\times 10 + 50 + 2\times 45)} = 1.33\ ^{kgf}/_{cm^2} < \tau_{a3} = 8.8\ ^{kgf}/_{cm^2} \text{..........O.K}$$

(e) stress in the imaginary concrete section

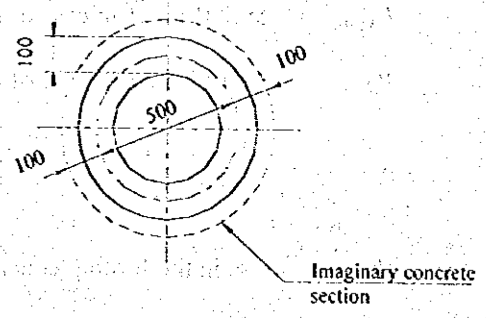
$N = N_{min} = 56.4$ tf (in case of earthquake condition)

$M = 10.65$ tf.m

$D = 50 + 10 \times 2 = 70.0$ cm

$a = 14.5$ cm $\times 2 = 29.0$ cm

d = 14.5 cm



$\delta_C = 57.8^{kgf}/_{cm^2} < \delta_{ca} = 75 \times 15 = 11$

$\delta_S = 150^{kgf}/_{cm^2} < \delta_{sa} = 2400^{kgf}/_{cm^2}$..........O.K

D16 – 8 bars

(f) reinforcing bar for inserted concrete

$L_1 \geqslant L_0$

bond length in footing	L_0	=	35Ø (mm)		
	Ø	=	reinforcing bar diameter (mm)		
	L_1	=	35 x 16 = 560 ÷ 600 mm		
bond length in footing	L_2	=	50Ø + L_0		
	Ø	=	PC cable diameter (mm)		
	L_2	=	50 x 9.0 + 35 x 16	=	1010 mm
				÷	1050 mm

Stirrup : D13 per 150 mm pitch

(g) height of inserted concrete

$L_2 \geqslant 1050$ mm

H-H

(a) normal stress in the footing concrete

P_{Nmax} = 27.2 tf/pile (in case of normal condition)

P_{Nmax} = 28.9 tf/pile (in case of earthquake condition)

$$\delta_{cv} = \frac{P_{N\max}}{\pi D^2/4} = \frac{28900}{\frac{\pi}{4}\times 50^2} = 14.7\,{}^{kgf}/_{cm^2} < \delta_{ca} = 60.0\times 1.5 = 90.0\,{}^{kgf}/_{cm^2}$$

(b) shearing stress in the footing concrete

$$\tau_V = \frac{P_{N\max}}{\pi(D+h)h} = \frac{28900}{\pi(50+70)\times 70} = 1.10\,{}^{kgf}/_{cm^2} < \tau ca = 8.8\,{}^{kgf}/_{cm^2}\text{.......}O.K.$$

(c) horizontal punching stress in the footing concrete

$$\delta_{ch} = \frac{H}{D\ell}$$

ℓ = inserted pile length (cm)

M = Moment (kgf.cm)

H = Axial Force

P_{Nmax}	=	28.7 tf/pile	M.x	=	3.43 tf.m	S.x	=	3.08 tf
P_{Nmax}	=	28.9 tf/pile	M.z	=	3.43 tf.m	S.z	=	3.08 tf

$$\delta_{ch\text{-}X} = \frac{3{,}080}{50\times 10} = 6.2\,{}^{kgf}/_{cm^2} < \delta_{ca} = 60.0\times 1.5 = 90.0\,{}^{kgf}/_{cm^2}\text{.......}O.K$$

$$\delta_{ch\text{-}Z} = \frac{3{,}080}{50\times 10} = 6.2\,{}^{kgf}/_{cm^2} < \delta_{ca} = 60.0\times 1.5 = 90.0\,{}^{kgf}/_{cm^2}\text{.......}O.K$$

(d) horizontal punching stress in the pile

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

h' = effective thickness of footing concrete against horizontal punching

h' = 45 cm (z direction)

(e) stress in the imaginary concrete section

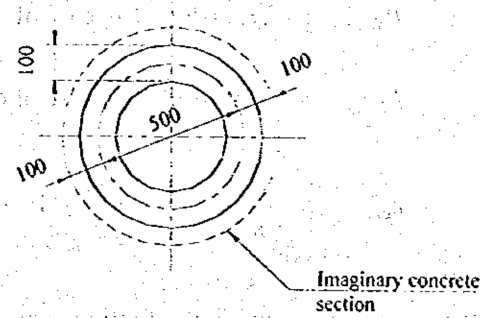
$N = N_{min} =$ 25.6 tf (in case of earthquake condition)

$M =$ 3.43 tf.m

$D = 50 + 10 \times 2 = 70.0$ cm

$a = 11.0$ cm $\times 2 = 22.0$ cm

d = 24.0 cm



$\delta_C = 17.3^{kgf}/_{cm^2} < \delta_{ca} = 75 \times 15 = 11$

$\delta_S = 34^{kgf}/_{cm^2} < \delta_{sa} = 2400^{kgf}/_{cm^2}$..........O.K

D16 – 8 bars

(f) reinforcing bar for inserted concrete

$L_1 \geqslant L_0$

bond length in footing $L_0 = 35Ø$ (mm)

$Ø$ = reinforcing bar diameter (mm)

$L_1 = 35 \times 16 = 560 \doteqdot 600$ mm

bond length in footing $L_2 = 50Ø + L_0$

$Ø$ = PC cable diameter (mm)

$L_2 = 50 \times 9.0 + 35 \times 16 = 1010$ mm

$\doteqdot 1050$ mm

Stirrup : D13 per 150 mm pitch

(g) height of inserted concrete

$L_2 \geqslant 1050$ mm

3.11 Safety Against Buoyancy

Safety against buoyancy was calculated as follows:

Safety Against Uplift (Baru)

Name of Structure	weight of structures (t)			uplift (t)	safety factor
	civil structure	machien and others	total		
Front Structure	614.7	90.5	705.2	415.4	1.70
Main Structure-A	662.8	35.7	698.5	508.3	1.37
Main Structure-B	352.6	181.9	534.5	152.6	3.50
Main Structure-C	378.7	131.6	510.3	27.3	18.69