CV-5 STRUCTURAL CALCULATION OF PUMP PIT

Contents of this calculation note is shown as below.

1.1 Soil Condition

Boring data around the construction area is shown in Fig 1.
Now the average N-value above the foundation level is calculated as follows.

$$\bar{N} = \frac{\frac{1}{2}\times\{(0+9)\times2.0+(9+11)\times2.0+(10+13)\times2.0+(13+30)\times2.0+(30+25)\times2.0\}}{10.0}$$

$$= 15$$

According to the above calculation, the angle of the internal friction is assumed by the following equation.

$$\phi = (\sqrt{15\cdot\bar{N}} + 15)^\circ = (\sqrt{15\times15} + 15)^\circ = 30^\circ$$

The bulk density of soil above the ground water $r = 1.9\ t/m^3$

The bulk density of soil under the ground water $r' = 1.0\ t/m^3$

Other design condition data are descripted in "Civil Design Condition" (vid.No EWC-1001).

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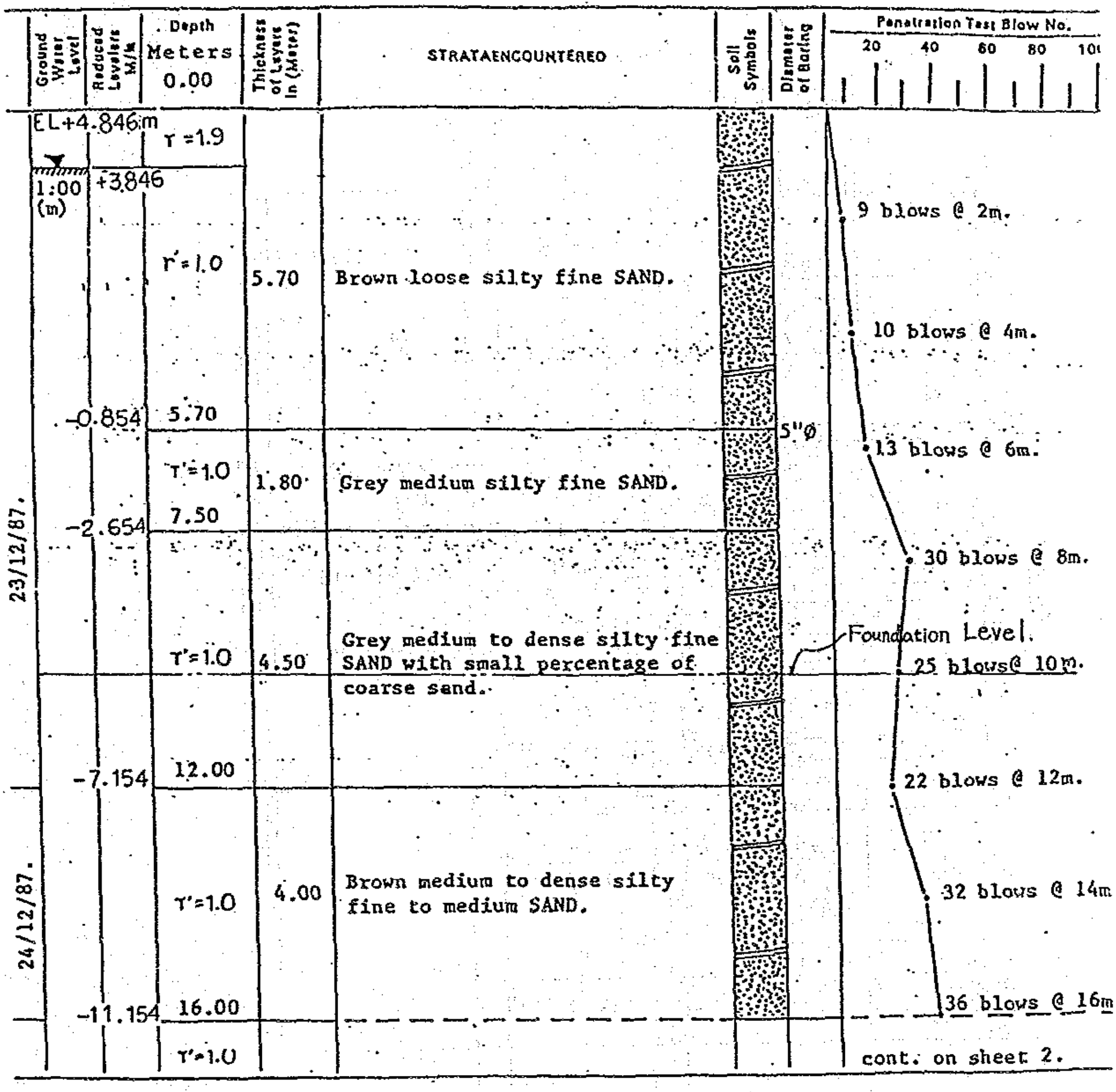
SITE : WEST WHARF THERMAL POWER STATION, KARACHI.

CLIENT : KARACHI ELECTRIC SUPPLY CORPORATION.

BORE CHART OF BORING No.2



Remarks : GROUNDWATER TABLE AT 1.00 METER.

Date :- 24/12/87

Fig 1. The soil column diagram

FORM 04

1.2 Outline of Pump Pit

Outline of Pump Pit is shown in Fig 2, 3.

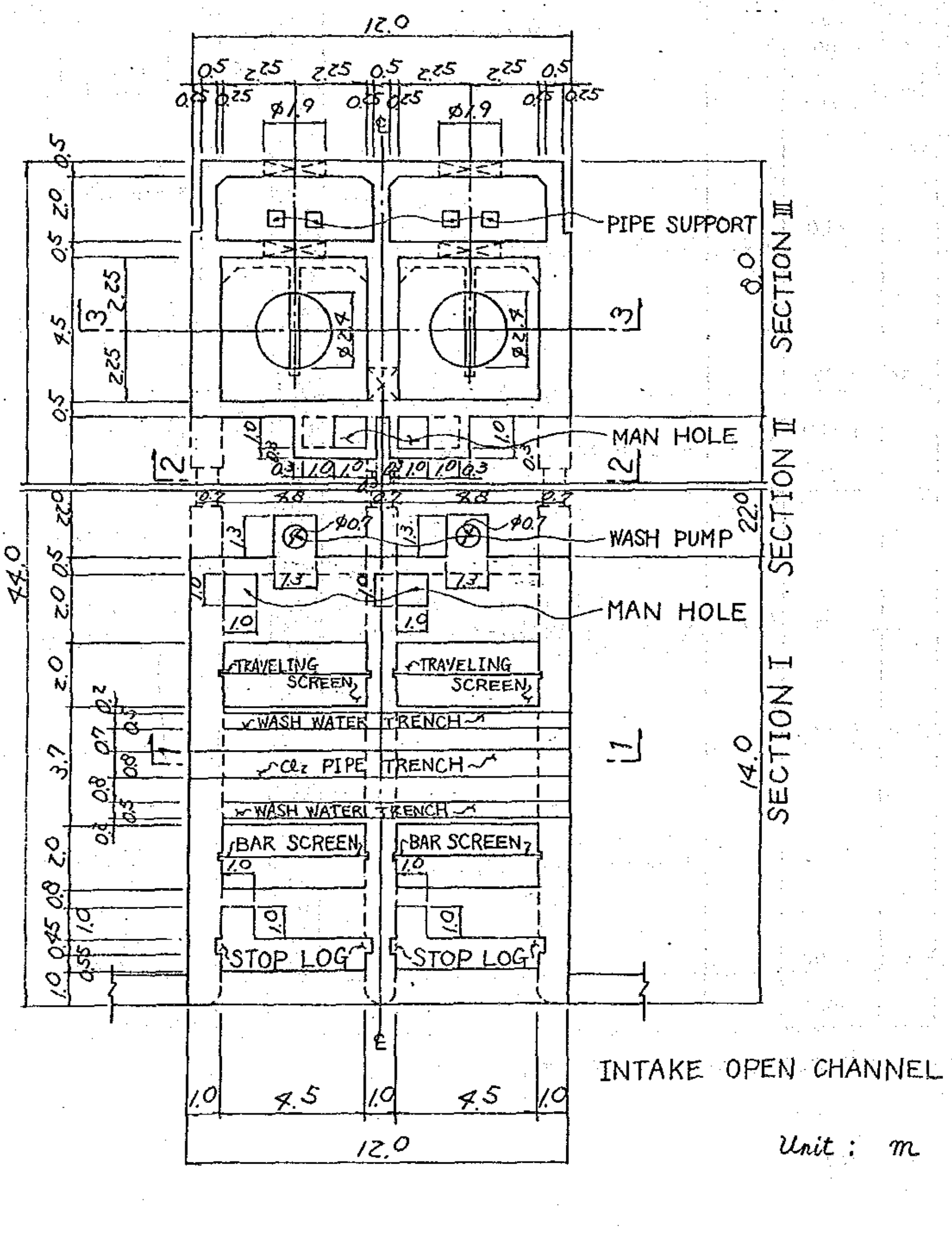


Fig 2. Plan of Pump pit

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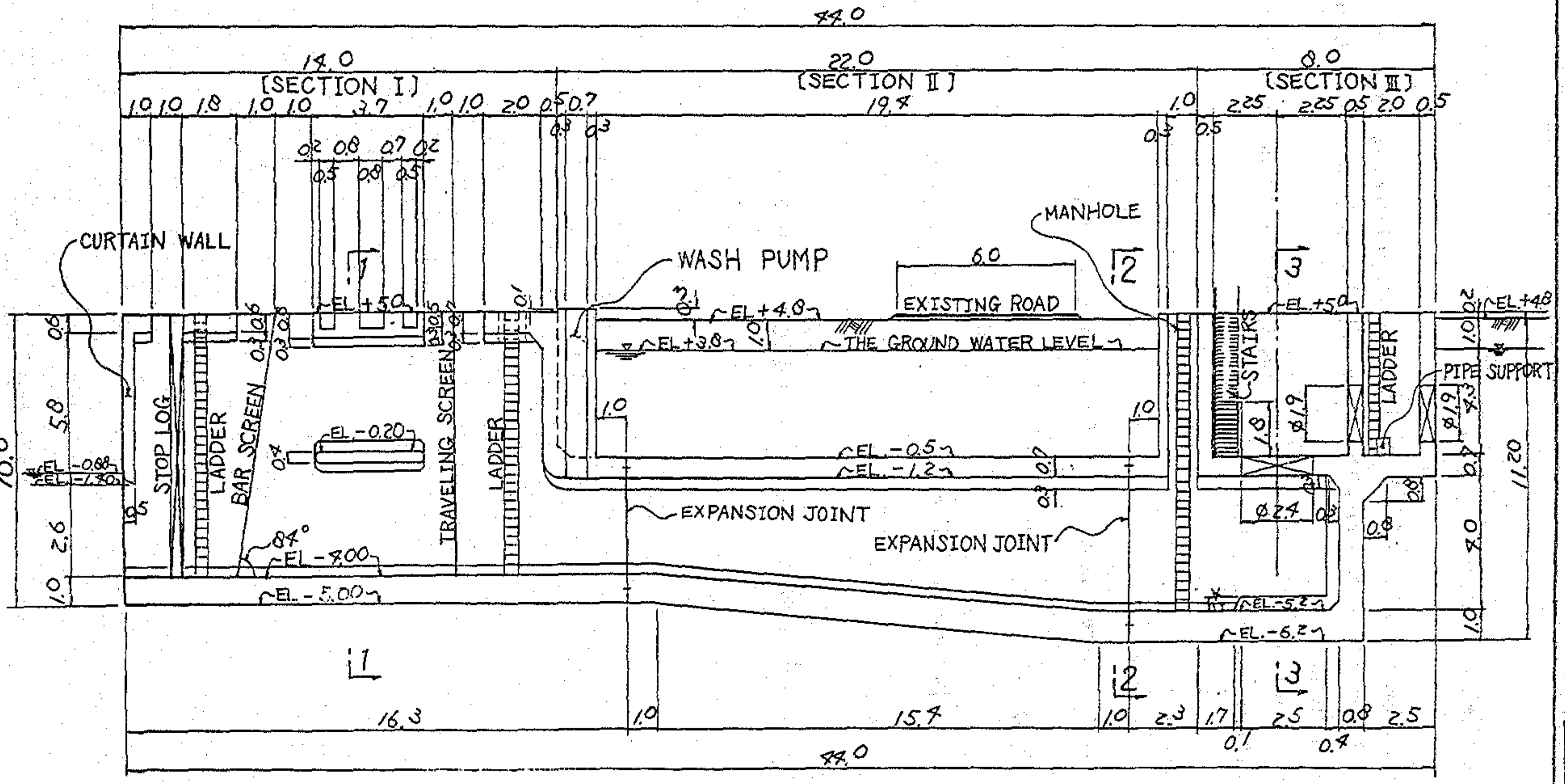

Fig 3. Profile of Pump Pit

1.3 The Design Structure

The structure of Pump Pit is devided into three blocks as shown in Fig 1 and 2. In the design of Pump Pit, the design calculation is executed individually for each block.

The summary of the design sections are as follows and the typical design sections are shown in Fig 3, 4 and 5.

1) Block I

Block I is Screen Room. Total length L_1 = 14.0m

2) Block II

Block II is Connected Culvert. Total length L_2 = 22.0m

3) Block III

Block III is Pump Room. Total length L_3 = 8.0m

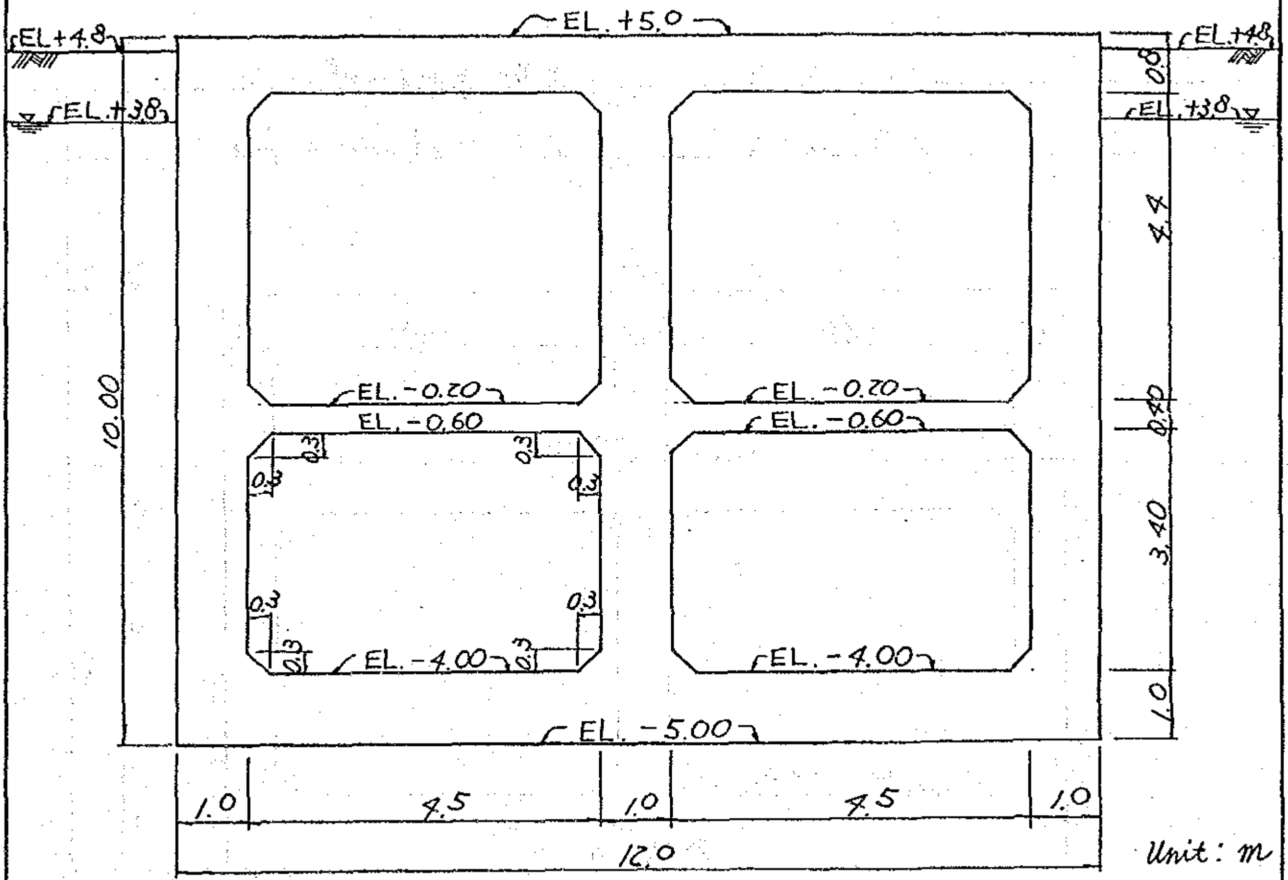

Fig 3. SECTION 1 − 1

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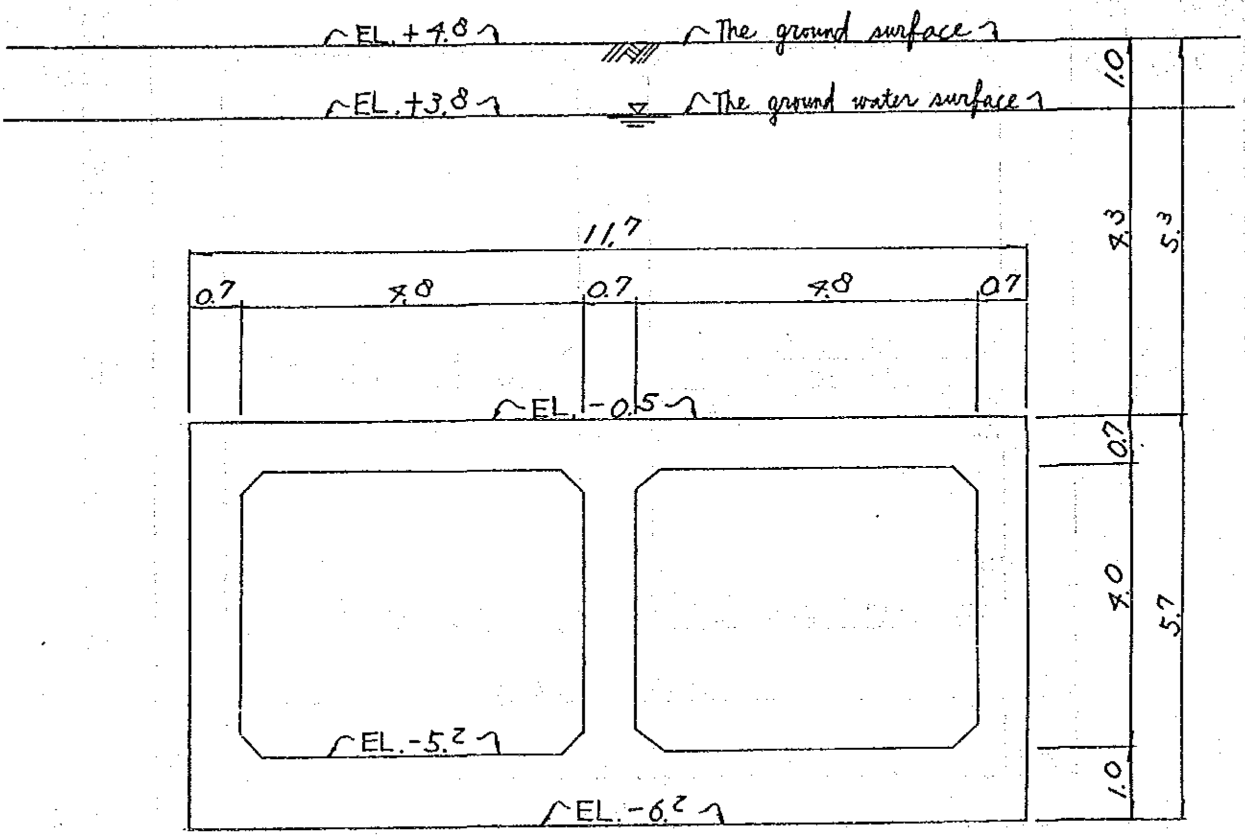

Unit : m

Fig 4. SECTION 2 - 2

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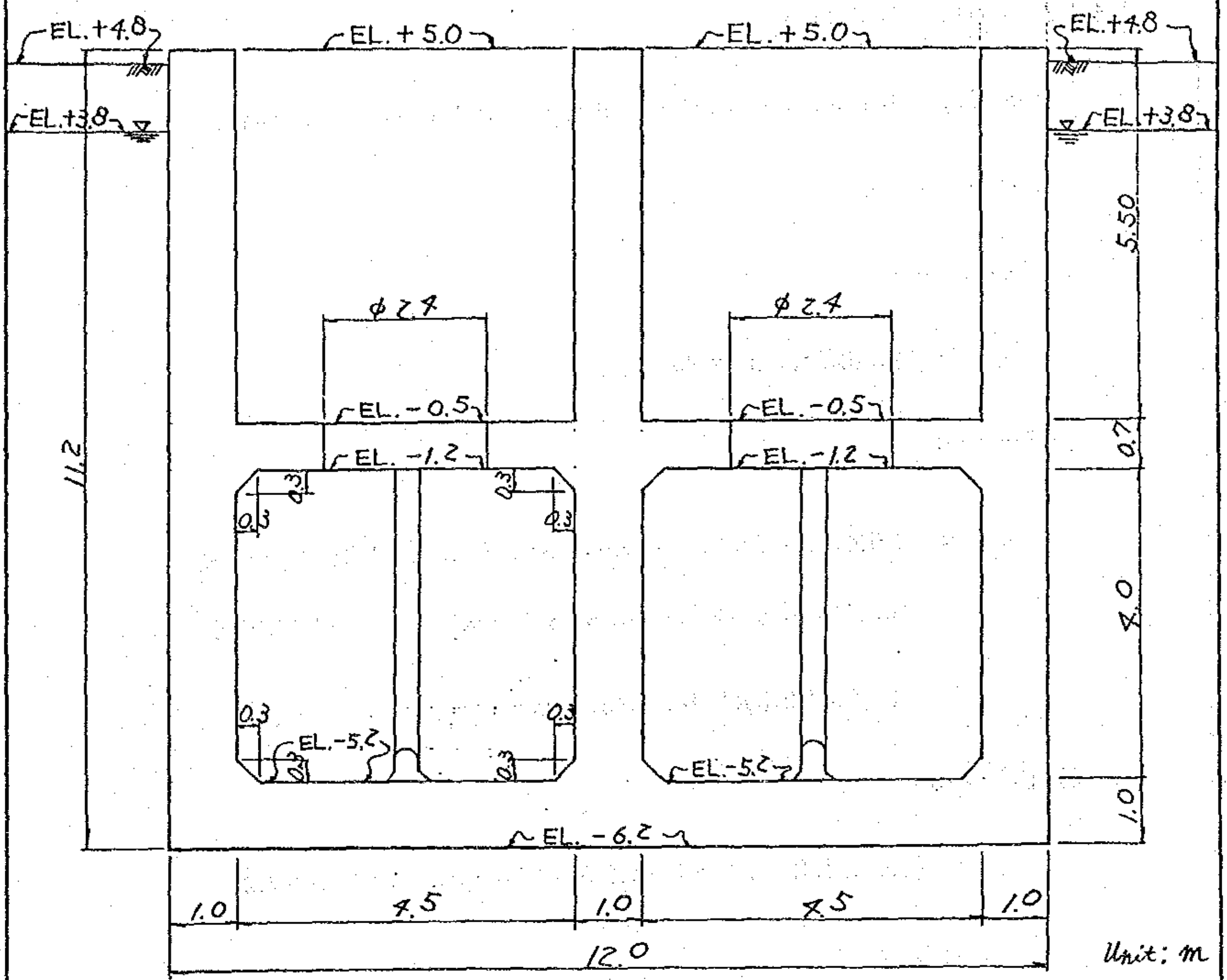

Fig 5. SECTION 3 - 3

FORM 04

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1.4 Study of block I (Screen Room)

1.4.1 Stability Calculation

Stability calculation is executed at the longitudinal direction.

1) Vertical forces

a) Base slab

$W_{c1} = 12 \times 16.3 \times 1.0 \times 2.45 = 479$ t

b) Side wall

$W_{c2} = \{9.0 \times (3 \times 1.0 \times 14.0 - 4 \times 0.45 \times 0.25 - 8 \times 0.05 \times 0.3 + 3 \times \frac{1}{2} \times \pi$

$\times 0.5^2) + 4 \times 0.3 \times 0.3 \times 15.5 + 3 \times 1.0 \times 2.3 \times 2.8 - 2 \times 0.5 \times 0.5 \times 1.0$

$-3 \times 0.8 \times 0.5 \times 1.0) \times 2.45 = 965$ t

c) Middle slab

$W_{c3} = \{2 \times 4.5 \times (3.3 \times 0.4 + \pi \times 0.2^2) + 4 \times 0.3 \times 0.3 \times 3.7\} \times 2.45$

$= 35$ t

d) Curtain wall

$W_{c4} = 2 \times 4.5 \times (0.5 \times 5.3 + \frac{1}{4} \times \pi \times 0.5^2) \times 2.45 = 63$ t

e) Back wall

$W_{c5} = 2 \times 4.5 \times (\frac{1}{2} \times 0.5 \times 0.5 + 0.5 \times 5.0 + \frac{1}{4} \times \pi \times 0.5 \times 0.5) \times 2.45$

$= 62$ t

f) The upper slab

$$W_{c6} = (2\times4.5\times0.6\times1.0+4\times(0.5\times0.5-\frac{1}{4}\times\pi\times0.5^2)\times0.6\times2.45$$
$$= 14\ t$$

$$W_{c7} = 2\times(1.8\times3.5+0.8\times1.0)\times0.6\times2.45 = 21\ t$$

$$W_{c8} = 2\times4.5\times(0.8\times3.7-2\times0.5\times0.5-0.8\times0.5)\times2.45 = 45\ t$$

$$W_{c9} = 2\times(0.7\times2.5\times4.5-1.0\times1.0\times0.7)\times2.45 = 35\ t$$

$$W_{c10} = (2\times4.5\times(2.3\times0.5+\frac{1}{2}\times0.3\times0.3)-2\times\pi\times0.35^2\times0.7)\times2.45$$
$$= 25\ t$$

g) Wash Pump Pit

$$W_{c11} = 2\times5.6\times(1.3\times1.3-\pi\times0.35^2)\times2.45 = 36\ t$$

h) Screens' weights

i) The weights of bar screen W_b

W_{b1} = 26 t/1set × 2 set = 52 t (at the upside)

W_{b2} = 14 t/1set × 2 set = 28 t (at the downside)

ii) The weights of traveling screen W_t

W_{t1} = 21 t/1set × 2 set = 42 t (at the upside)

W_{t2} = 6 t/1set × 2 set = 12 t (at the downside)

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i) The surcharge weights due to machineries W_{mc}

A unit surcharge weight is 0.5 t/m², therefore total surcharge weight W_{mc} is calculated as below.

$$W_{mc} = 0.5\times\{12.0\times14.0-2\times(1.0\times1.0+1.0\times4.5+2\times0.45\times0.25)$$

$$-4\times(2.0\times4.5+2\times0.05\times0.3)-2\times0.5\times11.0-0.8\times12.0\}$$

$$= 50\ t$$

j) The internal water weight W_w

Water weight W_w is calculated at the lowest low water level considered for the water head loss due to Intake Tunnel(vid. 1.b,P3,No. EWC−1004).

[H.H.W.L] EL. − 0.43 m − 0.45 m = EL. − 0.88 m

According to the above calculation, water weight is calculated as below.

$$W_w = 2\times4.5(3.12\times16.3-2.8\times0.38) = 448\ t$$

k) Soil weight W_s

Soil weight W_s is calculated as the back−fill of back wall, and this weight is including the ground water weight.

$$W_s = (2.3\times12-2\times1.3\times1.3)\times(1.0\times1.9+4.3\times2.0) = 254\ t$$

l) The weight of Wash Pump W_p

$$W_p = 5.0\ t$$

m) Buoyancy U_b

$$U_b = 12.0\times16.3\times3.12 = 610\ t$$

FORM 04

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2) Horizontal forces

a) The water pressure P_w

As the water pressure P_w is working to the front face of side wall, P_w is calculated as below.

$$P_w = 3 \times \frac{1}{2} \times 1.0 \times 3.12^2 \times 1.0 = 14.6 \text{ t}$$

b) The earth pressures P_{ei}

As the earth pressures P_{ei} are working to the back face of back wall, P_{ei} are calculated as follows.

$$P_{e1} = \frac{1}{2} \times (0.5+1.45) \times 1.0 \times 12.0 = 12 \text{ t}$$

$$P_{e2} = \frac{1}{2} \times (1.45+3.6) \times 1.0 \times 12.0 = 30 \text{ t}$$

Accordingly the calculation results of the external forces are shown in Fig 6.

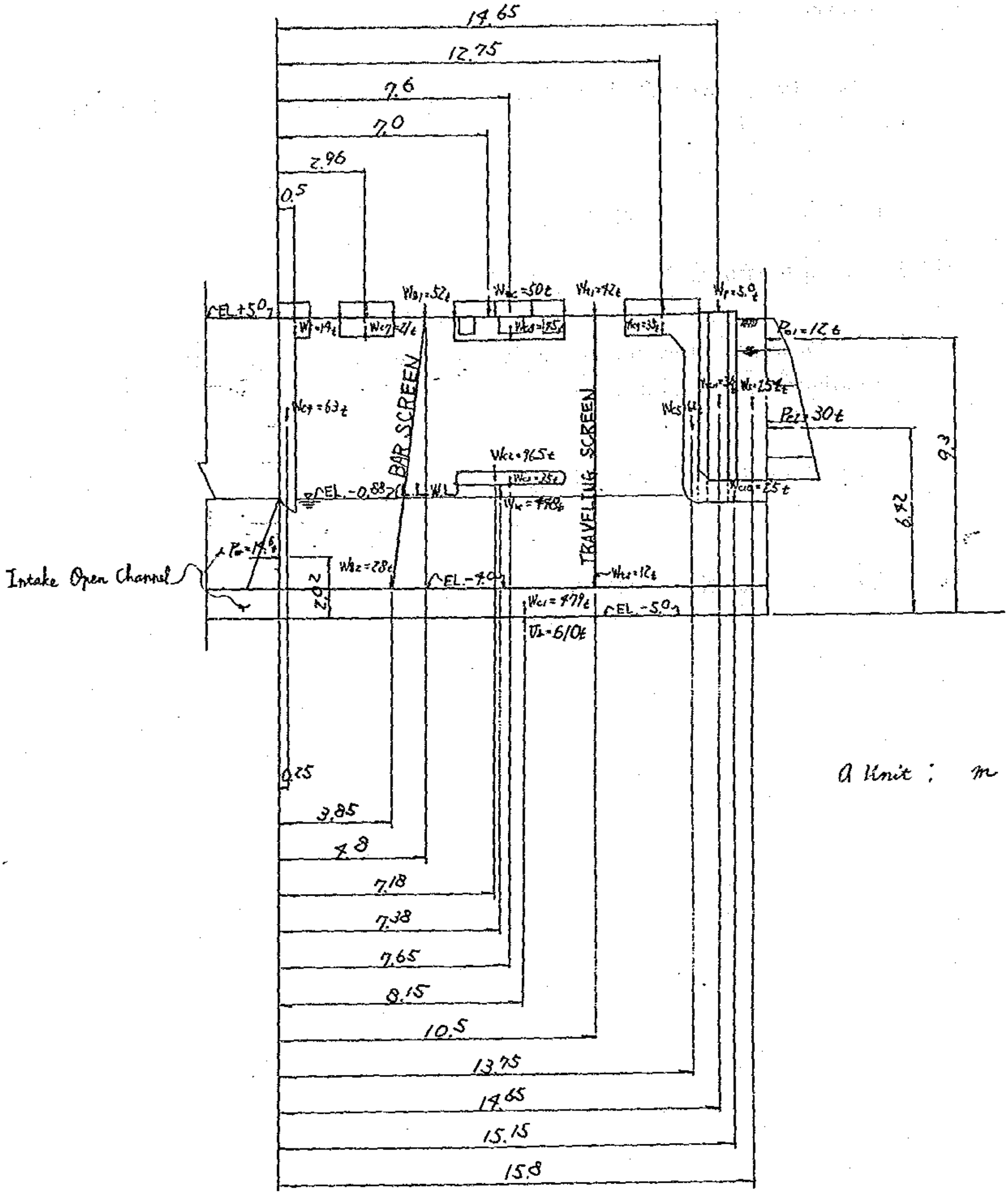

Fig 6. The calculation results of external forces

3) The calculation of the ground reaction

a) The calculation of the eccentric distance

The eccentric distance is determined by the external moment calculations, then the summarized table of the external moments is shown in Table 1.

Table 1. The summarized table of the external moments

Species	Vertical force V_i [t]	Arm X_i [m]	Moment M_i [t·m]	Horizontal force H_i [t]	Arm Y_i [m]	Moment M_i [t·m]
W_{c1}	479	8.15	3 904			
W_{c2}	965	7.18	6 929			
W_{c3}	35	7.65	268			
W_{c4}	63	0.25	16			
W_{c5}	62	13.75	853			
W_{c6}	14	0.5	7			
W_{c7}	21	2.96	62			
W_{c8}	45	7.6	342			
W_{c9}	35	12.75	446			
W_{c10}	25	15.15	379			
W_{c11}	36	14.65	527			
W_p	5	14.65	73			
W_{mc}	50	7.0	350			
W_{b1}	52	4.8	250			
W_{b2}	28	3.85	108			
W_{t1}	42	10.5	441			
W_{t2}	12	10.5	126			
W_s	254	15.8	4 013			
W_w	448	7.38	3 306			
P_{e1}				−12	9.3	−112
P_{e2}				−30	6.42	−193
P_w				15	3.34	50
U_b	−610	8.15	−4 972			
TOTAL	2 061		17 428	−27		−255

According to Table 1, the eccentric distance e is calculated as follows.

$$e = \frac{\Sigma M_i}{\Sigma V_i} - \frac{L}{2} = \frac{17\ 428 - 255}{2\ 061} - \frac{16.3}{2}$$

$$= 8.33 - 8.15$$

$$= 0.18\ m < \frac{L}{6} = \frac{16.3}{6} = 2.72\ m$$

Therefore working point of the composite force at the basement is within the middle-third.

b) The calculation of the ground reaction q_{max}, q_{min}

$$\left.\begin{matrix} q_{max} \\ q_{min} \end{matrix}\right\} = \frac{\Sigma V}{B \cdot L} \cdot \left(1 \pm \frac{6e}{L}\right)$$

$$= \frac{2\ 061}{12.0 \times 16.3} \left(1 \pm \frac{6 \times 0.18}{16.3}\right)$$

$$= \begin{cases} q_{max} = 11.2\ t/m^2 \\ q_{min} = 9.8\ t/m^2 \end{cases}$$

4) Study of the bearing capacity

a) The ultimate bearing capacity q_u

The ultimate bearing capacity q_u is calculated as follows.

$$q_u = \alpha K C N_c + K q N_q + \frac{1}{2} r_1 \beta B N_r$$

where C : cohesion C = 0

q : the surcharge load

$$q = 1.9 \times 1.0 + 1.0 \times 8.8 = 10.7\ t/m^2$$

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r_1 : the bulk density of the bearing soil

$r_1 = 1.0\ t/m^3$

B' : the effective width considered for the eccentric distance

$B' = 12.0\ m$

α, β : the coefficient of the basic form

$$\alpha = 1+0.3\cdot\frac{B'}{L'} = 1+0.3\times\frac{12.0}{16.3-2\times0.10}$$

$$= 1.23$$

$$\beta = 1-0.4\cdot\frac{B'}{L'} = 1-0.4\times\frac{12.0}{16.3-2\times0.10}$$

$$= 0.70$$

K : the extra coefficient for the embedded effect

$K = 1.0$

N_c, N_q, N_r : the bearing coefficients considered for the load inclination, and these coefficients are adopted from graphs are shown as follows.

$N_c = 30$ (from Fig 7.)

$N_q = 18$ (from Fig 8.)

$N_r = 14$ (from Fig 9.)

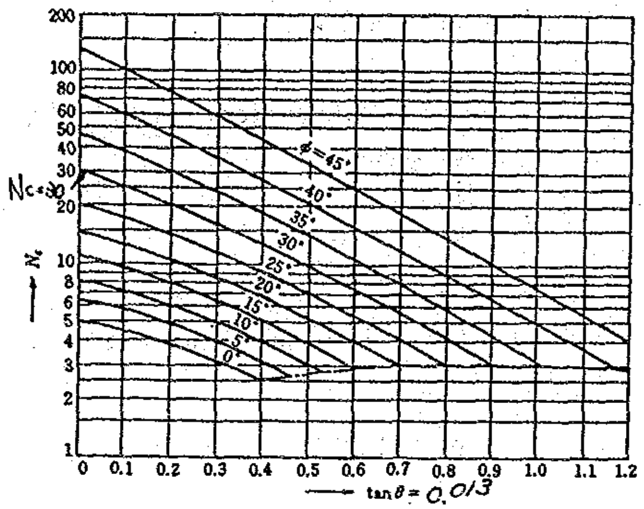

Fig 7. Graph of the bearing coefficient N_c

Where tan θ: $\tan\theta = \dfrac{H}{V} = \dfrac{27}{2\,061} = 0.013$

V: vertical force at the foundation

$V = 2\,061$ t

H: horizontal force at the foundation

$H = 27$ t

ϕ: the angle of the internal friction

$\phi = 30°$

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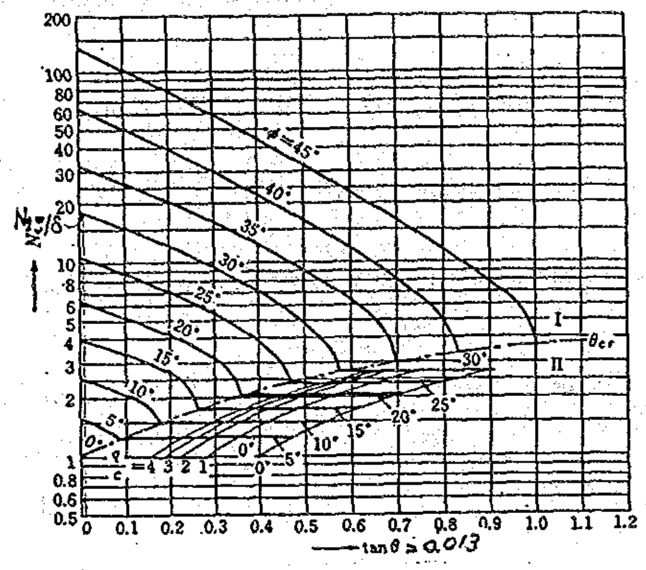

Fig 8. Graph of the bearing coefficient N_q

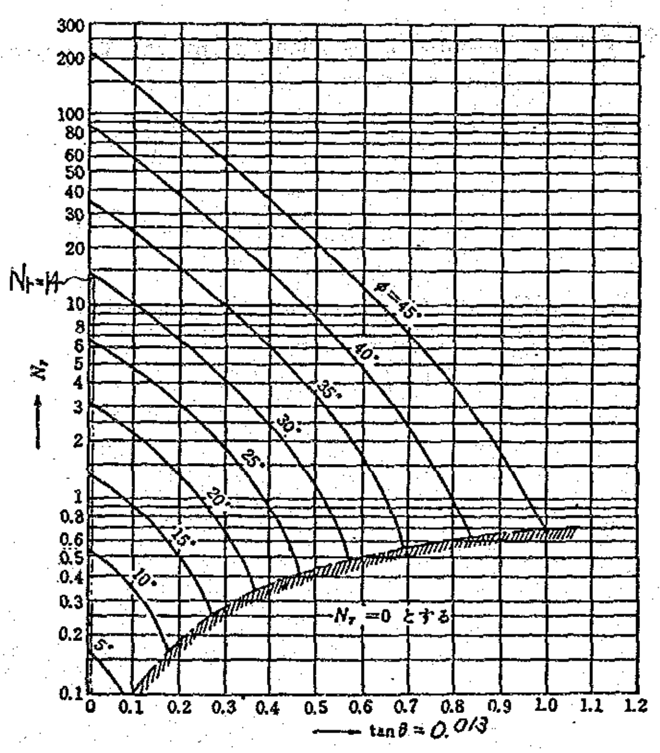

Fig 9. Graph of the bearing coefficient N_r

Accordingly the ultimate bearing capacity q_u is calculated as follows.

$$q_u = 1.0 \times 10.7 \times 18 + \frac{1}{2} \times 1.0 \times 0.70 \times 12.0 \times 14.0 = 251 \text{ t}$$

b) The allowable bearing capacity q_a

The allowable bearing capacity q_a is calculated by the following equation.

$$q_a = \frac{1}{F_s} \cdot q_u$$

where F_s: the factor of safety at normal condition

$$= \frac{1}{3} \times 251$$

$F_s = 3$

$$= 83 \text{ t/m}^2 > q_{max} = 11.2 \text{ t/m}^2$$

OK

Accordingly the spread foundation is adopted for the foundation of Screen Room.

5) Study of floating

The calculation of floating is executed at Normal and at Constuction, so this calculation is as follows.

a) Total vertical force

i) at Normal (L.L.W.L)

$V_1 = 2\,061 + 610 - 50 = 2\,621$ t

ii) at Construction (Empty)

$V_2 = 2\,061 + 610 - 448 - 50 = 2\,173$ t

b) Up lift U

Up lift U is calculated as below.

$U = r \cdot h_w \cdot A = 1.0 \times 8.8 \times 12.0 \times 16.3 = 1\,721$ t

c) Checking on the safety factor of floating F_1

The safety factor of floating is checked by the following two cases.

i) at Normal

$$F_{11} = \frac{V_1}{U} = \frac{2\,621}{1\,721} = 1.52 \underset{OK}{>} 1.1$$

ii) at Construction

$$F_{12} = \frac{V_2}{U} = \frac{2\,173}{1\,721} = 1.26 \underset{OK}{>} 1.0$$

1.4.2 The structural Design Case

The following three cases are considered for the structural design cases.

Table 2. The summary of the design cases

Case	1	2	3
Condition	at Normal	at Construction	at Inspection
Period	Long term	Short term	Short term
The internal water condition	L.L.W.L	Empty	Empty (oneside)
The distributed surcharge load	1.0 t/m²	1.0 t/m²	1.0 t/m²
The incremental of coefficient of the allowable stress	1.0	1.25	1.25

Now considering for the seismic load case, total horizontal force at earthquake is less than total horizonatl force at normal in consideration of the incrimental coefficient for the allowable stress (= 1.5), so the seismic load case is excluded from the structural design cases.

1.4.3 The Structural Design Calculation of Case−1

1) Frame of the design structure

Frame of the design structure is shown in Fig 10.

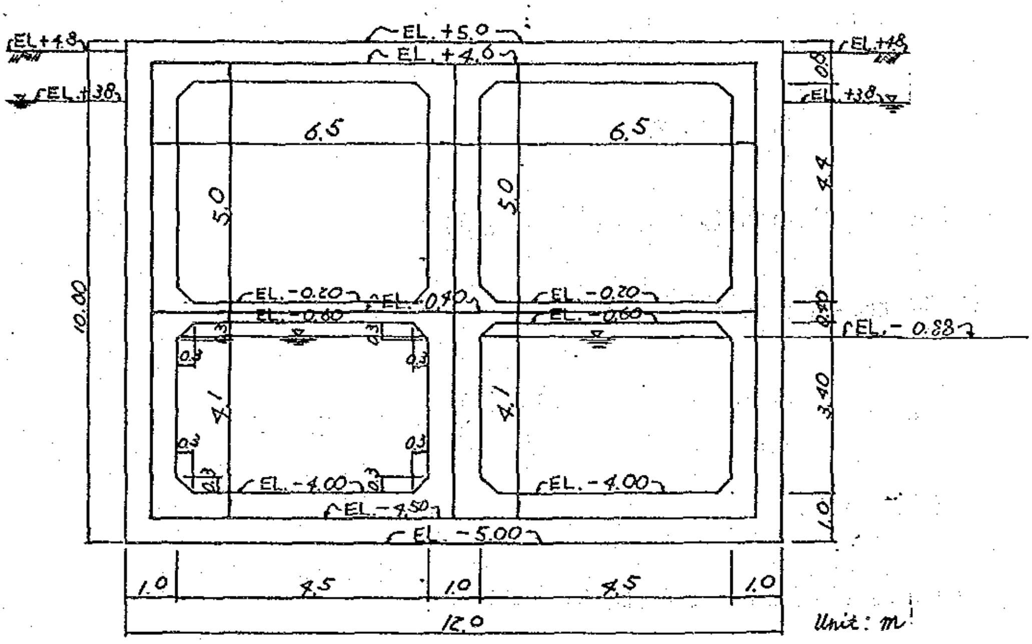

Fig 10. Frame of the design structure

Considering for manholes and other opening areas, the converted thickness of members are calculated as follows.

a) The upper slab

Considering the effects of the setting areas for screens and manholes, now the converted thickness of the upper slab is calculated as follows.

$$t_c = \{2\times0.6\times1.0\times4.5+2\times0.6\times(3.5\times1.8+0.8\times1.0)+2\times(3.7\times4.5\times0.8$$

$$-2\times0.5\times0.5\times4.5-0.8\times0.5\times4.5)+2\times0.7\times(2.5\times4.5-1.0\times1.0)\}$$

$$\div(9.0\times14.0)$$

$$\fallingdotseq 0.36\ \text{m}$$

b) The middle slab

As the converted thickness t_m is setted up the same value with the moment of inertia, t_m is calculated as below.

$$\frac{3.7 \times 0.4^3}{12} = \frac{13.5 \times t_m^3}{12}$$

$$t_m \fallingdotseq 0.26 \text{ m}$$

2) Load calculation (per 1 m unit length)

a) The ground reaction

$$q = \frac{q_{max} + q_{min}}{2} = \frac{13.3 + 12.3}{2} = 12.8 \text{ t/m}^2$$

b) Self weight

i) a side wall and a partition wall

$$W_{c1} = 1.0 \times 2.45 = 2.45 \text{ t/m}^2$$

ii) the upper slab

$$W_{c2} = 0.37 \times 2.45 = 0.91 \text{ t/m}^2$$

iii) the middle slab

$$W_{c3} = 0.26 \times 2.45 = 0.64 \text{ t/m}^2$$

iv) the base slab

$$W_{c4} = 1.0 \times 2.45 = 2.45 \text{ t/m}^2$$

c) The weight of screen

i) the upper slab

$$W_{s1} = (52+42) \div \{2\times(4.5\times14.0-1.8\times3.5-1.0\times0.8-2.0\times4.5-1.0\times1.0)\}$$

$$= 1.02\ t/m^2$$

ii) the base slab

$$W_{s2} = (28+12) \div (12.0\times15.5) = 0.22\ t/m^2$$

d) The weight of machineries

$$W_m = 0.5\ t/m^2$$

e) Water weight

$$W_w = 1.0\times3.12 = 3.12\ t/m^2$$

f) Up lift

$$q_u = 1.0\times8.8 = 8.8\ t/m^2$$

g) The water pressure

i) Outside

$$P_{wo} = 1.0\times(3.8+4.5) = 8.3\ t/m^2$$

ii) Inside

$$P_{wi} = 1.0\times3.12 = 3.12\ t/m^2$$

h) The earth pressure

The ground surface surcharge load is considered for $q = 1.0\ t/m^3$.

$P_{e0} = 0.5\times(1.0+1.9\times0.2) = 0.69\ t/m^2$ (at EL. + 4.6 m)

$P_{e1} = 0.5\times(1.0+1.9\times1.0) = 1.45\ t/m^2$ (at EL. + 3.8 m)

$P_{e2} = 0.5\times(1.0+1.9\times1.0+1.0\times8.3) = 5.6\ t/m^2$ (at EL. − 4.5 m)

According to the above calculations, the results of the load calculations are shown in Fig 11.

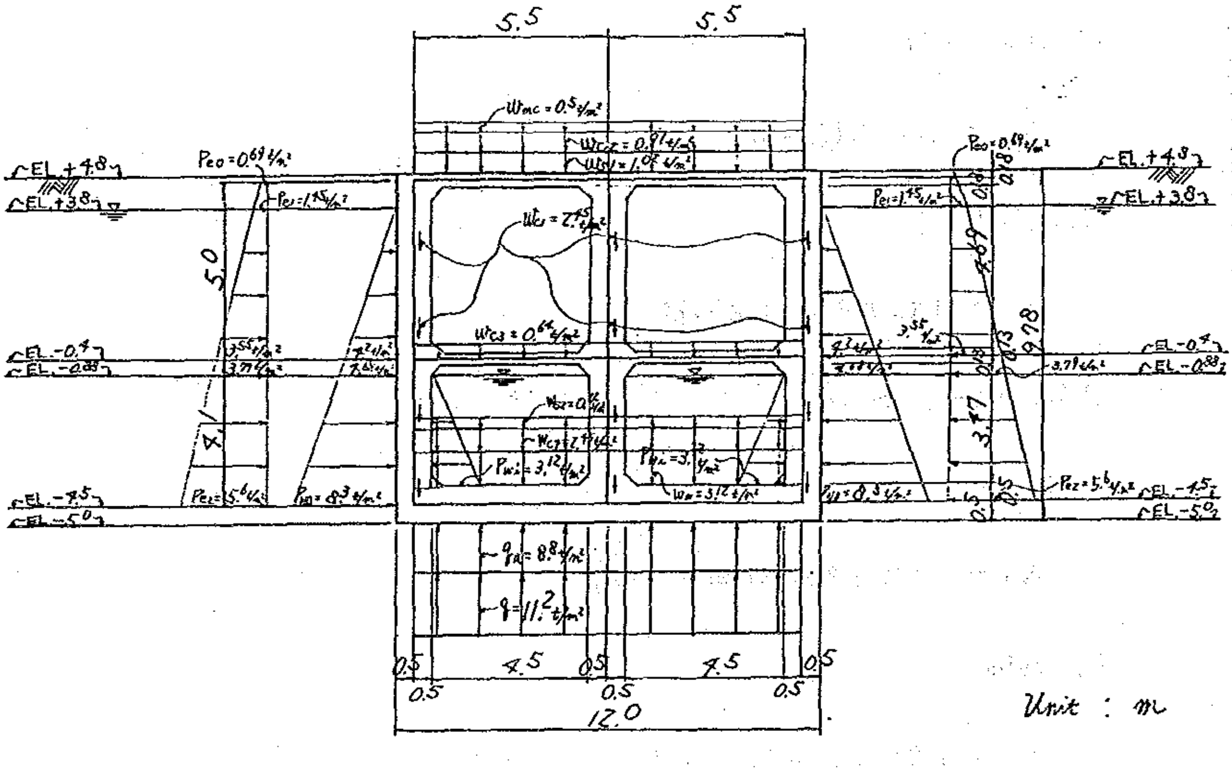

Fig 11. The results of the load calculations

3) The load diagram

The load diagram is shown in Fig 12.

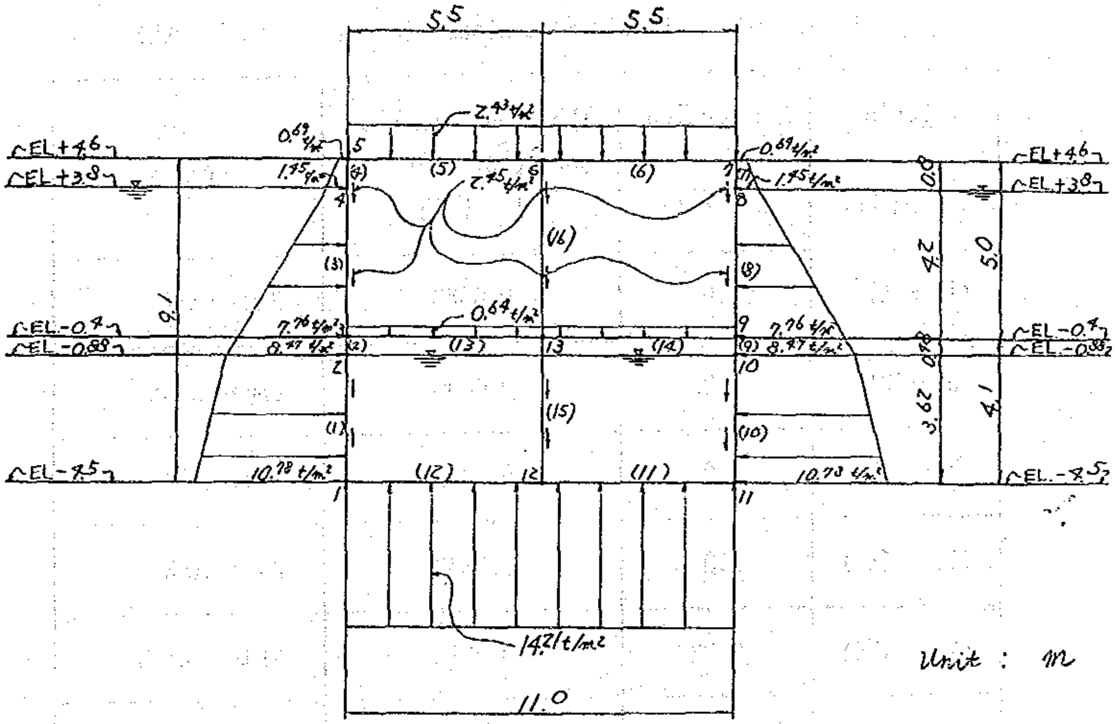

Fig 12. The load diagram

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4) Input data for the sectional dimensions

The sectional forces are calculated by computer, so input data for the sectional dimensions are summarized in Table 3.

Table 3. The sectional dimensions (per 1 m unit length)

Member's number	The section area A [m^2]	The geometrical moment of inertia I [m^4]	Remarks
(1)－(4)	1.0	0.0833	Side wall
(5)－(6)	0.36	0.0039	Upper slab
(7)－(10)	1.0	0.0833	Side wall
(11)－(12)	1.0	0.0833	Base slab
(13)－(14)	0.26	0.0015	Middle slab
(15)－(16)	1.0	0.0833	Partition wall

5) The computer calculation results

The computer calculation results are the bending moment, the shearing force and the axial force, so they are shown in the following figures and Table (Fig 13－15, Table 4).

WEST WHARF PROJECT PUMP PIT CASE-1 (NORMAL)

BENDING MOMENT

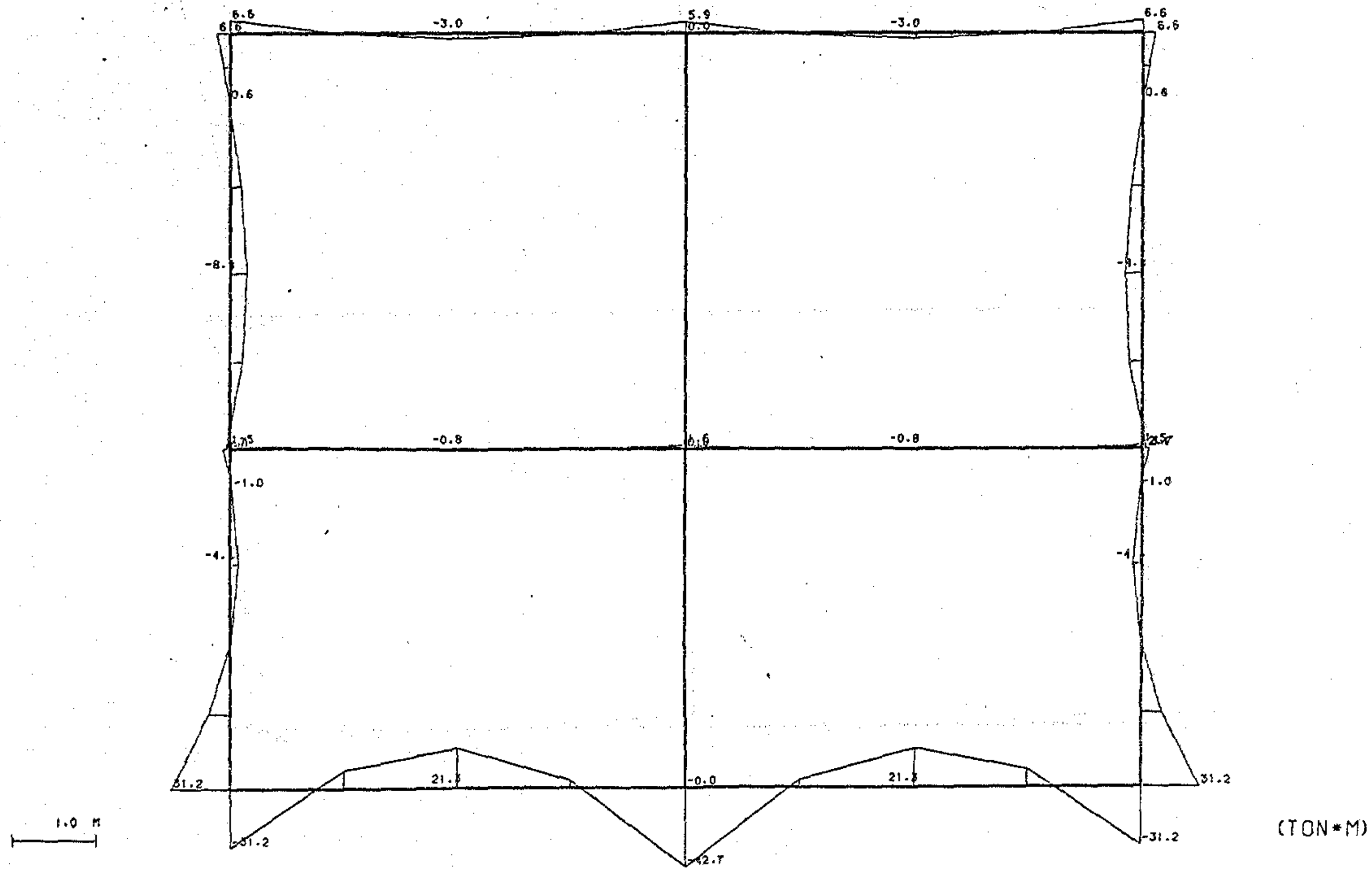

Fig 13. The bending moment diagram

WEST WHARF PROJECT PUMP PIT CASE-1 (NORMAL)

SHEARING FORCE

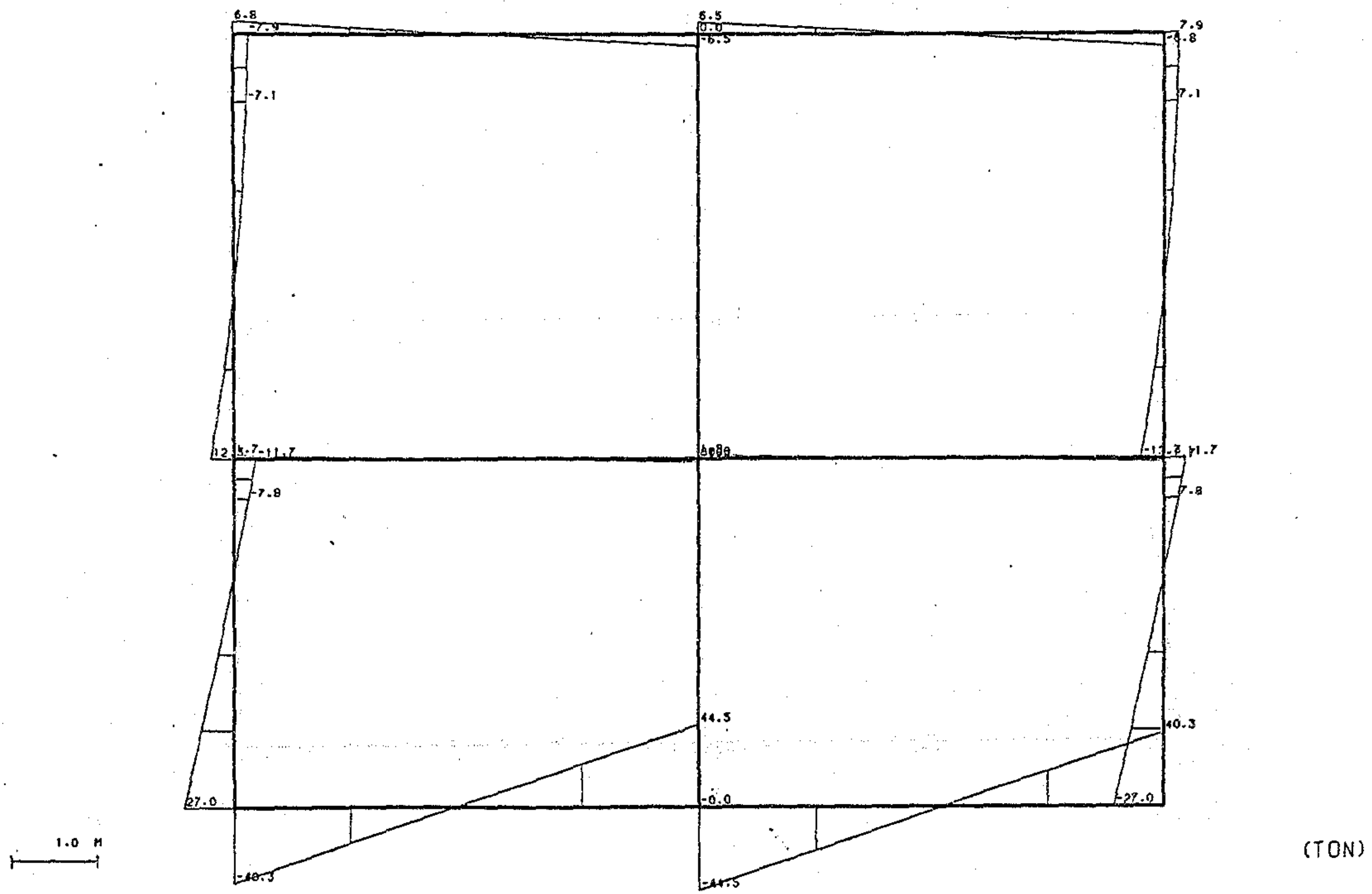

Fig 14. The shearing force diagram

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WEST WHARF PROJECT PUMP PIT CASE-1 (NORMAL)

AXIAL FORCE

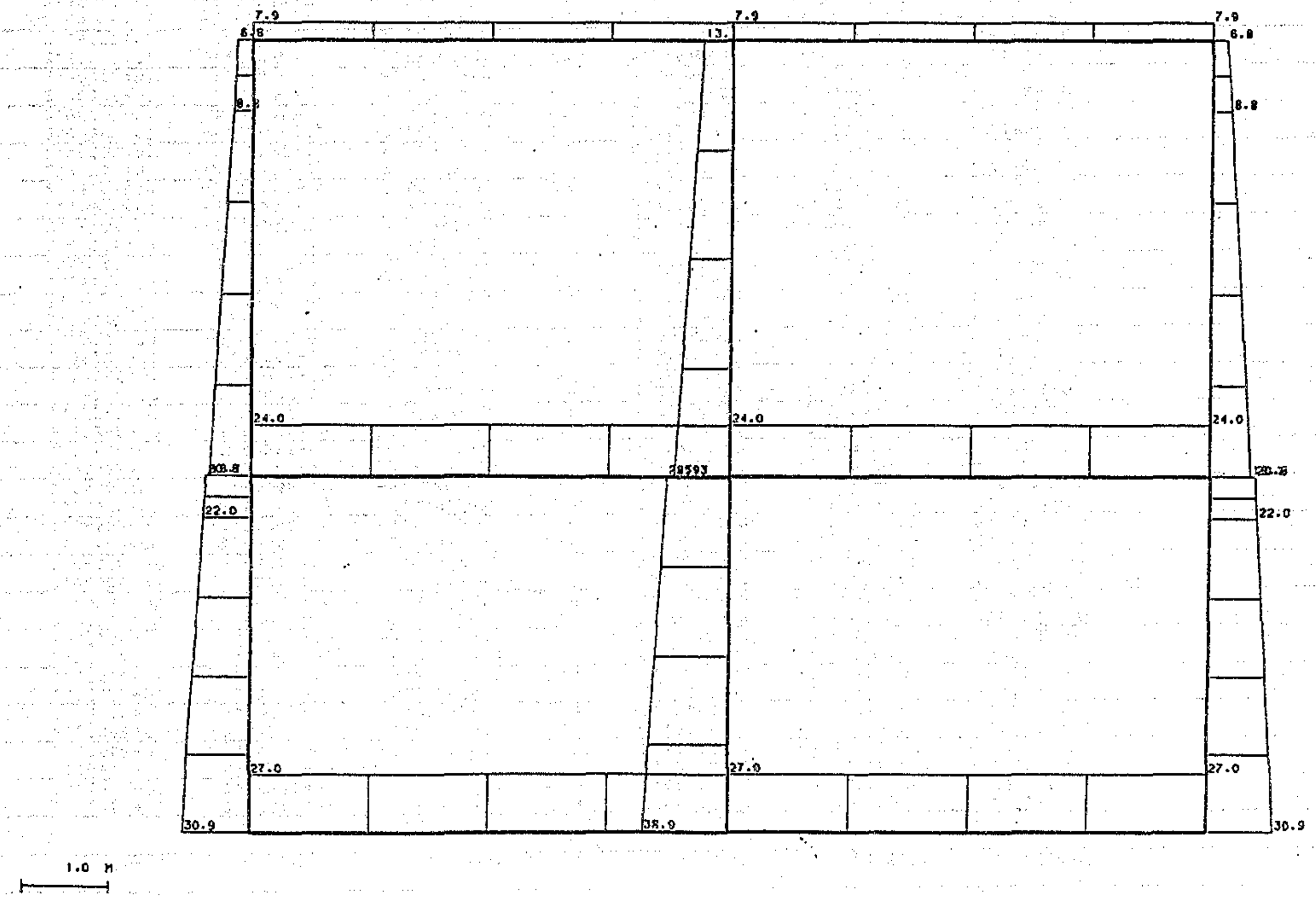

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Fig 15. The axial force diagram

Table 4-1. The calculation results of the sectional forces (Normal)

** ELEMENTAL FORCES **

ELEM	I-END	AXIAL	SHEAR	MOMENT	J-END	AXIAL	SHEAR	MOMENT
1	1	3.0858E+01	2.7030E+01	3.1230E+01	14	2.8641E+01	1.7535E+01	1.1112E+01
2	14	2.8641E+01	1.7535E+01	1.1104E+01	15	2.6424E+01	8.5634E+00	-6.5821E-01
3	15	2.6424E+01	8.5634E+00	-5.6610E-01	16	2.4206E+01	1.1407E-01	-4.5453E+00
4	16	2.4206E+01	1.1407E-01	-4.5532E+00	2	2.1989E+01	-7.8126E+00	-1.0223E+00
5	2	2.1989E+01	-7.8126E+00	-1.0302E+00	17	2.1401E+01	-9.8028E+00	1.0857E+00
6	17	2.1401E+01	-9.8028E+00	1.0853E+00	3	2.0813E+01	-1.1708E+01	3.6687E+00
7	3	1.9073E+01	1.2251E+01	2.1329E+00	18	1.6501E+01	4.9311E+00	-6.7138E+00
8	18	1.6501E+01	4.9311E+00	-6.7428E+00	19	1.3928E+01	-7.3230E-01	-8.7733E+00
9	19	1.3928E+01	-7.3230E-01	-8.8023E+00	20	1.1356E+01	-4.7394E+00	-5.7557E+00
10	20	1.1356E+01	-4.7394E+00	-5.7847E+00	4	8.7834E+00	-7.0900E+00	5.9965E-01
11	4	8.7834E+00	-7.0900E+00	5.7066E-01	21	7.8034E+00	-7.5940E+00	3.5136E+00
12	21	7.8034E+00	-7.5940E+00	3.5125E+00	5	6.8234E+00	-7.9460E+00	6.6266E+00
13	5	7.9460E+00	6.8234E+00	6.6256E+00	22	7.9460E+00	3.4821E+00	-4.5943E-01
14	22	7.9460E+00	3.4821E+00	-4.5943E-01	23	7.9460E+00	1.4090E-01	-2.9503E+00
15	23	7.9460E+00	1.4090E-01	-2.9503E+00	24	7.9460E+00	-3.2004E+00	-8.4689E-01
16	24	7.9460E+00	-3.2004E+00	-8.4689E-01	6	7.9460E+00	-6.5416E+00	5.8507E+00
17	6	7.9460E+00	6.5416E+00	5.8507E+00	25	7.9460E+00	3.2004E+00	-8.4689E-01
18	25	7.9460E+00	3.2004E+00	-8.4689E-01	26	7.9460E+00	-1.4090E-01	-2.9503E+00
19	26	7.9460E+00	-1.4090E-01	-2.9503E+00	27	7.9460E+00	-3.4821E+00	-4.5943E-01
20	27	7.9460E+00	-3.4821E+00	-4.5943E-01	7	7.9460E+00	-6.8234E+00	6.6256E+00
21	7	6.8234E+00	7.9460E+00	6.6256E+00	28	7.8034E+00	7.5940E+00	3.5115E+00
22	28	7.8034E+00	7.5940E+00	3.5125E+00	8	8.7834E+00	7.0900E+00	5.6965E-01
23	8	8.7834E+00	7.0900E+00	5.7066E-01	29	1.1356E+01	4.7394E+00	-5.8137E+00
24	29	1.1356E+01	4.7394E+00	-5.7847E+00	30	1.3928E+01	7.3230E-01	-8.8312E+00
25	30	1.3928E+01	7.3230E-01	-8.8023E+00	31	1.6501E+01	-4.9311E+00	-6.7718E+00
26	31	1.6501E+01	-4.9311E+00	-6.7428E+00	9	1.9073E+01	-1.2251E+01	2.1039E+00
27	9	2.0813E+01	1.1708E+01	3.6683E+00	32	2.1401E+01	9.8028E+00	1.0850E+00
28	32	2.1401E+01	9.8028E+00	1.0853E+00	10	2.1989E+01	7.8126E+00	-1.0306E+00
29	10	2.1989E+01	7.8126E+00	-1.0302E+00	33	2.4206E+01	-1.1407E-01	-4.5611E+00
30	33	2.4206E+01	-1.1407E-01	-4.5532E+00	34	2.6424E+01	-8.5634E+00	-6.7398E-01
31	34	2.6424E+01	-8.5634E+00	-6.6610E-01	35	2.8641E+01	-1.7535E+01	1.1096E+01
32	35	2.8641E+01	-1.7535E+01	1.1104E+01	11	3.0858E+01	-2.7030E+01	3.1223E+01
33	12	2.7030E+01	-4.4454E+01	-4.2654E+01	36	2.7030E+01	-2.3266E+01	3.9038E+00
34	36	2.7030E+01	-2.3266E+01	3.9038E+00	37	2.7030E+01	-2.0770E+00	2.1327E+01
35	37	2.7030E+01	-2.0770E+00	2.1327E+01	38	2.7030E+01	1.9112E+01	9.6155E+00
36	38	2.7030E+01	1.9112E+01	9.6155E+00	11	2.7030E+01	4.0301E+01	-3.1230E+01
37	1	2.7030E+01	-4.0301E+01	-3.1230E+01	39	2.7030E+01	-1.9112E+01	9.6155E+00
38	39	2.7030E+01	-1.9112E+01	9.6155E+00	40	2.7030E+01	2.0770E+00	2.1327E+01
39	40	2.7030E+01	2.0770E+00	2.1327E+01	41	2.7030E+01	2.3266E+01	3.9038E+00
40	41	2.7030E+01	2.3266E+01	3.9038E+00	12	2.7030E+01	4.4454E+01	-4.2654E+01
41	3	2.3959E+01	1.7397E+00	1.5354E+00	42	2.3959E+01	8.5965E-01	-2.5158E-01
42	42	2.3959E+01	8.5965E-01	-2.5158E-01	43	2.3959E+01	-2.0347E-02	-8.2860E-01
43	43	2.3959E+01	-2.0347E-02	-8.2860E-01	44	2.3959E+01	-9.0035E-01	-1.9563E-01
44	44	2.3959E+01	-9.0035E-01	-1.9563E-01	13	2.3959E+01	-1.7803E+00	1.6473E+00
45	13	2.3959E+01	1.7803E+00	1.6473E+00	45	2.3959E+01	9.0035E-01	-1.9563E-01
46	45	2.3959E+01	9.0035E-01	-1.9563E-01	46	2.3959E+01	2.0347E-02	-8.2860E-01
47	46	2.3959E+01	2.0347E-02	-8.2860E-01	47	2.3959E+01	-8.5965E-01	-2.5158E-01
48	47	2.3959E+01	-8.5965E-01	-2.5158E-01	9	2.3959E+01	-1.7397E+00	1.5354E+00
49	12	3.8935E+01	-2.8708E-12	-9.4537E-12	48	3.6428E+01	-2.8708E-12	-6.5111E-12
50	48	3.6428E+01	-2.8708E-12	-6.5111E-12	49	3.3916E+01	-2.8708E-12	-3.5685E-12
51	49	3.3916E+01	-2.8708E-12	-3.5685E-12	50	3.1405E+01	-2.8708E-12	-6.2589E-13

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Table 4-2. The calculation results of the sectional forces (Normal)

52	50	3.1405E+01	-2.8708E-12	-6.2589E-13	13	2.9894E+01	-2.8708E-12	2.3167E-12
53	13	2.5333E+01	1.1755E-13	1.6808E-12	51	2.2271E+01	1.1755E-13	1.5339E-12
54	51	2.2271E+01	1.1755E-13	1.5339E-12	52	1.9208E+01	1.1755E-13	1.3869E-12
55	52	1.9208E+01	1.1755E-13	1.3869E-12	53	1.6146E+01	1.1755E-13	1.2409E-12
56	53	1.6146E+01	1.1755E-13	1.2400E-12	6	1.3083E+01	1.1755E-13	1.0931E-12

1.4.4 Structural Design Analysis of Case−2 (at construction)

1) Frame of the design structure

Frame of the design structure is the same structure as that of Case−1 excluding a point that the internal water condition is empty.

2) The load calculation

The load calculations are the same calculations as those of Case−1 excluding a point that the internal water pressures are 0.

3) The load diagram

The load diagram is shown in Fig 16.

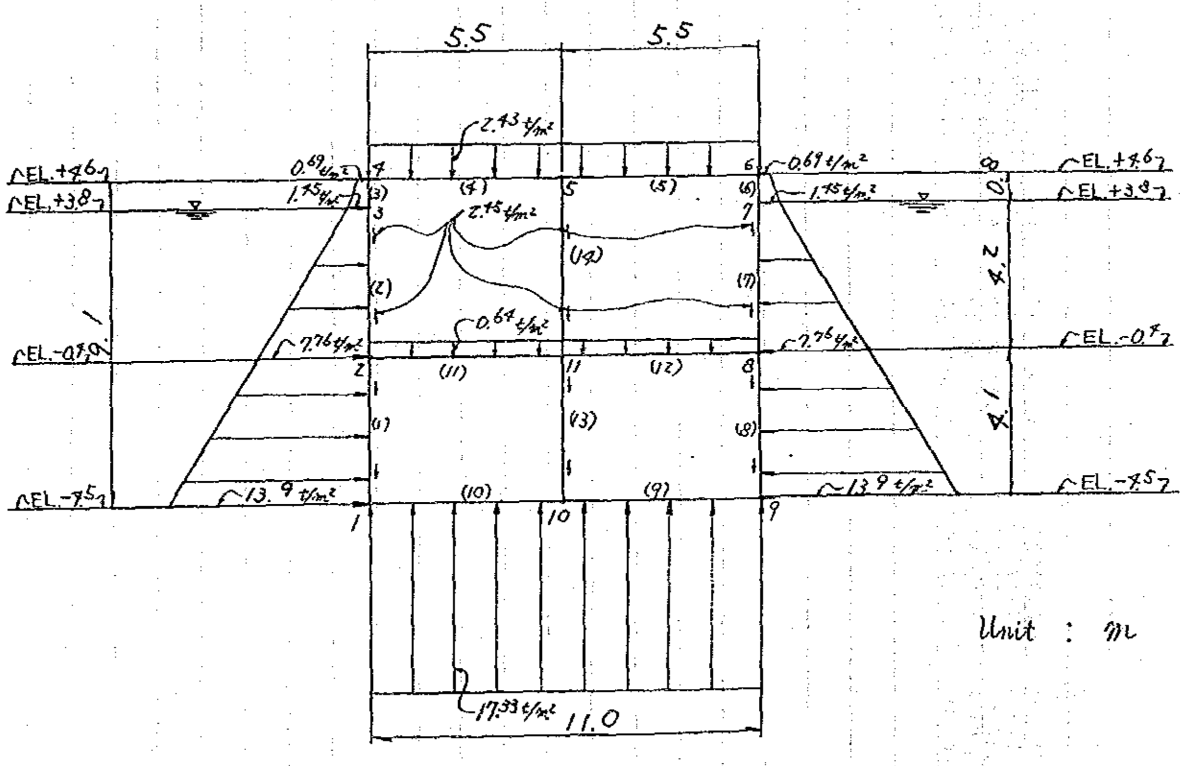

Fig 16. The load diagram

4) Input data for the sectional dimensions

Input data for the sectional dimensions are summarized in Table 5.

Table 5. The sectional dimensions (Per 1 m unit length)

Member's number	The section area A [m^2]	The geometrical moment of inertia I [m^4]	Remarks
(1)－(3)	1.0	0.0833	Side wall
(4)－(5)	0.36	0.0039	Upper slab
(6)－(8)	1.0	0.0833	Side wall
(9)－(10)	1.0	0.0833	Base slab
(11)－(12)	0.26	0.0015	Middle slab
(13)－(14)	1.0	0.0833	Partition wall

5) The computer calculation results

The computer calculation results are shown in the following figures and Table (Fig 17－Fig 19, Table 6).

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WEST WHARF PROJECT PUMP PIT CASE-2 (CONSTRUCTION) BENDING MOMENT

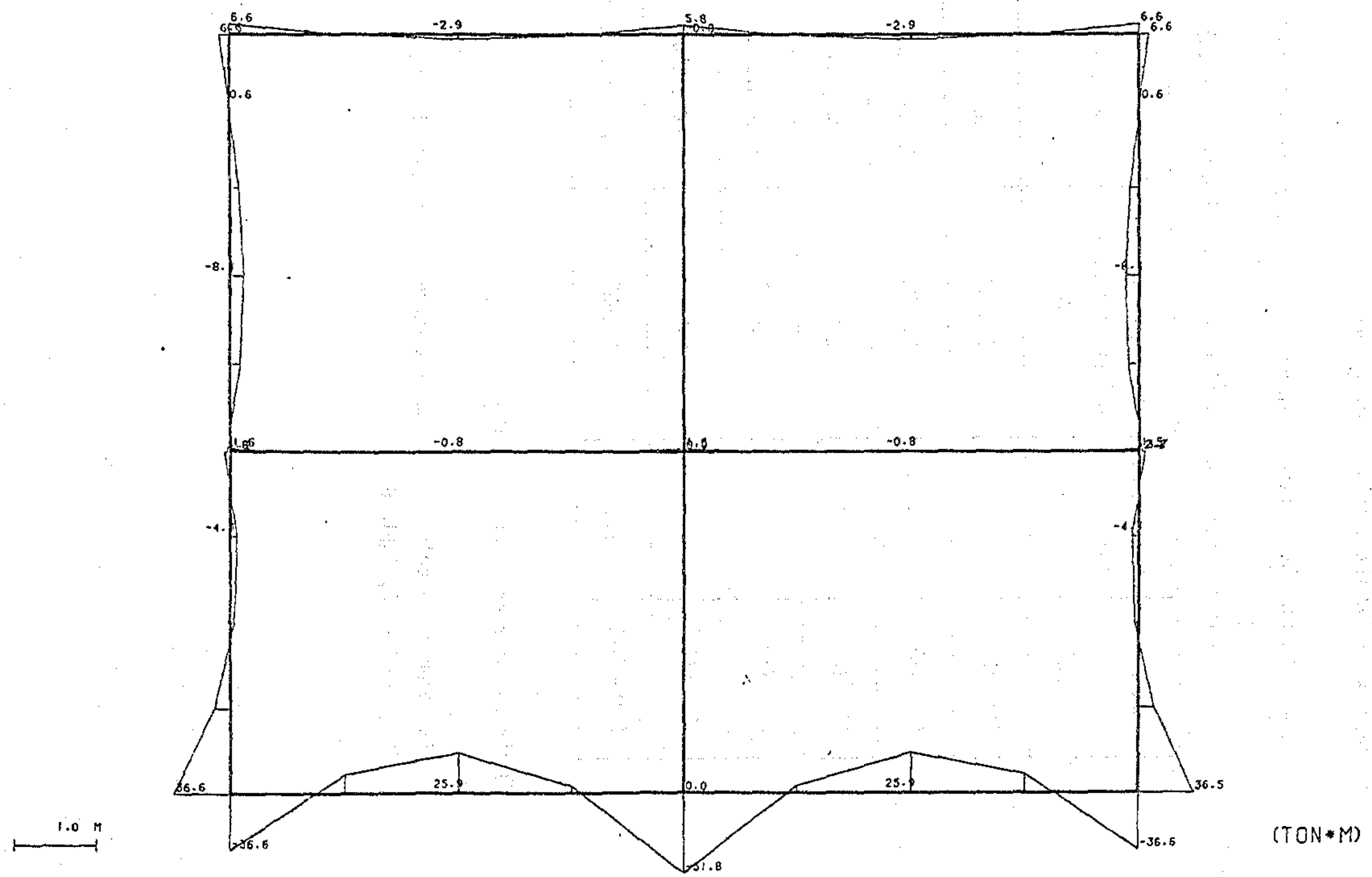
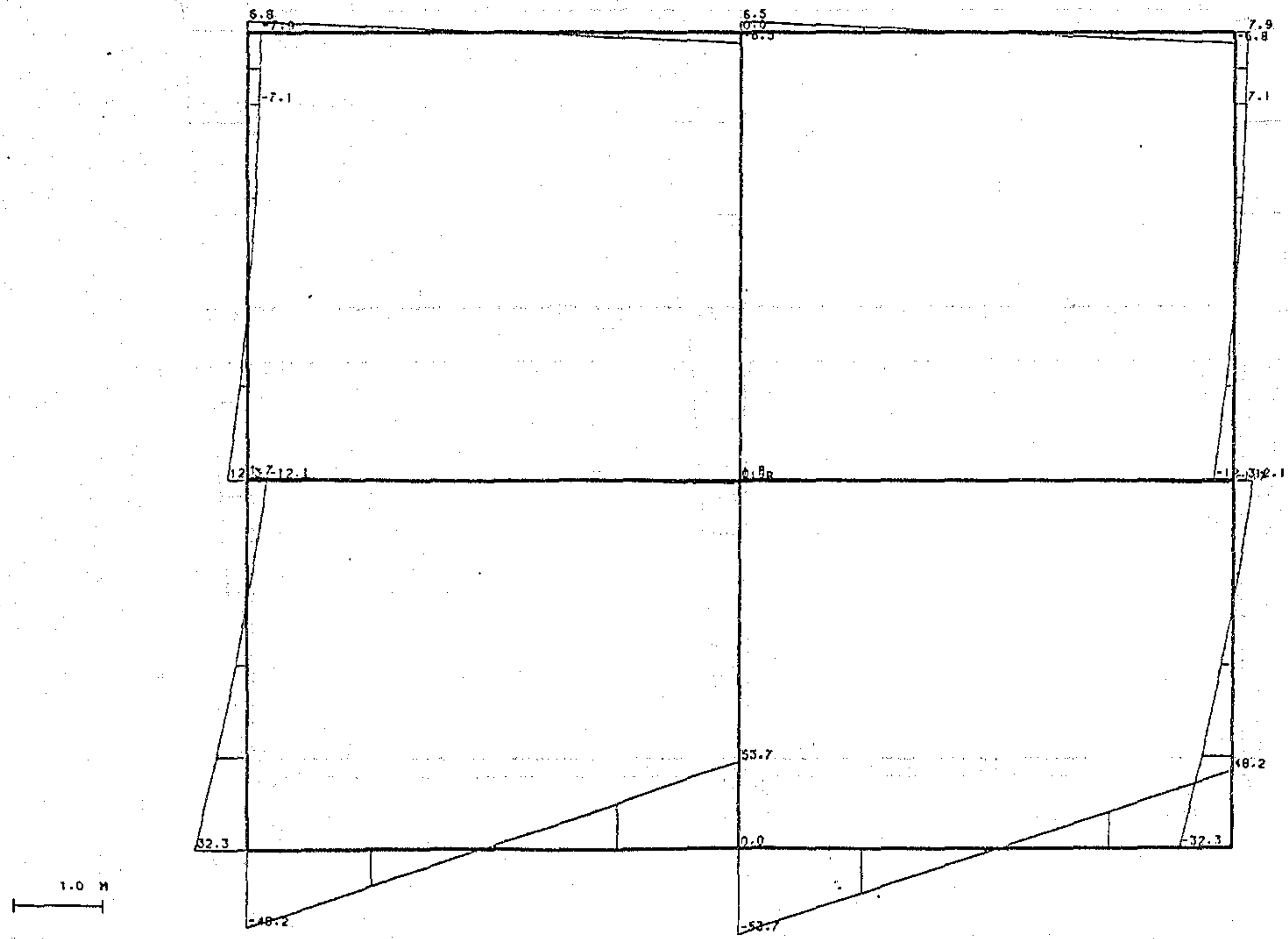


Fig 17. The bending moment diagram

1190

16''

WEST WHARF PROJECT PUMP PIT CASE-2 (CONSTRUCTION) SHEARING FORCE



(TON)

Fig 18. The shearing force diagram

SHEET 38 OF

WEST WHARF PROJECT PUMP PIT CASE-2 (CONSTRUCTION) AXIAL FORCE

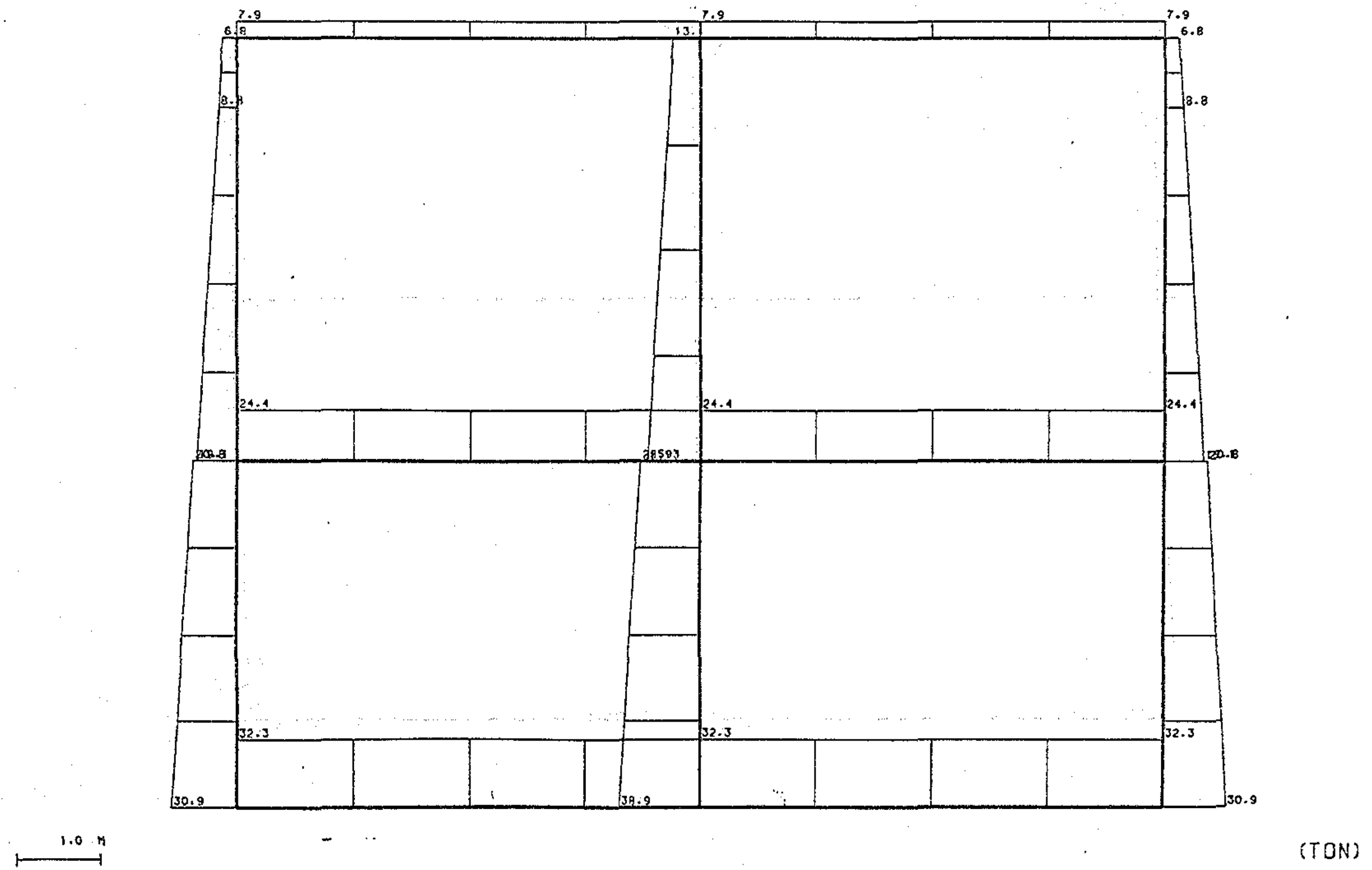


Fig 19. The axial force diagram

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** ELEMENTAL FORCES **

Table 6-1. The calculation results of the sectional forces (Construction)

FLEM	I-END	AXIAL	SHEAR	MOMENT	J-END	AXIAL	SHEAR	MOMENT
1	1	3.0860E+01	3.2303E+01	3.6555E+01	12	2.8349E+01	1.8842E+01	1.0504E+01
2	12	2.8249E+01	1.8842E+01	1.0478E+01	13	2.5837E+01	6.9549E+00	-2.5823E+00
3	13	2.5837E+01	6.9549E+00	-2.6092E+00	14	2.3326E+01	-3.3592E+00	-4.2907E+00
4	14	2.3326E+01	-3.3592E+00	-4.3176E+00	2	2.0815E+01	-1.2100E+01	3.7664E+00
5	2	1.9074E+01	1.2264E+01	2.2007E+00	15	1.6502E+01	4.9441E+00	-6.6596E+00
6	15	1.6502E+01	4.9441E+00	-6.6886E+00	16	1.3929E+01	-7.1930E-01	-8.7327E+00
7	16	1.3929E+01	-7.1930E-01	-8.7617E+00	17	1.1357E+01	-4.7264E+00	-5.7288E+00
8	17	1.1357E+01	-4.7264E+00	-5.7578E+00	3	8.7842E+00	-7.0771E+00	6.1290E-01
9	3	8.7842E+00	-7.0771E+00	5.8392E-01	18	7.8042E+00	-7.5811E+00	3.5216E+00
10	18	7.8042E+00	-7.5811E+00	3.5206E+00	4	6.8242E+00	-7.9331E+00	6.6295E+00
11	4	7.9331E+00	6.8242E+00	6.6285E+00	19	7.9331E+00	3.4829E+00	-4.5764E-01
12	19	7.9331E+00	3.4829E+00	-4.5764E-01	20	7.9331E+00	1.4167E-01	-2.9495E+00
13	20	7.9331E+00	1.4167E-01	-2.9495E+00	21	7.9331E+00	-3.1996E+00	-8.4724E-01
14	21	7.9331E+00	-3.1996E+00	-8.4724E-01	5	7.9331E+00	-6.5408E+00	5.8493E+00
15	5	7.9331E+00	6.5408E+00	5.8493E+00	22	7.9331E+00	3.1996E+00	-8.4724E-01
16	22	7.9331E+00	3.1996E+00	-8.4724E-01	23	7.9331E+00	-1.4167E-01	-2.9495E+00
17	23	7.9331E+00	-1.4167E-01	-2.9495E+00	24	7.9331E+00	-3.4829E+00	-4.5764E-01
18	24	7.9331E+00	-3.4829E+00	-4.5764E-01	6	7.9331E+00	-6.8242E+00	6.6285E+00
19	6	6.8242E+00	7.9331E+00	6.6285E+00	25	7.8042E+00	7.5811E+00	3.5196E+00
20	25	7.8042E+00	7.5811E+00	3.5206E+00	7	8.7842E+00	7.0771E+00	5.8290E-01
21	7	8.7842E+00	7.0771E+00	5.8392E-01	26	1.1357E+01	4.7264E+00	-5.7868E+00
22	26	1.1357E+01	4.7264E+00	-5.7578E+00	27	1.3929E+01	7.1930E-01	-8.7907E+00
23	27	1.3929E+01	7.1930E-01	-8.7617E+00	28	1.6502E+01	-4.9441E+00	-6.7176E+00
24	28	1.6502E+01	-4.9441E+00	-6.6886E+00	8	1.9074E+01	-1.2264E+01	2.1717E+00
25	8	2.0815E+01	1.2100E+01	3.7396E+00	29	2.3326E+01	3.3592E+00	-4.3445E+00
26	29	2.3326E+01	3.3592E+00	-4.3176E+00	30	2.5837E+01	-6.9549E+00	-2.6360E+00
27	30	2.5837E+01	-6.9549E+00	-2.6092E+00	31	2.8349E+01	-1.8842E+01	1.0451E+01
28	31	2.8349E+01	-1.8842E+01	1.0478E+01	9	3.0860E+01	-3.2303E+01	3.6528E+01
29	10	3.2303E+01	-5.3727E+01	-5.1789E+01	32	3.2303E+01	-2.8249E+01	4.5694E+00
30	32	3.2303E+01	-2.8249E+01	4.5694E+00	33	3.2303E+01	-2.7698E+00	2.5894E+01
31	33	3.2303E+01	-2.7698E+00	2.5894E+01	34	3.2303E+01	2.2709E+01	1.2186E+01
32	34	3.2303E+01	2.2709E+01	1.2186E+01	9	3.2303E+01	4.8188E+01	-3.6555E+01
33	1	3.2303E+01	-4.8188E+01	-3.6555E+01	35	3.2303E+01	-2.2709E+01	1.2186E+01
34	35	3.2303E+01	-2.2709E+01	1.2186E+01	36	3.2303E+01	2.7698E+00	2.5894E+01
35	36	3.2303E+01	2.7698E+00	2.5894E+01	37	3.2303E+01	2.8249E+01	4.5694E+00
36	37	3.2303E+01	2.8249E+01	4.5694E+00	10	3.2303E+01	5.3727E+01	-5.1789E+01
37	2	2.4364E+01	1.7406E+00	1.5389E+00	38	2.4364E+01	8.6058E-01	-2.4944E-01
38	38	2.4364E+01	8.6058E-01	-2.4944E-01	39	2.4364E+01	-1.9415E-02	-8.2775E-01
39	39	2.4364E+01	-1.9415E-02	-8.2775E-01	40	2.4364E+01	-8.9942E-01	-1.9605E-01
40	40	2.4364E+01	-8.9942E-01	-1.9605E-01	11	2.4364E+01	-1.7794E+00	1.6456E+00
41	11	2.4364E+01	1.7794E+00	1.6456E+00	41	2.4364E+01	8.9942E-01	-1.9605E-01
42	41	2.4364E+01	8.9942E-01	-1.9605E-01	42	2.4364E+01	1.9415E-02	-8.2775E-01
43	42	2.4364E+01	1.9415E-02	-8.2775E-01	43	2.4364E+01	-8.6058E-01	-2.4944E-01
44	43	2.4364E+01	-8.6058E-01	-2.4944E-01	8	2.4364E+01	-1.7406E+00	1.5389E+00
45	10	3.8935E+01	3.8028E-14	1.8389E-13	44	3.6424E+01	3.8028E-14	1.4491E-13
46	44	3.6424E+01	3.8028E-14	1.4491E-13	45	3.3913E+01	3.8028E-14	1.0594E-13
47	45	3.3913E+01	3.8028E-14	1.0594E-13	46	3.1402E+01	3.8028E-14	6.6957E-14
48	46	3.1402E+01	3.8028E-14	6.6957E-14	11	2.8890E+01	3.8028E-14	2.7978E-14
49	11	2.5332E+01	1.9973E-14	4.6877E-14	47	2.2269E+01	1.9973E-14	2.1911E-14
50	47	2.2269E+01	1.9973E-14	2.1911E-14	48	1.9207E+01	1.9973E-14	-3.0556E-15
51	48	1.9207E+01	1.9973E-14	-3.0556E-15	49	1.6144E+01	1.9973E-14	-2.8022E-14

Table 6-2. The calculation results of the sectional forces (Consyruction)

52	49	1.6144E+01	1.9973E-14	-2.8022E-14	5	1.3082E+01	1.9973E-14	-5.2989E-14

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1.4.5 Structural design analysis of Case−3 (at Inspection)

1) Frame of the design structure

Frame of the design structure is the same structure as that of Case−1 excluding a point that the internal water condition is empty at oneside.

2) The load calculation

The load calculations are the same calculations as those of Case−1 excluding a point that the internal water pressure and water weight are 0 at oneside.

3) The load diagram

The load diagram is shown in Fig 20.

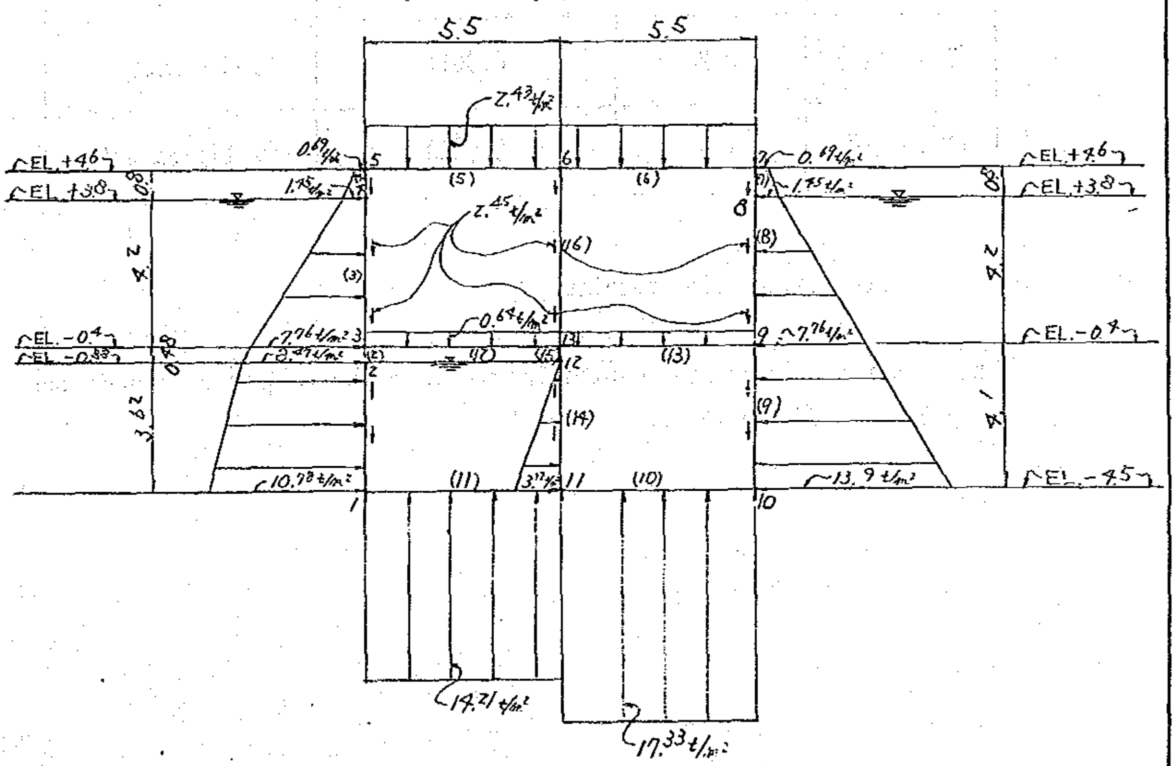

Fig 20. The load diagram

4) Input data for the sectional dimensions

Input data for the sectional dimensions are summarized in Table 7.

Table 7. The sectional dimensions (Per 1 m unit length)

Member's number	The section area A [m^2]	The geometrical moment of inertia I [m^4]	Remarks
(1)－(4)	1.0	0.0833	Side wall
(5)－(6)	0.36	0.0039	Upper slab
(7)－(8)	1.0	0.0833	Side wall
(9)－(11)	1.0	0.0833	Base slab
(12)－(13)	0.26	0.0015	Middle slab
(14)－(16)	1.0	0.0833	Partition wall

5) The computer calculation results

The computer calculation results are shown in the following figures and Table (Fig 21－Fig 23, Table 7).

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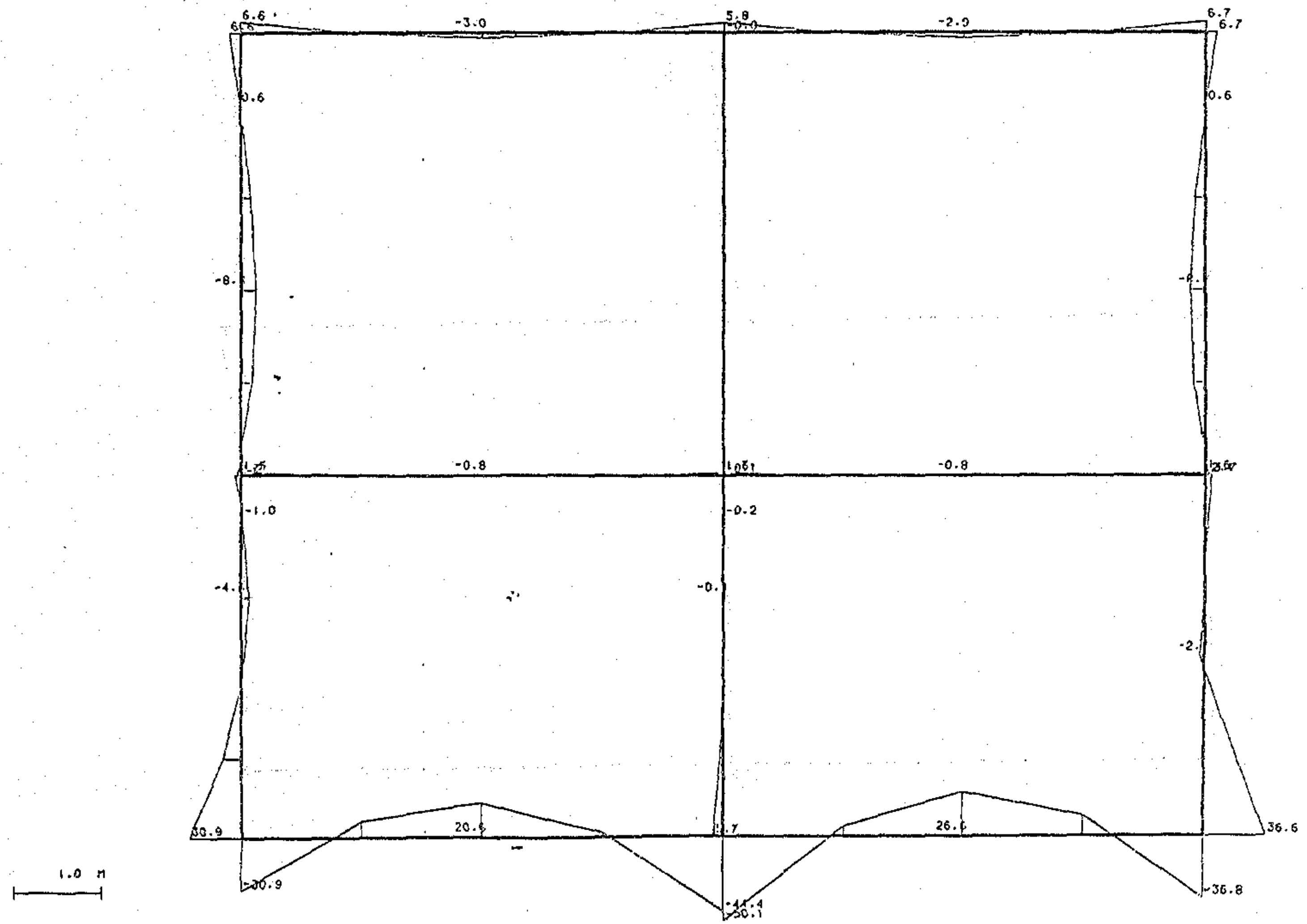
WEST WHARF PUMP PIT CASE-3 (INSPECTION)

BENDING MOMENT



(TON*M)

Fig 21. The bending moment diagram

WEST WHARF PUMP PIT CASE-3 (INSPECTION)

SHEARING FORCE

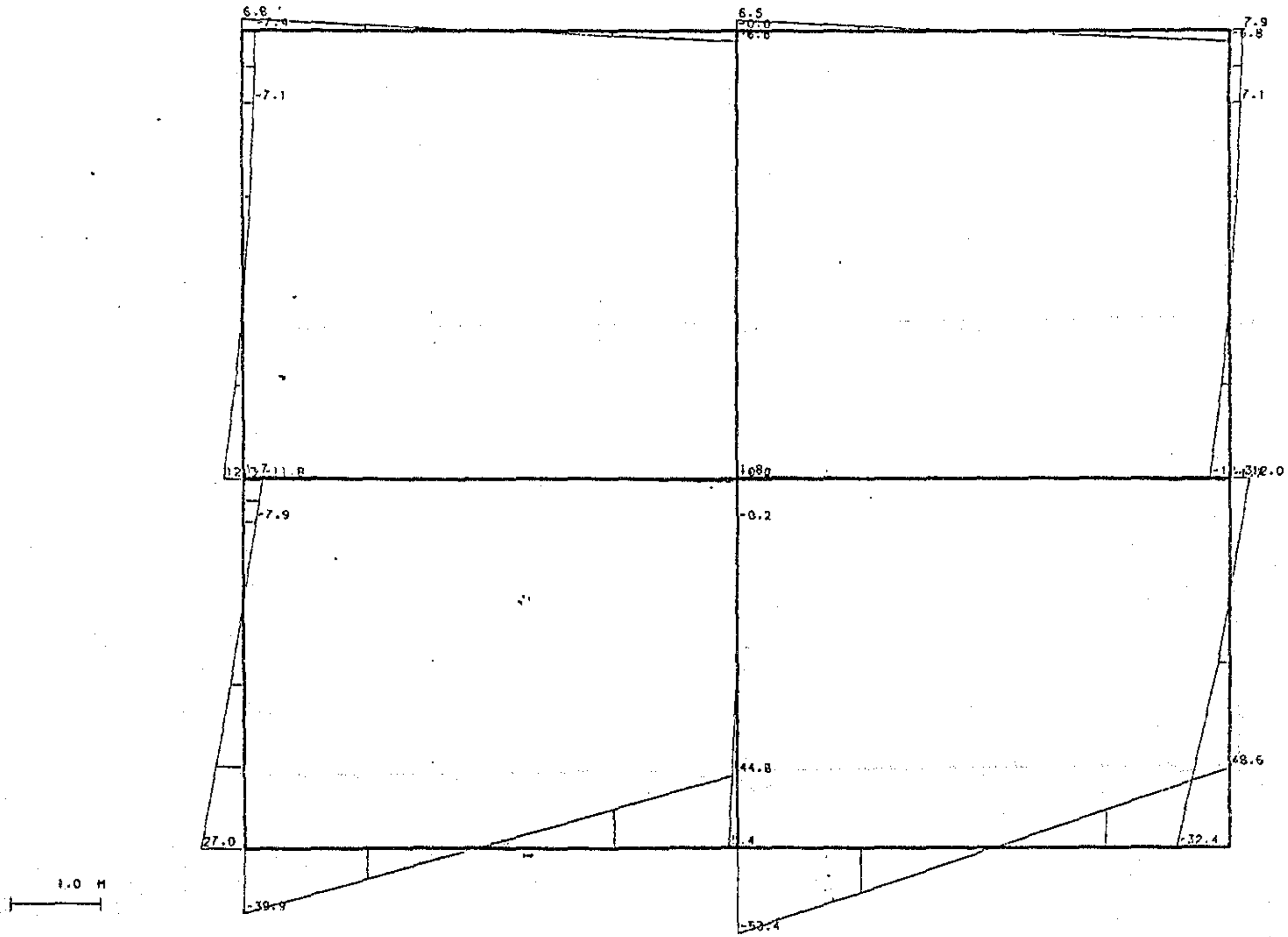


Fig 22. The shearing force diagram

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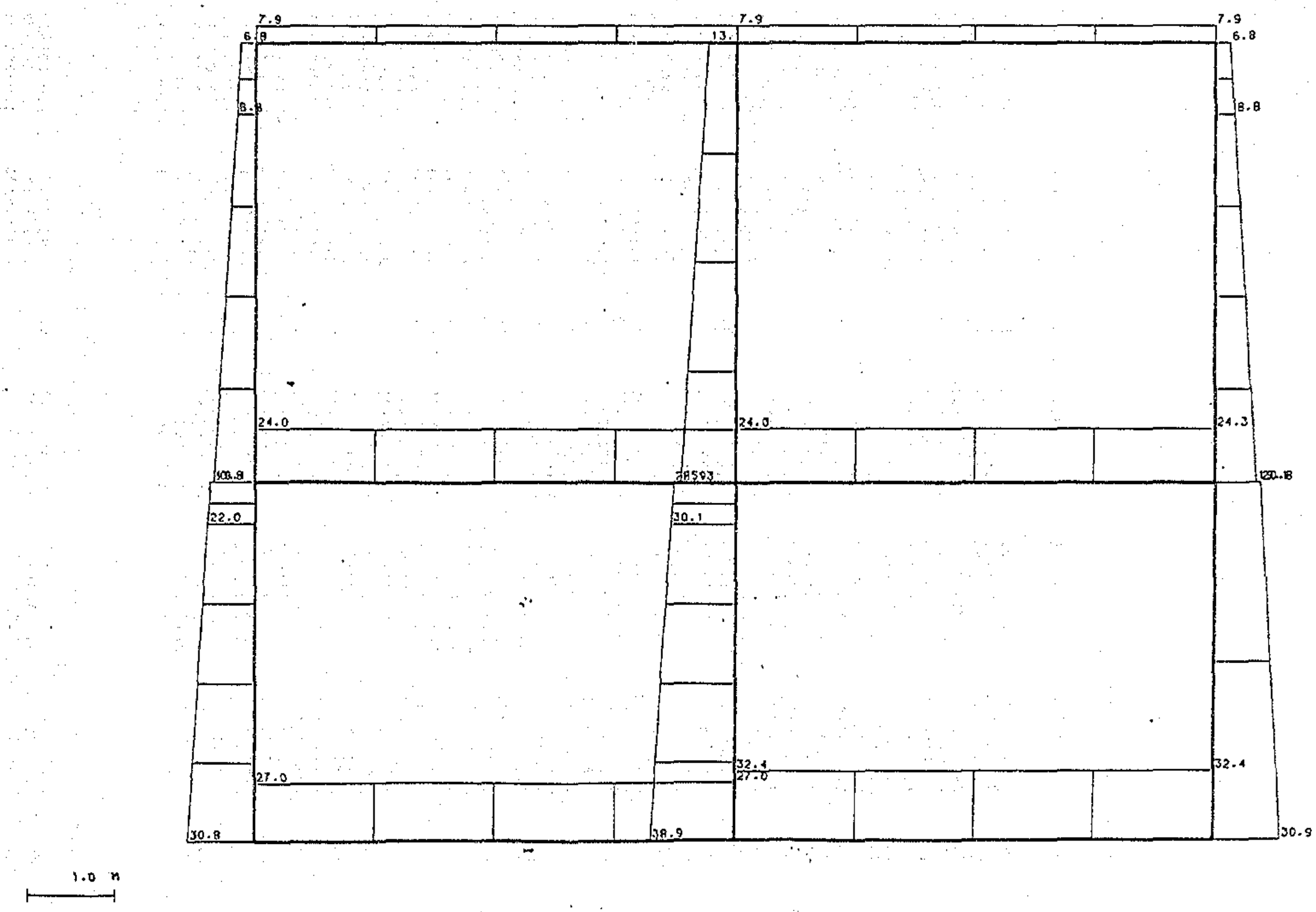
WEST WHARF PUMP PIT CASE-3(INSPECTION)

AXIAL FORCE



(TON)

Fig 23. The axial force diagram

Table 7. The calculation results of the sectional forces

** ELEMENTAL FORCES **

ELEM	I-END	AXIAL	SHEAR	MOMENT	J-END	AXIAL	SHEAR	MOMENT
1	1	3.0845E+01	2.6953E+01	3.0939E+01	14	2.9628E+01	1.7458E+01	1.0990E+01
2	14	2.8623E+01	1.7458E+01	1.0882E+01	15	2.6411E+01	8.4964E+00	-8.1046E-01
3	15	2.6411E+01	8.4964E+00	-3.1834E-01	16	2.4193E+01	3.7143E-02	-4.6290E+00
4	16	2.4193E+01	3.7143E-02	-4.6359E+00	2	2.1975E+01	-7.8895E+00	-1.0354E+00
5	2	2.1976E+01	-7.8895E+00	-1.0432E+00	17	2.1388E+01	-9.8797E+00	1.0911E+00
6	17	2.1338E+01	-9.8797E+00	1.0908E+00	3	2.0820E+01	-1.1785E+01	3.6926E+00
7	3	1.9065E+01	1.2263E+01	2.1682E+00	18	1.6492E+01	4.9431E+00	-6.6910E+00
8	18	1.6492E+01	4.9431E+00	-5.7200E+00	19	1.3920E+01	-7.2038E-01	-8.7630E+00
9	19	1.3920E+01	-7.2038E-01	-8.7920E+00	20	1.1347E+01	-4.7274E+00	-5.7580E+00
10	20	1.1347E+01	-4.7274E+00	-5.7869E+00	4	8.7749E+00	-7.0781E+00	5.8490E-01
11	4	8.7749E+00	-7.0781E+00	5.5592E-01	21	7.7949E+00	-7.5821E+00	2.4941E+00
12	21	7.7949E+00	-7.5821E+00	3.4930E+00	5	6.8149E+00	-7.9341E+00	6.6024E+00
13	5	7.9341E+00	5.8149E+00	6.6014E+00	22	7.9341E+00	3.4737E+00	-4.7206E-01
14	22	7.9341E+00	3.4737E+00	-4.7206E-01	23	7.9341E+00	1.3243E-01	-2.9512E+00
15	23	7.9341E+00	1.3243E-01	-2.9512E+00	24	7.9341E+00	-3.2038E+00	-8.3622E-01
16	24	7.9341E+00	-3.2038E+00	-8.3622E-01	6	7.9341E+00	-6.5501E+00	5.8730E+00
17	6	7.9450E+00	6.5324E+00	5.8270E+00	25	7.9450E+00	3.1911E+00	-8.5791E-01
18	25	7.9450E+00	3.1911E+00	-8.5791E-01	26	7.9450E+00	-1.5015E-01	-2.9486E+00
19	26	7.9450E+00	-1.5015E-01	-2.9486E+00	27	7.9450E+00	-3.4914E+00	-4.4501E-01
20	27	7.9450E+00	-3.4914E+00	-4.4501E-01	7	7.9450E+00	-6.8326E+00	6.6523E+00
21	7	6.8326E+00	7.9450E+00	5.6528E+00	28	7.8126E+00	7.5930E+00	3.5391E+00
22	28	7.8126E+00	7.5930E+00	3.5401E+00	8	8.7926E+00	7.0890E+00	5.9765E-01
23	8	8.7926E+00	7.0890E+00	5.9366E-01	29	1.1365E+01	4.7383E+00	-5.7846E+00
24	29	1.1265E+01	4.7383E+00	-5.7556E+00	30	1.3938E+01	7.3121E-01	-8.8010E+00
25	30	1.3938E+01	7.3121E-01	-8.7720E+00	31	1.6510E+01	-4.9322E+00	-6.7404E+00
26	31	1.6510E+01	-4.9322E+00	-6.7114E+00	9	1.9083E+01	-1.2252E+01	2.1364E+00
27	9	2.0828E+01	1.2023E+01	3.7157E+00	32	2.5850E+01	-7.0318E+00	-2.6904E+00
28	32	2.5850E+01	-7.0318E+00	-2.4754E+00	10	3.0873E+01	-3.2380E+01	3.6632E+01
29	11	3.2380E+01	-5.3363E+01	-5.0076E+01	33	3.2380E+01	-2.7834E+01	5.7812E+00
30	33	3.2380E+01	-2.7834E+01	5.7812E+00	34	3.2380E+01	-2.4053E+00	2.6605E+01
31	34	3.2380E+01	-2.4053E+00	2.6605E+01	35	3.2380E+01	2.3073E+01	1.2396E+01
32	35	3.2380E+01	2.3073E+01	1.2396E+01	10	3.2380E+01	4.8552E+01	-3.6847E+01
33	1	2.6953E+01	-2.9936E+01	-3.0939E+01	36	2.6953E+01	-1.8747E+01	9.4059E+00
34	36	2.6953E+01	-1.8747E+01	9.4059E+00	37	2.6953E+01	2.4414E+00	2.0616E+01
35	37	2.6953E+01	2.4414E+00	2.0616E+01	38	2.6953E+01	2.3630E+01	2.6920E+00
36	38	2.6953E+01	2.3630E+01	2.6920E+00	11	2.6953E+01	4.4819E+01	-4.4367E+01
37	3	2.4048E+01	1.7252E+00	1.5241E+00	39	2.4048E+01	8.5518E-01	-2.5692E-01
38	39	2.4048E+01	8.5518E-01	-2.5622E-01	40	2.4048E+01	-2.4917E-02	-8.2769E-01
39	40	2.4048E+01	-2.4317E-02	-3.2769E-01	41	2.4048E+01	-9.0482E-01	-1.9557E-01
40	41	2.4048E+01	-9.0482E-01	-1.8357E-01	13	2.4048E+01	-1.7349E+00	1.6606E+00
41	13	2.4275E+01	1.7749E+00	1.6324E+00	42	2.4275E+01	8.9495E-01	-2.0311E-01
42	42	2.4275E+01	8.9495E-01	-2.0311E-01	43	2.4275E+01	1.4945E-02	-8.2856E-01
43	43	2.4275E+01	1.4945E-02	-1.2365E-01	44	2.4275E+01	-8.6505E-01	-2.4421E-01
44	44	2.4275E+01	-8.6505E-01	-2.4421E-01	9	2.4275E+01	-1.7451E+00	1.5592E+00
45	11	3.8927E+01	5.4190E+00	5.7093E+00	45	3.6720E+01	2.9393E+00	1.9960E+00
46	45	3.6720E+01	2.9393E+00	1.9354E+00	46	3.4503E+01	1.1726E+00	1.8863E-01
47	46	3.4503E+01	1.1726E+00	1.7798E-01	47	3.2286E+01	1.1474E-01	-3.4111E-01
48	47	3.2286E+01	1.1474E-01	-3.5175E-01	12	3.0069E+01	-2.3821E-01	-2.3200E-01
49	12	3.0069E+01	-2.3321E-01	-2.4365E-01	48	2.9480E+01	-2.3921E-01	-1.8549E-01
50	48	2.9480E+01	-2.3921E-01	-1.8548E-01	13	2.8992E+01	-2.3921E-01	-1.2831E-01
51	13	2.5332E+01	-1.0829E-02	-1.1121E-01	49	2.2270E+01	-1.0829E-02	-8.6662E-02
52	49	2.2270E+01	-1.0829E-02	-3.6662E-02	50	1.9207E+01	-1.0829E-02	-7.3126E-02
53	50	1.9207E+01	-1.0829E-02	-7.3126E-02	51	1.6145E+01	-1.0829E-02	-5.9589E-02
54	51	1.6145E+01	-1.0829E-02	-5.9589E-02	6	1.3082E+01	-1.0829E-02	-4.6053E-02

1.4.6 The Stress calculation

Before calculating the stress, the sectional force for the structural design is determined by selecting one case among three design cases from a view point of the safety design, and the stress calculations are executed, after that the stress calculation results are indicated in Table 8 and the arrangement of the reinforcing bars is shown in Fig 24.

1) The reinforcement of opening portion at the middle slab

The reinforcement of opening portion at the middle slab considering for the reinforcement of the openig portion of the middle slab, the opening portion shall be dealt with a fixed beam, so the bending moment M_b and the shearing force S are calculated as follows, then a distributed load W t/m is the same value as the axial force to the middle slab N = 24 t/m at normal.

$$M_b = \frac{1}{12} Wl^2 = \frac{1}{12} \times 24 \times 5.3^2 = 56.2 \text{ t·m}$$

$$S = \frac{1}{2} Wl = \frac{24 \times 5.3}{2} = 63.6 \text{ t}$$

Accordingly the stress calculation results are shown in Table 9.

[Pump Pit]

Table.8-1 The Calculation Results of The Stress (Section I)

Member	Point	The Sectional Force M [kg·cm]	N [kg]	S [kg]	The Sectional Dimensions B [cm]	H [cm]	d [cm]	d' [cm]	The Arrangement of Reinforcing Bars D [mm]	Pitch [mm]	As [cm²] / A's [cm²]	The strees (kg/cm²) σ_b	σ_c	τ	Remarks
(1)	1	3 120 000	30 900	27 000	100	110	100	20	D22 / D22	150 / 150	25.8 / 25.8	792	27.4	2.7	As+As' ≧0.004B·H = 30cm²
(1)	Center	-67 000	26 400	8 600	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	41	2.8	1.0	DITTO
(1)	2	-100 000	22 000	7 800	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	37	2.6	0.9	DITTO
(2)	2	-100 000	22 000	7 800	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	37	2.6	0.9	DITTO
(2)	Center	110 000	21 400	9 800	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	37	2.6	1.1	DITTO
(2)	3	210 000	19 100	12 300	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	40	2.9	1.4	DITTO
(3)	3	210 000	19 100	12 300	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	40	2.9	1.4	DITTO
(3)	Center	-880 000	13 900	700	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	177	8.5	0.1	DITTO
(3)	4	-60 000	8 800	7 100	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	16	1.1	0.8	DITTO
(4)	4	-60 000	8 800	7 100	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	16	1.1	0.8	DITTO
(4)	Center	350 000	7 800	7 600	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	92	3.3	0.8	DITTO
(4)	5	660 000	6 800	7 900	100	110	100	20	D22 / D22	150 / 150	25.8 / 25.8	189	6.5	0.9	DITTO

Where
M : Bending moment
N : Axial force
S : Shearing force
B : The Width
H : The Height
d : The effective height
d' : The covering of compression bar
D : Diameter of bars
As : The area of tension bars
A's : The area of compression bars
σ_b : The bending stress
σ_c : The compressive stress
τ : The shearing stress

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[Pump Pit]

Table.8-2 The Calculation Results of The Stress (Section I)

Member	Point	The Sectional Force M [kg·cm]	N [kg]	S [kg]	The Sectional Dimensions B [cm]	H [cm]	d [cm]	d' [cm]	The Arrangement of Reinforcing Bars D [mm]	Pitch [mm]	As [cm²] / A's [cm²]	The strees (kg/cm²) σ_b	σ_c	τ	Remarks
(5)	5	1 470 000	17 700	15 100	100	90	80	20	D19 / D19	150 / 300	19.1 / 9.54	621	21.2	1.9	
	Center	-660 000	17 700	300	100	80	70	10	D19 / D19	300 / 150	9.54 / 19.1	229	11.6	0	
	6	1 300 000	17 700	14 500	100	90	80	20	D19 / D19	150 / 300	19.1 / 9.54	505	18.6	1.8	
(6)	6	1 300 000	17 700	14 500	100	90	80	20	D19 / D19	150 / 300	19.1 / 9.54	505	18.6	1.8	
	Center	-660 000	17 700	300	100	80	70	10	D19 / D19	300 / 150	9.54 / 19.1	229	11.6	0	
	7	1 470 000	17 700	15 100	100	90	80	20	D19 / D19	150 / 300	19.1 / 9.54	621	21.2	1.9	
(7)	7	660 000	6 800	7 900	100	110	100	20	D22 / D22	150 / 150	25.8 / 25.8	189	6.5	0.9	As+A's ≧0.004B·H =40cm²
	Center	350 000	7 800	7 600	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	42	3.3	0.8	DITTO
	8	-60 000	8 800	7 100	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	16	1.1	0.8	DITTO
(8)	8	-60 000	8 800	7 100	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	16	1.1	0.8	DITTO
	Center	-880 000	13 900	700	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	177	8.5	0.1	DITTO
	9	210 000	19 100	12 300	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	40	2.9	1.4	DITTO

Where
M : Bending moment
N : Axial force
S : Shearing force
B : The Width
H : The Height
d : The effective height
d' : The covering of compression bar
D : Diameter of bars
As : The area of tension bars
A's : The area of compression bars
σ_b : The bending stress
σ_c : The compressive stress
τ : The shearing stress

(Pump Pit)

Table.8-3 The Calculation Results of The Stress (Section I)

Member	Point	The Sectional Force M [kg·cm]	N [kg]	S [kg]	The Sectional Dimensions B [cm]	H [cm]	d [cm]	d' [cm]	The Arrangement of Reinforcing Bars D [mm]	Pitch [mm]	As [cm²] / A's [cm²]	The strees (kg/cm²) σ_b	σ_c	τ	Remarks
(9)	9	210 000	19 100	12 300	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	40	2.9	1.4	As+A's ≧0.004B·H =40 cm²
	Center	110 000	21 400	9 800	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	37	2.6	1.1	DITTO
	10	-100 000	22 000	7 800	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	37	2.6	0.9	DITTO
(10)	10	-100 000	22 000	7 800	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	37	2.6	0.9	DITTO
	Center	-67 000	26 400	8 600	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	41	2.8	1.0	DITTO
	11	3 120 000	30 900	27 000	100	110	100	20	D22 / D22	150 / 150	25.8 / 25.8	792	27.4	2.7	DITTO
(11)	11	-3 120 000	27 000	40 300	100	110	100	20	D22 / D22	150 / 150	25.8 / 25.8	855	27.6	4.0	
	Center	2 130 000	27 000	2 100	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	528	20.9	0.2	
	12	-4 270 000	27 000	44 500	100	110	100	20	D22 / D22	150 / 150	25.8 / 25.8	1335	37.9	4.5	
(12)	12	-4 270 000	27 000	44 500	100	110	100	20	D22 / D22	150 / 150	25.8 / 25.8	1335	37.9	4.5	
	Center	2 130 000	27 000	2 100	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	528	20.9	0.2	
	1	-3 120 000	27 000	40 300	100	110	100	20	D22 / D22	150 / 150	25.8 / 25.8	855	27.6	4.0	

Where
M : Bending moment
N : Axial force
S : Shearing force
B : The Width
H : The Height
d : The effective height
d' : The covering of compression bar
D : Diameter of bars
As : The area of tension bars
A's : The area of compression bars
σ_b : The bending stress
σ_c : The compressive stress
τ : The shearing stress

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(Pump Pit)

Table.8-4 The Calculation Results of The Stress (Section I)

Member	Point	The Sectional Force M [kg·cm]	N [kg]	S [kg]	The Sectional Dimensions B [cm]	H [cm]	d [cm]	d' [cm]	The Arrangement of Reinforcing Bars D [mm]	Pitch [mm]	As [cm²] / A's [cm²]	The strees (kg/cm²) σ_b	σ_c	τ	Remarks
(13)	3	240 000	36 900	2 700	100	40	30	10	D19 / D19	150 / 150	19.1 / 19.1	182	16.2	0.9	As+As' ≧0.008 B·H = 32 cm²
	Center	−130 000	36 900	300	100	40	30	10	D19 / D19	150 / 150	19.1 / 19.1	154	12.5	0.1	DITTO
	13	240 000	36 900	2 700	100	40	30	10	D19 / D19	150 / 150	19.1 / 19.1	182	16.2	0.9	DITTO
(14)	13	240 000	36 900	2 700	100	40	30	10	D19 / D19	150 / 150	19.1 / 19.1	182	16.2	0.9	DITTO
	Center	−130 000	36 900	300	100	40	30	10	D19 / D19	150 / 150	19.1 / 19.1	154	12.5	0.1	DITTO
	9	240 000	36 900	2 700	100	40	30	10	D19 / D19	150 / 150	19.1 / 19.1	182	16.2	0.9	DITTO
(15)	12	457 000	38 900	4 300	100	120	100	20	D22 / D22	150 / 150	25.8 / 25.8	28	4.8	0.4	As+As' ≧0.004 B·H = 40 cm²
	Center	14 000	33 900	940	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	46	3.2	0.1	DITTO
	13	−10 000	28 900	200	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	70	2.7	0	DITTO
(16)	13	0	28 900	200	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	40	2.7	0	DITTO
	Center	0	19 200	0	100	100	90	10	D22 / D22	150 / 150	25.8 / 25.8	27	1.8	0	DITTO
	6	0	13 100	0	100	120	100	20	D22 / D22	150 / 150	25.8 / 25.8	15	1.0	0	DITTO

Where
M : Bending moment
N : Axial force
S : Shearing force
B : The Width
H : The Height
d : The effective height
d' : The covering of compression bar
D : Diameter of bars
As : The area of tension bars
A's : The area of compression bars
σ_b : The bending stress
σ_c : The compressive stress
τ : The shearing stress

[Pump Pit]

The opening portion at the middle slab

Table. 9 The Calculation Results of The Stress

(Section I)

Member	Point	The Sectional Force M [kg·cm]	N [kg]	S [kg]	The Sectional Dimensions B [cm]	H [cm]	d [cm]	d' [cm]	The Arrangement of Reinforcing Bars D [mm]	Pitch [mm]	As [cm²] / A's [cm²]	The strees (kg/cm²) σ_b	σ_c	τ	Remarks
		5620000	0	63600	100	100	90	10	2×D22 2×D22	125 125	62.0 62.0	1128	37.6	7.1	

Where
M : Bending moment
N : Axial force
S : Shearing force
B : The Width
H : The Height
d : The effective height
d' : The covering of compression bar
D : Diameter of bars
As : The area of tension bars
A's : The area of compression bars
σ_b : The bending stress
σ_c : The compressive stress
τ : The shearing stress

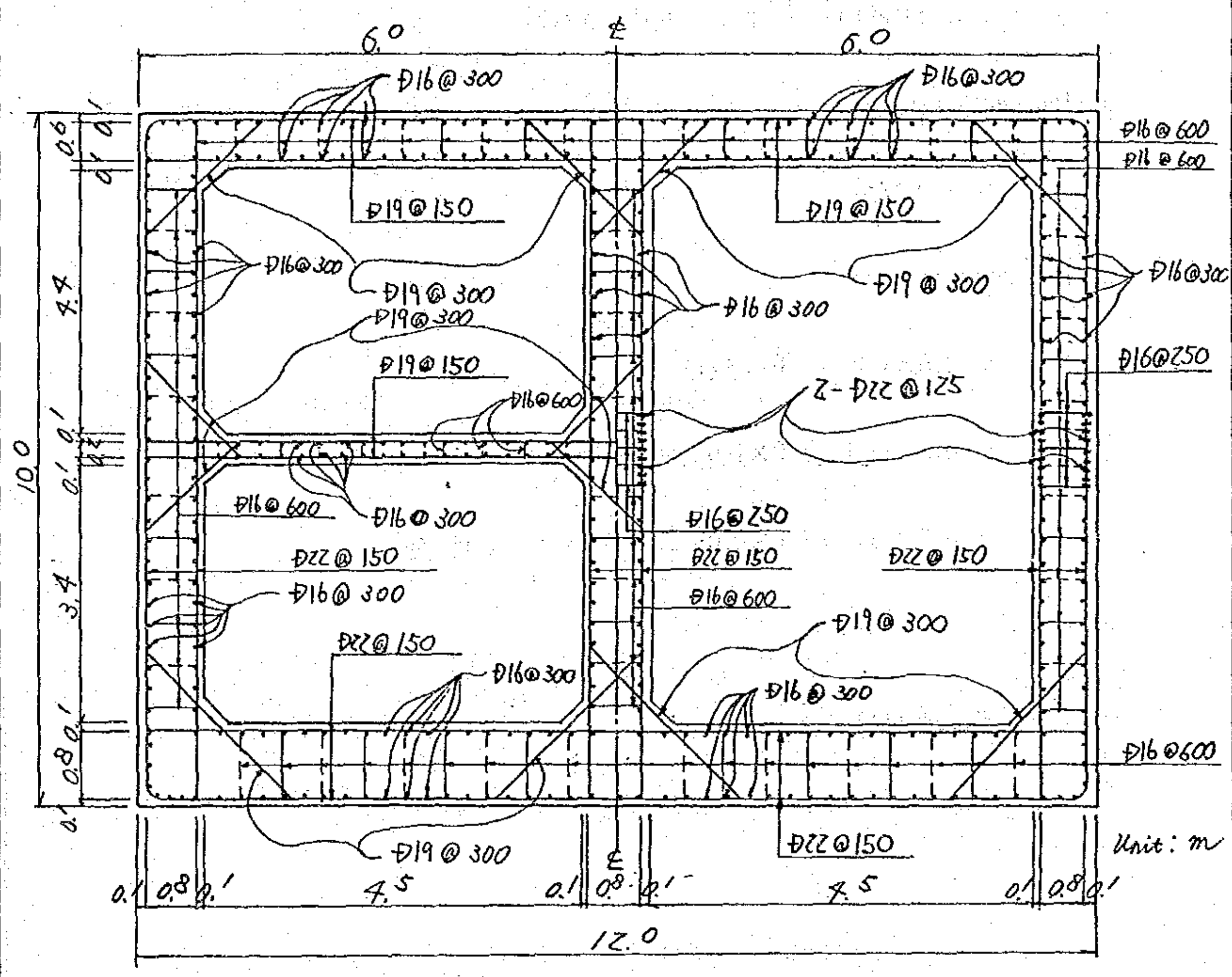

Fig 24. The general arrangement of reinforcing bars [Section I]

1.4.7 Study of the back wall of Screen Room

1) The load calculation (per 1 m unit length)

a) The surcharge load

$q = 1.0\ t/m^2$

b) The earth pressure

$P_{e0} = 0.5\times1.0 = \underline{0.5\ t/m^2}$

$P_{e1} = 0.5\times(1.0+1.9\times1.0) = \underline{1.45\ t/m^2}$

$P_{e2} = 0.5\times(1.0+1.9\times1.0+1.0\times4.3) = \underline{3.6\ t/m^2}$

c) The water pressure

$P_w = \underline{4.3\ t/m^2}$

Accordingly the load diagram is shown in Fig 25.

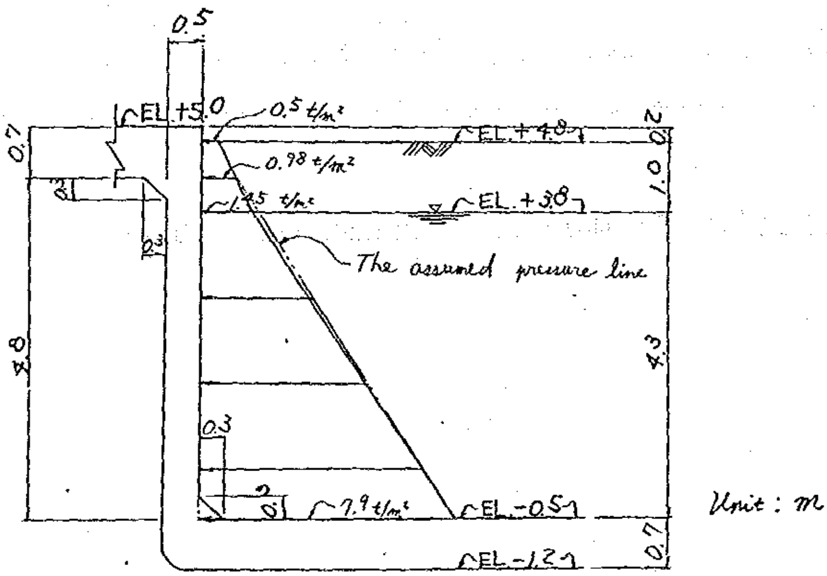

Fig 25. The load diagram

2) Structural design calculation

The design structure of the back wall is considered for the plate with four sides fixed, so the bending moments and the shearing forces are calculated as follows.

a) the moments

$$M_1 = 0.0231 \times 0.98 \times 4.8^2 - 0.0115 \times 6.92 \times 4.8^2 = -1.31 \text{ t·m}$$

$$M_2 = -0.0513 \times 0.98 \times 4.8^2 - 0.0334 \times 6.92 \times 4.8^2 = -6.48 \text{ t·m}$$

$$M_3 = -0.0513 \times 0.98 \times 4.8^2 - 0.0179 \times 6.92 \times 4.8^2 = -4.01 \text{ t·m}$$

$$M_4 = -0.0513 \times 0.98 \times 4.8^2 - 0.0257 \times 6.92 \times 4.8^2 = -5.26 \text{ t·m}$$

b) the shearing forces

$$S_1 = \frac{1}{2} \times \left(\frac{1}{40} \times 5.92 \times 4.8 \right) \times 4.5 = 1.87 \text{ t}$$

$$S_2 = \frac{1}{2} \times \left(\frac{1}{2} \times 0.98 \times 4.8 + \frac{7}{20} \times 6.92 \times 4.8 \right) \times 4.5 = 1.87 \text{ t}$$

$$S_3 = \frac{1}{2} \times \left(\frac{1}{2} \times 0.98 \times 4.8 + \frac{3}{20} \times 6.92 \times 4.8 \right) \times 4.5 = 16.50 \text{ t}$$

Accordingly the moment diagram is shown in Fig 26 and the shearing force diagram is shown in Fig 27.

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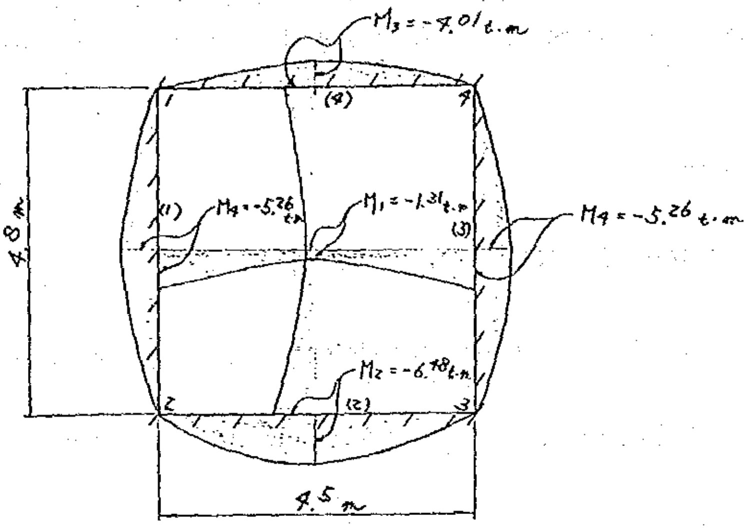

Fig 26. The bending moment diagram

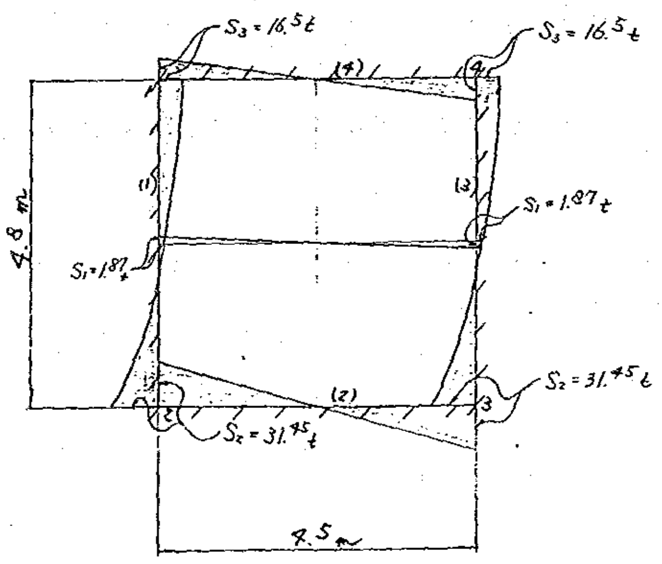

Fig 27. The shearing force diagram

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c) The stress calculation

The stress calculation results are shown in Table 10.

[The Back Wall of Screen Room]

Table. 10 The Calculation Results of The Stress

Member	Point	The Sectional Force M [kg·cm]	N [kg]	S [kg]	The Sectional Dimensions B [cm]	H [cm]	d [cm]	d' [cm]	The Arrangement of Reinforcing Bars D [mm]	Pitch [mm]	As [cm²] A's [cm²]	The stress (kg/cm²) σb	σc	τ	Remarks
(1)	1	0	0	16 500	100	60	50	20	D19 D19	200 200	14.3 14.3	0	0	3.3	As+A's ≧0.007B·H = 20cm²
	Center	-526 000	0	1 900	100	50	40	10	D19 D19	200 200	14.3 14.3	1018	25.7	0.5	DITTO
	2	0	0	31 500	100	60	50	20	D19 D19	200 200	14.3 14.3	0	0	6.3	DITTO
(2)	2	0	0	31 500	100	60	50	20	D19 D19	200 200	14.3 14.3	0	0	6.3	DITTO
	Center	-698 000	0	0	100	50	40	10	D19 D19	200 200	14.3 14.3	1254	31.6	0	DITTO
	3	0	0	31 500	100	60	50	20	D19 D19	200 200	14.3 14.3	0	0	6.3	DITTO
(3)	3	0	0	31 500	100	60	50	20	D19 D19	200 200	14.3 14.3	0	0	6.3	DITTO
	Center	-526 000	0	1 900	100	50	40	10	D19 D19	200 200	14.3 14.3	1018	25.7	0.5	DITTO
	4	0	0	16 500	100	60	50	20	D19 D19	200 200	14.3 14.3	0	0	3.3	DITTO
(4)	4	0	0	16 500	100	60	50	20	D19 D19	200 200	14.3 14.3	0	0	3.3	DITTO
	Center	-901 000	0	0	100	50	40	10	D19 D19	200 200	14.3 14.3	776	19.6	0.0	DITTO
	1	0	0	16 500	100	60	50	20	D19 D19	200 200	14.3 14.3	0	0	3.3	DITTO

Where
M : Bending moment
N : Axial force
S : Shearing force
B : The Width
H : The Height
d : The effective height
d' : The covering of compression bar
D : Diameter of bars
As : The area of tension bars
A's : The area of compression bars
σ_b : The bending stress
σ_c' : The compressive stress
τ : The shearing stress

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1.4.8 Study of Wash Pump Pit

1) Plan of Wash Pump Pit

Plan of wash Pump Pit is shown in Fig 28, then the opening area is transformed to be the two dots chain line for the structural design.

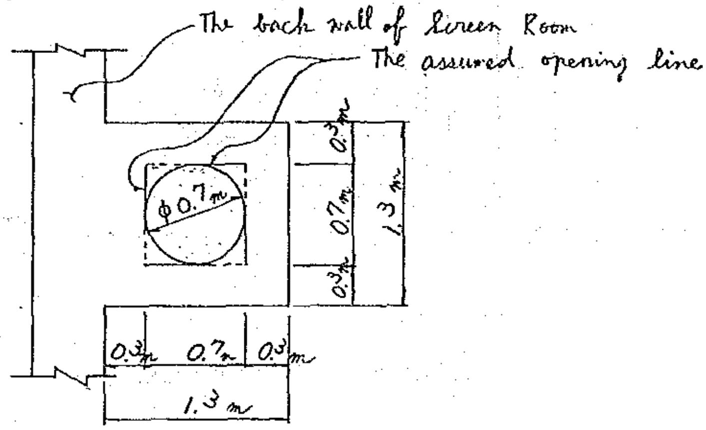

Fig 28. Plan of Wash Pump Pit

2) The load calculation

a) The surcharge load

$q = 1.0\ t/m^2$

b) The earth pressure

$P_{e0} = 0.5\times1.0 = 0.5\ t/m^2$

$P_{e1} = 0.5\times(1.0+1.9\times1.0) = 1.45\ t/m^2$

$P_{e2} = 0.5\times(1.0+1.9\times1.0+1.0\times4.3) = 3.6\ t/m^2$

c) The water pressure

$P_w = \underline{4.3\ t/m^2}$

Accordingly the load diagram is shown in Fig 29.

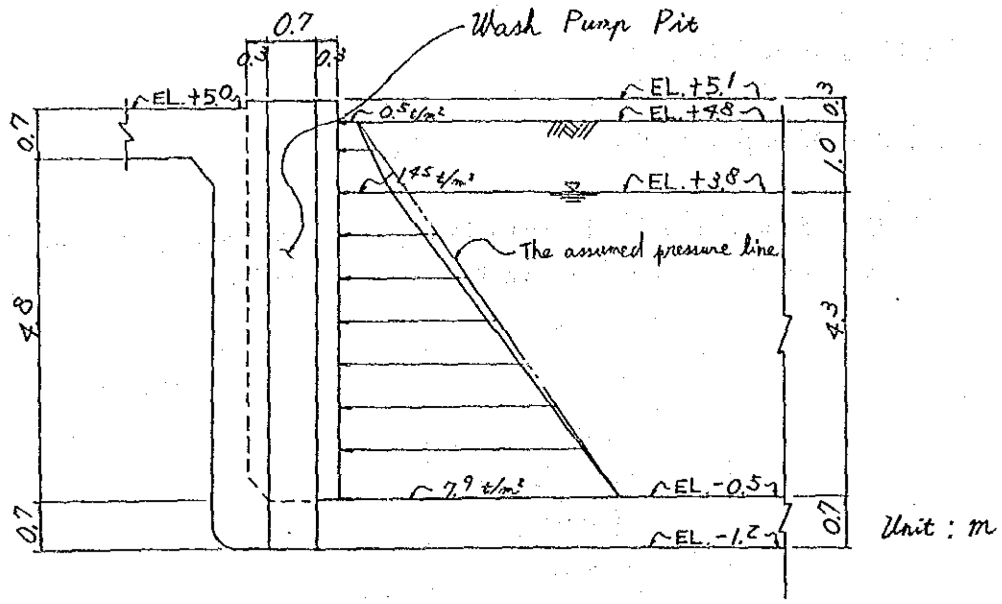

Fig 29. The load diagram

3) The structural design calculation

The design structure of Wash Pump Pit is considered for the two dimensional plate with three sides fixed and one side free, so the structural design calculation is executed as follows.

a) The bending moments

$M_{1x} = 0.0454\times0.5\times0.7^2+0.0065\times7.4\times0.7^2 = 0.04$ t·m

$M_{2x} = 0.0402\times0.5\times0.7^2+0.0191\times7.4\times0.7^2 = 0.08$ t·m

$M_{2y} = 0.0118\times0.5\times0.7^2+0.0075\times7.4\times0.7^2 = 0.03$ t·m

$M_{3x} = -0.0842\times0.5\times0.7^2-0.0087\times7.4\times0.7^2 = -0.05$ t·m

$M_{4x} = -0.0755\times0.5\times0.7^2-0.0364\times7.4\times0.7^2 = -0.15$ t·m

$M_{5y} = -0.0418\times0.5\times0.7^2-0.0291\times7.4\times0.7^2 = -0.12$ t·m

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b) The shearing forces

$S_{1x} = 0.527 \times 0.5 \times 0.7 - 0.006 \times 7.4 \times 0.7 = 0.15$ t

$S_{2x} = 0.491 \times 0.5 \times 0.7 + 0.245 \times 7.4 \times 0.7 = 1.44$ t

$S_{3x} = 0.373 \times 0.5 \times 0.7 + 0.311 \times 7.4 \times 0.7 = 1.74$ t

Accordingly the moment diagram is shown in Fig 30 and the shearing force is shown in Fig 31.

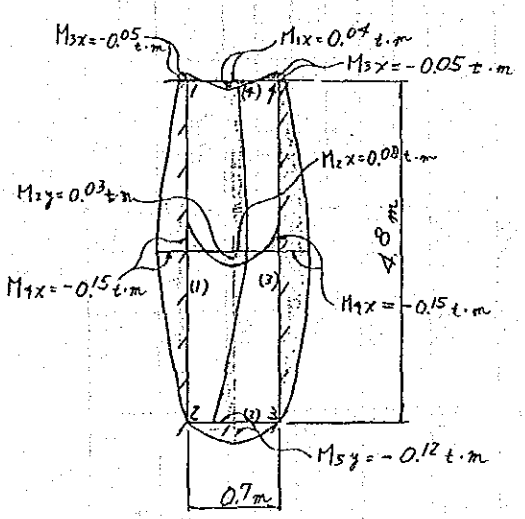

Fig 30. The moment diagram

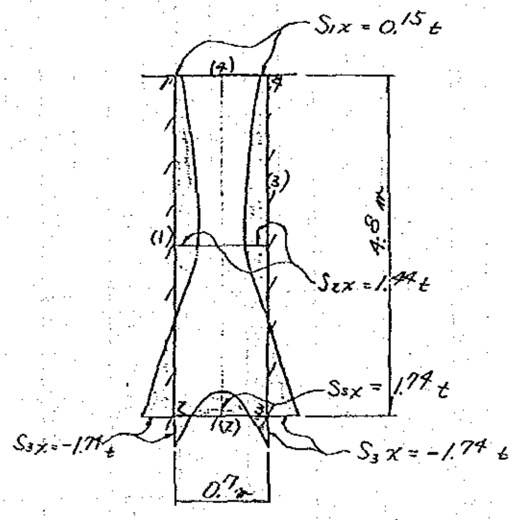

Fig 31. The shearing force diagram

c) The stress calculation

The stress calculation results are shown in Table 11.

〔Wash Pump Pit〕

Table. 11 The Calculation Results of The Stress

Member	Point	The Sectional Force M [kg·cm]	N [kg]	S [kg]	The Sectional Dimensions B [cm]	H [cm]	d [cm]	d' [cm]	The Arrangement of Reinforcing Bars D [mm]	Pitch [mm]	As [cm²] / A's [cm²]	The strees (kg/cm²) σ_b	σ_c	τ	Remarks
(1)	1	-5 000	0	150	100	30	20	10	D13 D13	300 300	4.22 4.22	56	1.3	0.1	As+As' ≧0.004B·H = 8.4 cm²
	Center	-15 000	0	1 440	100	30	20	10	D13 D13	300 300	4.22 4.22	169	3.8	0.7	DITTO
	2	0	0	1 740	100	30	20	10	D13 D13	300 300	4.22 4.22	0	0	0.9	DITTO
(2)	2	0	0	1740	100	30	20	10	D13 D13	300 300	4.22 4.22	0	0	0.9	DITTO
	Center	-12 000	0	1740	100	30	20	10	D13 D13	300 300	4.22 4.22	1	0	0.9	DITTO
	3	0	0	1740	100	30	20	10	D13 D13	300 300	4.22 4.22	0	0	0.9	DITTO
(3)	3	0	0	1740	100	30	20	10	D13 D13	300 300	4.22 4.22	0	0	0.9	DITTO
	Center	-15 000	0	1440	100	30	20	10	D13 D13	300 300	4.22 4.22	169	3.8	0.7	DITTO
	4	-5 000	0	150	100	30	20	10	D13 D13	300 300	4.22 4.22	56	1.3	0.1	DITTO
(4)	4	-5 000	0	150	100	30	20	10	D13 D13	300 300	4.22 4.22	56	1.3	0.1	DITTO
	Center	4 000	0	0	100	30	20	10	D13 D13	300 300	4.22 4.22	45	1.0	0	DITTO
	1	-5 000	0	150	100	30	20	10	D13 D13	300 300	4.22 4.22	56	1.3	0.1	DITTO

Where
M : Bending moment
N : Axial force
S : Shearing force
B : The Width
H : The Height
d : The effective height
d' : The covering of compression bar
D : Diameter of bars
As : The area of tension bars
A's : The area of compression bars
σ_b : The bending stress
σ_c : The compressive stress
τ : The shearing stress

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1.5 Study of Block II

1.5.1 Stability calculation

Stability calculation is exectued at the longitudinal direction.

1) Vertical forces

a) Base slab

W_{c1} = 11.7×17.4×1.0×2.45 = 499 t

b) Side wall

W_{c2} = (3×0.7×3.4×17.4+4×0.3×0.3×17.4)×2.45

= 320 t

c) Upper slab

W_{c3} = 11.7×17.4×0.7×2.45 = 349 t

d) Water weight

i) Water weight at the inside of Culverts W_{wi}

Water is filled up Culverts, so water weight at the inside of Culverts W_{wi} is calculated as below.

W_{wi} = 2×4.8×3.4×17.4−4×0.3×0.3×17.4 = 562 t

ii) Water weight at the outside of Culverts

The weight of water included in the soil is calculated as follows.

W_{wo} =1.0×4.3×11.7×17.4+ $\frac{1}{2}$ ×(1.0+16.4)×1.2×11.7

= 997 t

e) Soil weight

Soil weight is including the surcharge load $q = 1.0\ t/m^2$ and divided between the upside of Culvert and the underside of Culvert, so the calculations of soil weights are as follows.

i) the upside of Culvert

$$W_{s1} = (1.0+1.9\times1.0+1.0\times4.3)\times11.7\times17.4 = 1\,466\ t$$

ii) the underside of Culvert

$$W_{s2} = 1.0\times\frac{1}{2}\times(1.0+16.4)\times1.2\times11.7 = 122\ t$$

f) Buoyancy

Buoyancy U_b is calculated as follows.

$$U_b = 11.7 \times 17.4 \times 10.0 = 2\,036\ t$$

Accordingly the calculation results of the external forces at Block II are shown in Fig 32.

2) Horizontal forces

Horizontal forces are equilibriumed at both sides, so it is dealt with 0.

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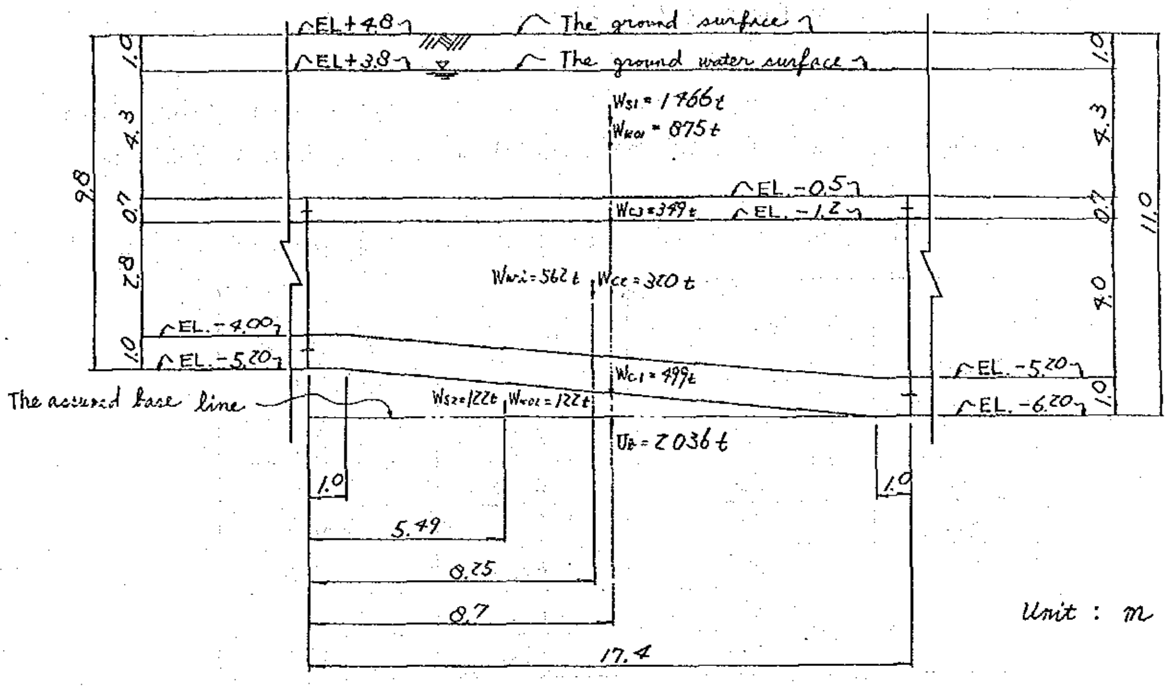

Fig 32. The calculation results of the external forces

3) The calculation of the ground reaction

a) The calculation of the eccentric distance

The eccentric distance is determined by the external monent calculations, then the summarized table of the external moments is shown in Table 12.

Table 12. The summarized table of the external moments

Species	Vertical forces V_i [t]	Arm x_i [m]	Moment M_i [t·m]
W_{c1}	499	8.7	4 341
W_{c2}	320	8.25	2 640
W_{c3}	349	8.7	3 036
W_{wi}	562	8.25	4 637
W_{w01}	875	8.7	7 613
W_{w02}	122	5.49	670
W_{s1}	1 466	8.7	12 754
W_{s2}	122	5.49	670
U_b	−2 036	8.7	−17 713
TOTAL	2 279 t		18 648

According to the above Table, the eccentric distance e is calculated as follows.

$$e = \frac{L}{2} - \frac{\Sigma M_i}{\Sigma V_i} = \frac{17.4}{2} - \frac{18\ 648}{2\ 279}$$

$$= 8.7 - 8.183$$

$$= 0.52\ \text{m} < \frac{L}{6} = \frac{17.4}{6} = 2.9\ \text{m}$$

Therefore working point of the composite force at the basement is within the middle−third.

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b) The calculation of the ground reaction q_{max}, q_{min}

$$\left.\begin{matrix} q_{max} \\ q_{min} \end{matrix}\right\} = \frac{\Sigma V_i}{B \cdot L} \cdot \left(1 \pm \frac{6e}{L}\right)$$

$$= \frac{2\ 279}{11.7 \times 17.4} \left(1 \pm \frac{6 \times 0.52}{17.4}\right)$$

$$= \begin{cases} q_{max} = 13.2\ t/m^2 \\ q_{min} = 9.2\ t/m^2 \end{cases}$$

4) Study of the bearing capacity

a) The ultimate bearing capacity q_u

The ultimate bearing capacity q_u is calculated as follows.

$$q_u = \alpha K C N_c + K q N_q + \frac{1}{2} r_i \beta B' N_r$$

where C : cohesion $C = 0$

q : the surcharge load
$q = 1.9 \times 1.0 + 1.0 \times 9.4 = 11.3\ t/m^2$

r_i : the bulk density of the bearing soil
$r_i = 1.0\ t/m^3$

B' : the effective width $B' = 11.7\ m$

α, β : the coefficient of the basic form

$$\alpha = 1 + 0.3 \cdot \frac{B'}{L'} = 1 + 0.3 \times \frac{11.7}{17.4 - 2 \times 0.308}$$

$$= 1.21$$

$$\beta = 1 - 0.4 \cdot \frac{B'}{L'} = 1 - 0.4 \times \frac{11.7}{17.4 - 2 \times 0.308}$$

$$= 0.72$$

K : the extra coefficient for the embedded effect

$K = 1.0$

N_c, N_q, N_r : the bearing coefficients considered for the load inclination

$N_c = 30$

$N_q = 18$

$N_r = 14$

Accordingly the ultimate bearing capacity q_u is calculated as follows.

$$q_u = 1.0 \times 11.3 \times 18 + \frac{1}{2} \times 1.0 \times 0.72 \times 14$$

$$= 262 \text{ t}$$

b) The allowable bearing capacity q_a

The allowable bearing capacity q_a is calculated as follows.

$$q_a = \frac{1}{F_s} \cdot q_u$$

where F_s : the factor of safety at normal

$F_s = 3$

$$= \frac{1}{3} \times 262$$

$$= 87.3 \text{ t/m}^2 > q_{max} = 13.2 \text{ t/m}^2$$

O.K

Accordingly the spread foundation is adopted for the foundation of the connected culvert.

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5) Study of floating

Checking against the floating is executed at Normal and at Construction, so checking is as follows.

a) Total vertical force

i) at normal

$$V_1 = 2\ 279 + 2\ 036 = \underline{4\ 315\ t}$$

ii) at construction (empty)

$$V_2 = 4\ 315 - 562 = \underline{3\ 753\ t}$$

b) Up lift U

$$U = r \cdot H_w \cdot A = 1.0 \times 10.0 \times 11.7 \times 17.4 = \underline{2\ 036\ t}$$

c) Checking on the safety factor of floating F_1

The safety factor of floating is checked by the following two cases.

i) at normal

$$F_{11} = \frac{V_1}{U} = \frac{4\ 315}{2\ 036} = 2.1 \underset{O.K}{>} 1.1$$

ii) at construction

$$F_{12} = \frac{V_2}{U} = \frac{3\ 753}{2\ 036} = 1.8 \underset{O.K}{>} 1.0$$

1.5.2 Design Case

The following three cases are considered for the structural design cases.

Table 13. The summary of the design cases

Case	1	2	3
Condition	at Normal	at Construction	at Inspection
Period	Long term	Short term	Short term
The internal water condition	L.L.W.L	Empty	Empty (oneside)
The distributed surcharge load	1.0 t/m²	1.0 t/m²	1.0 t/m²
The incremental of coefficient of the allowable stress	1.0	1.25	1.25

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1.5.3 The Structural Design Calculation of Case-1

1) Frame of the design structure

Frame of the design structure is shown in Fig 33.

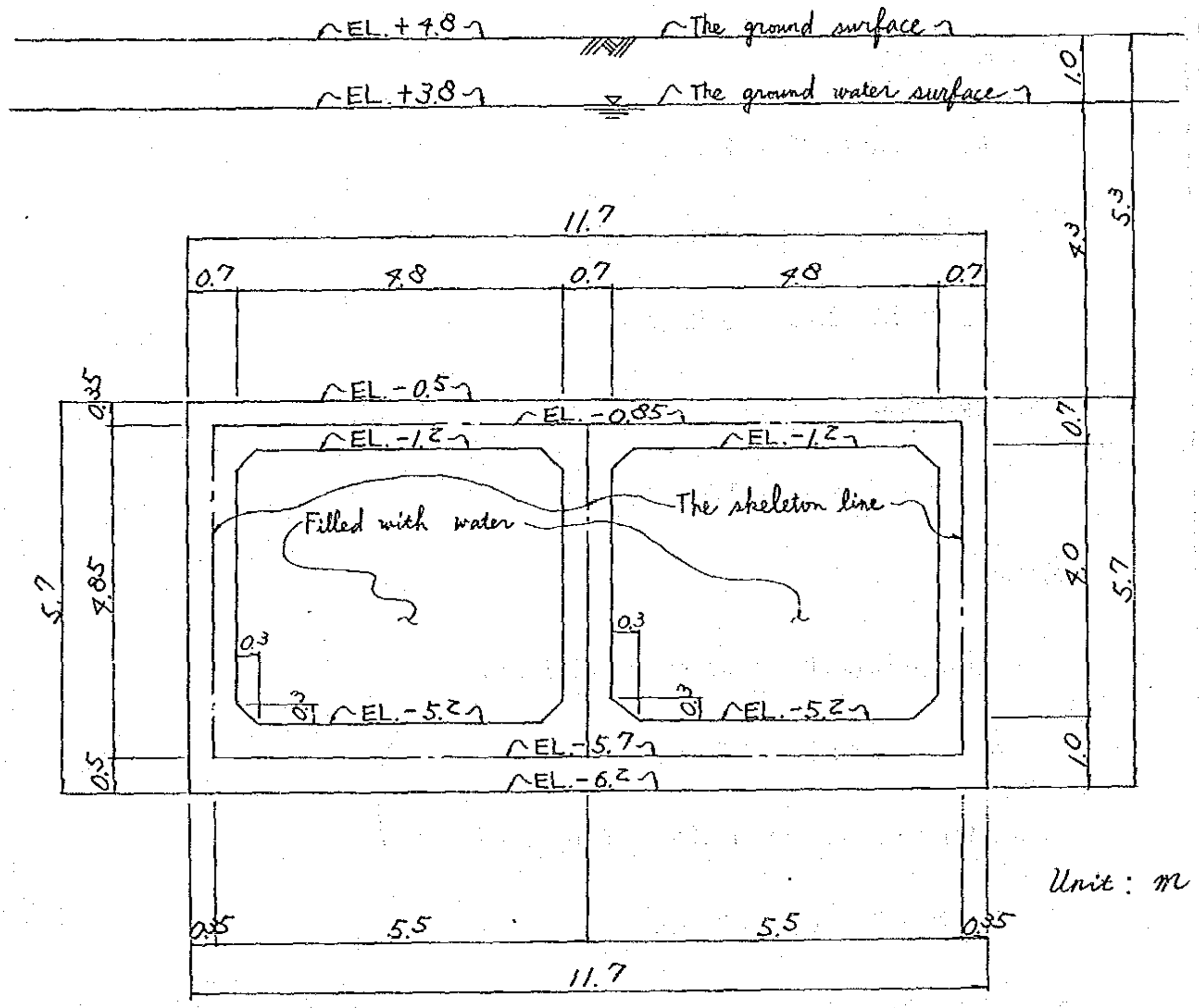

Fig 33. Frame of the design structure

All connections of this structure are considered for the rigid connection.

2) Load calculation (per 1m unit length)

a) The ground reaction

$$q_r = \frac{q_{max}+q_{min}}{2} = \frac{13.2+9.2}{2} = 11.2 \ t/m^2$$

b) Self weight

i) base slab

$$W_{c1} = 1.0\times2.45 = 2.45 \ t/m^2$$

ii) a side wall and a partition wall

$$W_{c2} = 0.7\times2.45 = 1.72 \ t/m^2$$

iii) upper slab

$$W_{c3} = 0.7\times2.45 = 1.72 \ t/m^2$$

c) Water weight

i) water weight at the upside of Culvert W_{wu}

$$W_{wu} = 1.0\times4.3 = 4.3 \ t/m^2$$

ii) water weight at the inside of Culvert W_{wi}

$$W_{wi} = 1.0\times4.0 = 4.0 \ t/m^2$$

d) Soil weight

Soil weight W_s is calculated by including the surcharge load $q = 1.0 \ t/m^2$ as follows.

$$W_s = 1.0+1.9\times1.0+1.0\times4.3 = 7.2 \ t/m^2$$

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e) Up lift

$P_u = 1.0 \times 10.0 = 10.0\ t/m^2$

f) The water pressure

i) the outside of Culvert

$P_{wo1} = 1.0 \times 4.65 = 4.65\ t/m^2$

$P_{wo2} = 1.0 \times 9.5 = 9.5\ t/m^2$

ii) the inside of Culvert

$P_{wi} = 1.0 \times 4.0 = 4.0\ t/m^2$

g) The earth pressure

$P_{e1} = 0.5 \times (1.0 + 1.9 \times 1.0 + 1.0 \times 4.65) = 3.78\ t/m^2$

$P_{e2} = 0.5 \times (1.0 + 1.9 \times 1.0 + 1.0 \times 9.0) = 5.95\ t/m^2$

According to the above calculations, the load calculation results are shown in Fig 34.

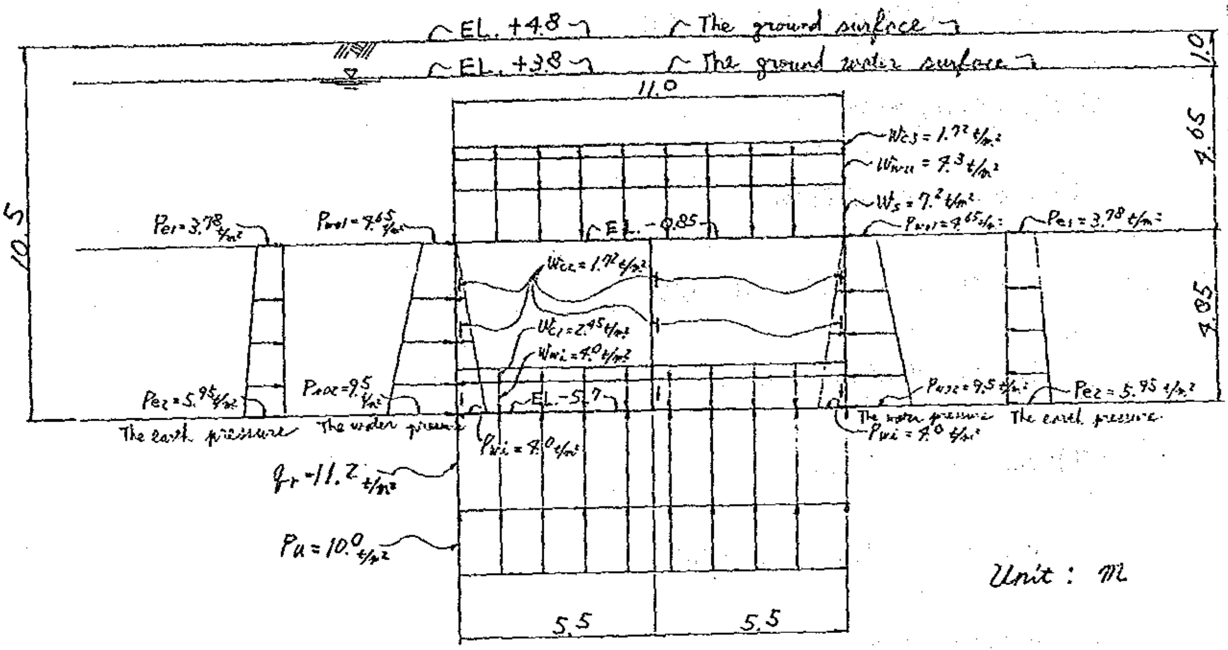

Fig 34. The load calculation results

3) The load diagram

The load diagram is shown in Fig 35.

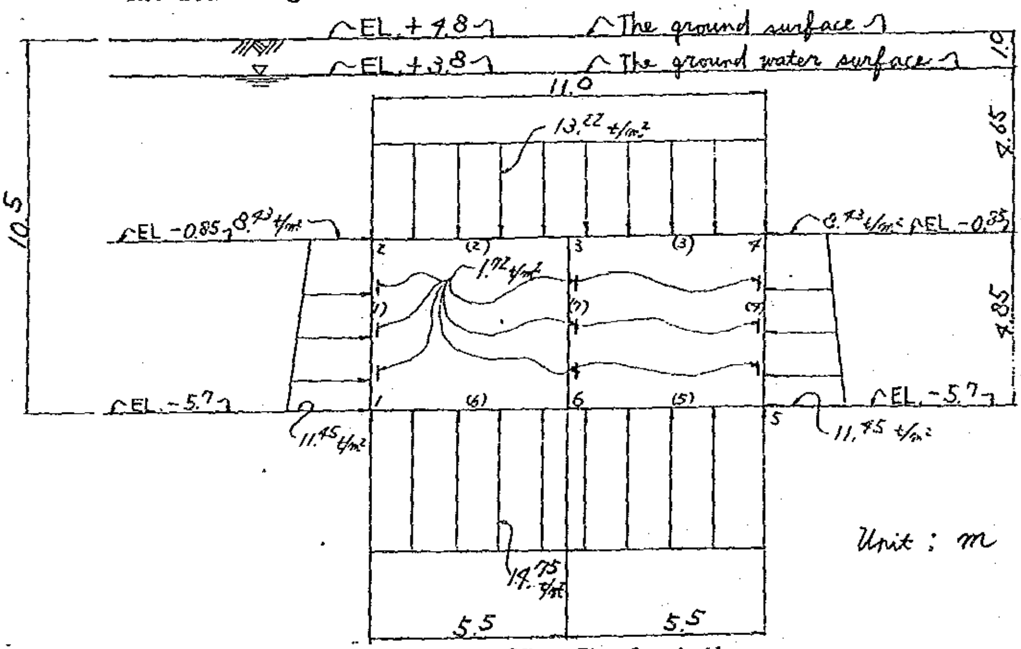

Fig 35. The load diagram

4) Input data for the sectional dimensions

The sectional forces are calculated by computer, so input data for the sectional dimensions are summarized in Table 14.

Table 14. The sectional dimensions (per 1 m unit length)

Member's number	The section area A [m²]	The geometrical moment of inertia I [m⁴]	Remarks
(1)	0.7	0.0286	Side wall
(2)-(3)	0.7	0.0286	Upper slab
(4)	0.7	0.0286	Side wall
(5)-(6)	1.0	0.0833	Base slab
(7)	0.7	0.0286	Partition wall

5) The computer calculation results

The computer calculation results are the bending moment, the shearing force and the axial force, so they are shown in the following figures and Table (Fig 36-38, Table 15).

WEST WHARF CONNECTED CULVERT CASE-1 (NORMAL)

BENDING MOMENT

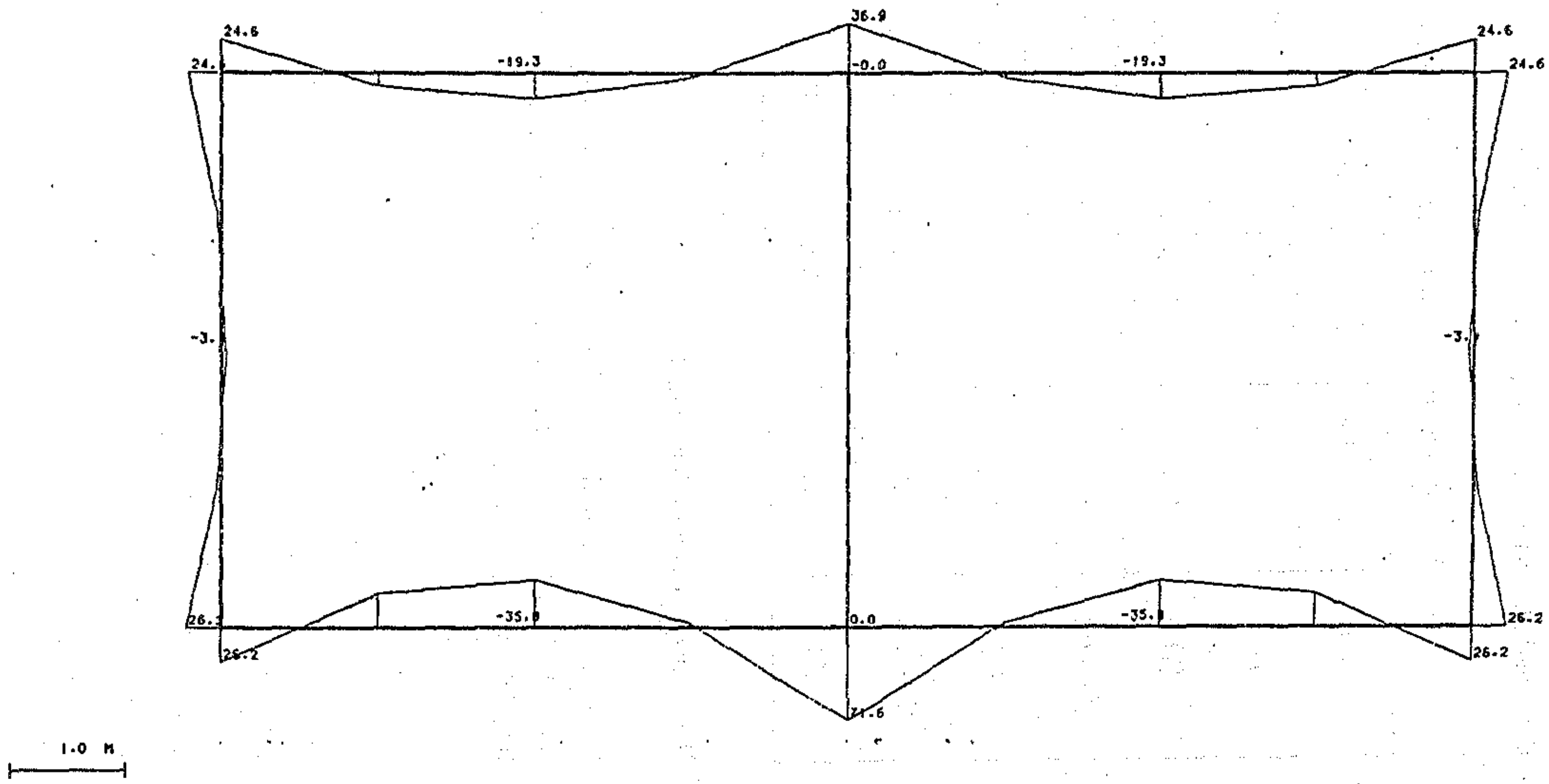

Fig 36. The bending moment diagram

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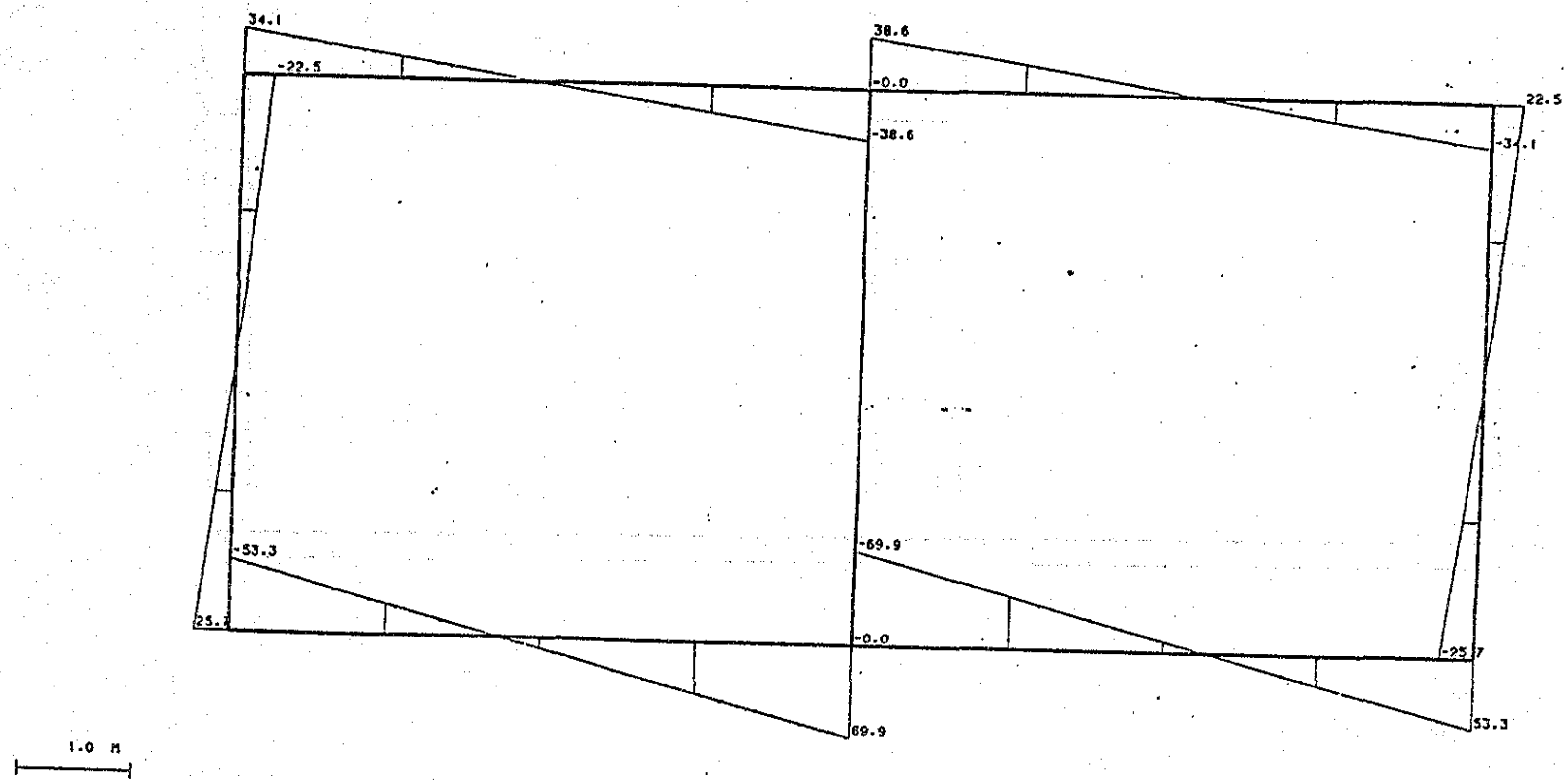
WEST WHARF CONNECTED CULVERT CASE-1 (NORMAL)

SHEARING FORCE



(TON)

Fig 37. The shearing force diagram

WEST WHARF CONNECTED CULVERT CASE-1 (NORMAL) AXIAL FORCE

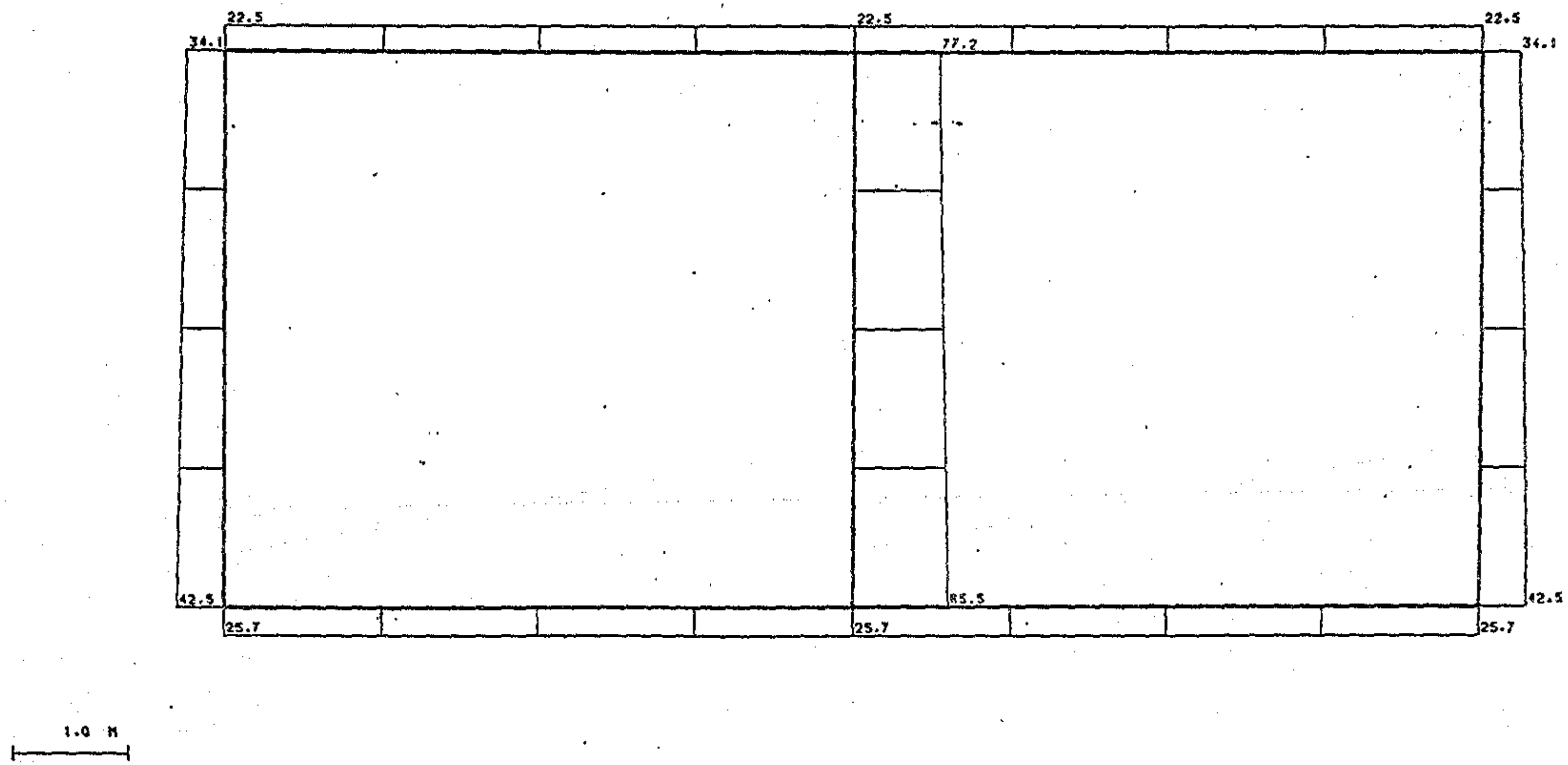


Fig 38. The axial force diagram

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Table 15. The calculation results of the sectional forces

** ELEMENTAL FORCES **

ELEM	I-END	AXIAL	SHEAR	MOMENT	J-END	AXIAL	SHEAR	MOMENT
1	1	4.2465E+01	2.5660E+01	2.6203E+01	7	4.0379E+01	1.2235E+01	3.3400E+00
2	7	4.0379E+01	1.2235E+01	3.3215E+00	8	3.8294E+01	-2.7512E-01	-3.8181E+00
3	8	3.8294E+01	-2.7512E-01	-3.8366E+00	9	3.6208E+01	-1.1870E+01	3.6372E+00
4	9	3.6208E+01	-1.1870E+01	3.6187E+00	2	3.4123E+01	-2.2549E+01	2.4596E+01
5	2	2.2549E+01	3.4123E+01	2.4577E+01	10	2.2549E+01	1.5945E+01	-9.8447E+00
6	10	2.2549E+01	1.5945E+01	-9.8447E+00	11	2.2549E+01	-2.2320E+00	-1.9273E+01
7	11	2.2549E+01	-2.2320E+00	-1.9273E+01	12	2.2549E+01	-2.0410E+01	-3.7067E+00
8	12	2.2549E+01	-2.0410E+01	-3.7067E+00	3	2.2549E+01	-3.8587E+01	3.6853E+01
9	3	2.2549E+01	3.8587E+01	3.6853E+01	13	2.2549E+01	2.0410E+01	-3.7067E+00
10	13	2.2549E+01	2.0410E+01	-3.7067E+00	14	2.2549E+01	2.2320E+00	-1.9273E+01
11	14	2.2549E+01	2.2320E+00	-1.9273E+01	15	2.2549E+01	-1.5945E+01	-9.8447E+00
12	15	2.2549E+01	-1.5945E+01	-9.8447E+00	4	2.2549E+01	-3.4123E+01	2.4577E+01
13	4	3.4123E+01	2.2549E+01	2.4577E+01	16	3.6208E+01	1.1870E+01	3.6002E+00
14	16	3.6208E+01	1.1870E+01	3.6187E+00	17	3.8294E+01	2.7512E-01	-3.8551E+00
15	17	3.8294E+01	2.7512E-01	-3.8366E+00	18	4.0379E+01	-1.2235E+01	3.3030E+00
16	18	4.0379E+01	-1.2235E+01	3.3215E+00	5	4.2465E+01	-2.5660E+01	2.6184E+01
17	5	2.5660E+01	5.3346E+01	2.6203E+01	19	2.5660E+01	2.2546E+01	-2.5973E+01
18	19	2.5660E+01	2.2546E+01	-2.5973E+01	20	2.5660E+01	-8.2538E+00	-3.5799E+01
19	20	2.5660E+01	-8.2538E+00	-3.5799E+01	21	2.5660E+01	-3.9054E+01	-3.2754E+00
20	21	2.5660E+01	-3.9054E+01	-3.2754E+00	6	2.5660E+01	-6.9854E+01	7.1599E+01
21	6	2.5660E+01	-6.9854E+01	7.1599E+01	22	2.5660E+01	3.9054E+01	-3.2754E+00
22	22	2.5660E+01	3.9054E+01	-3.2754E+00	23	2.5660E+01	8.2538E+00	-3.5799E+01
23	23	2.5660E+01	8.2538E+00	-3.5799E+01	24	2.5660E+01	-2.2546E+01	-2.5973E+01
24	24	2.5660E+01	-2.2546E+01	-2.5973E+01	1	2.5660E+01	-5.3346E+01	2.6203E+01
25	3	7.7174E+01	-1.3530E-14	-2.9013E-14	25	7.9260E+01	-1.3530E-14	-1.2607E-14
26	25	7.9260E+01	-1.3530E-14	-1.2607E-14	26	8.1345E+01	-1.3530E-14	3.7982E-15
27	26	8.1345E+01	-1.3530E-14	3.7982E-15	27	8.3431E+01	-1.3530E-14	2.0204E-14
28	27	8.3431E+01	-1.3530E-14	2.0204E-14	6	8.5516E+01	-1.3530E-14	3.6610E-14

1.5.4 The Structural Design Calculation of Case—2 (at Construction)

1) Frame of the design structure

Frame of the design structure is the same structure as that of design case—1.

2) Load calculation (per 1 m unit length)

Load calculations are the same calculations as those of case—1 excluding a part that the internal water loads are no considered(=0).

3) The load diagram

The load diagram is shown in Fig 39.

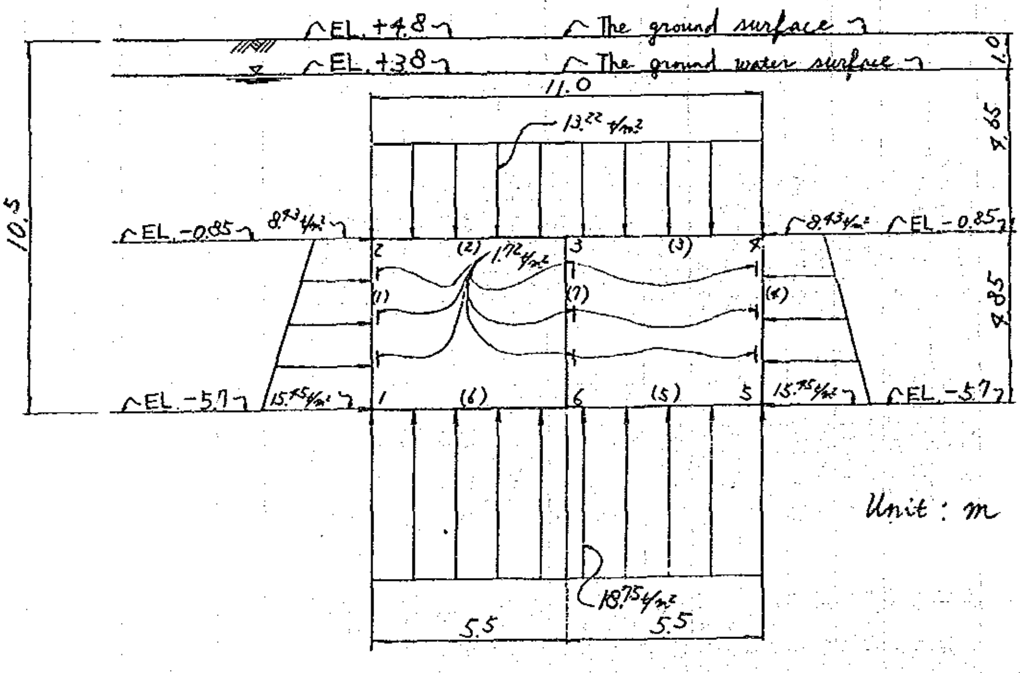

Fig 39. The load diagram

1234

4) Input data for the sectional dimensions

Input data for the sectional dimensions are the same values as those of design case－1.

5) The computer calculation results

The computer calculation results are shown in the following figures and Table (Fig 40－42, Table 16).

CONNECTED CULVERT AT PUMP PIT CASE-2 (CONSTRUCTION) BENDING MOMENT

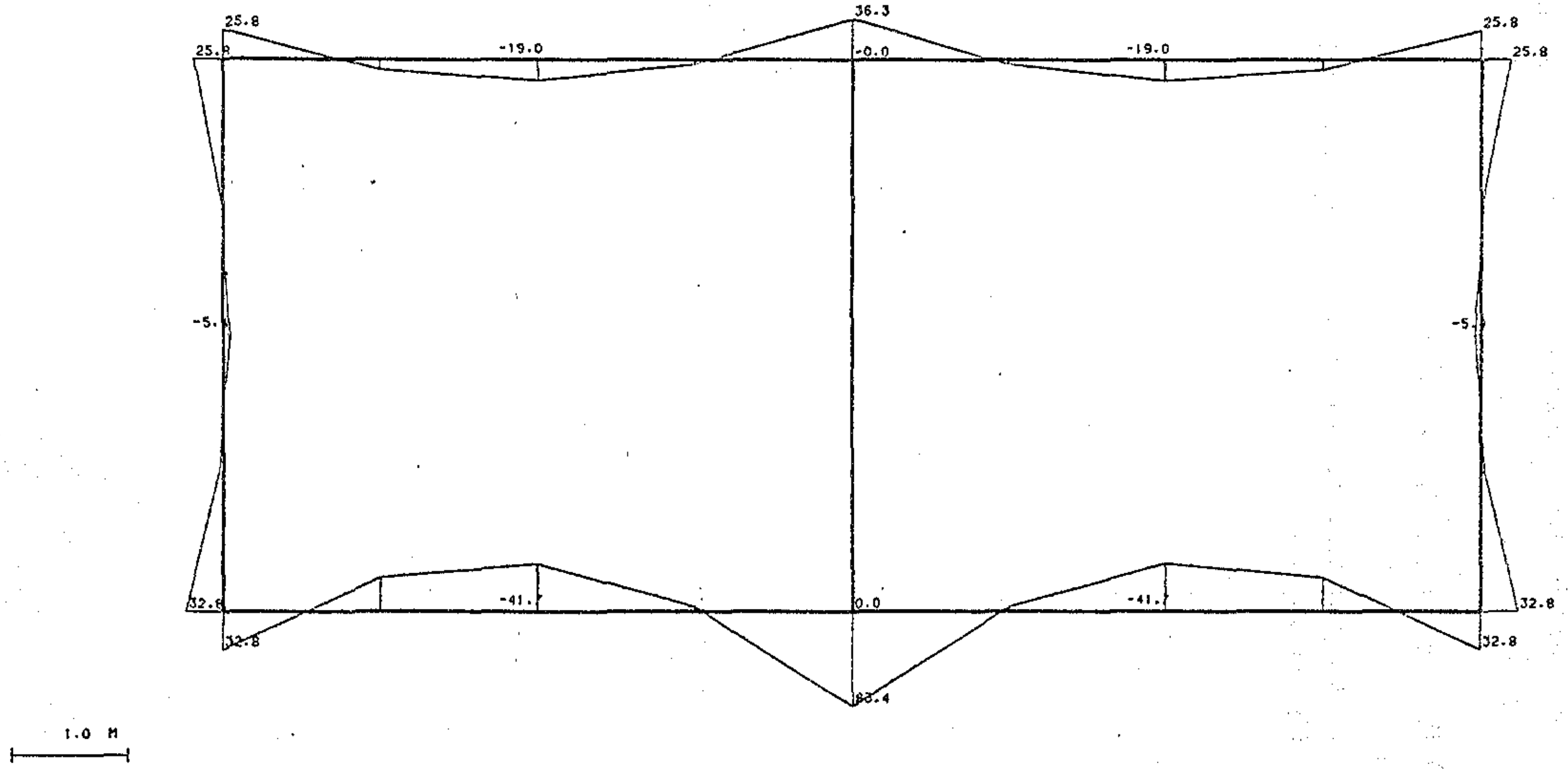

Fig 40. The bending moment diagram

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CONNECTED CULVERT AT PUMP PIT CASE-2 (CONSTRUCTION) SHEARING FORCE

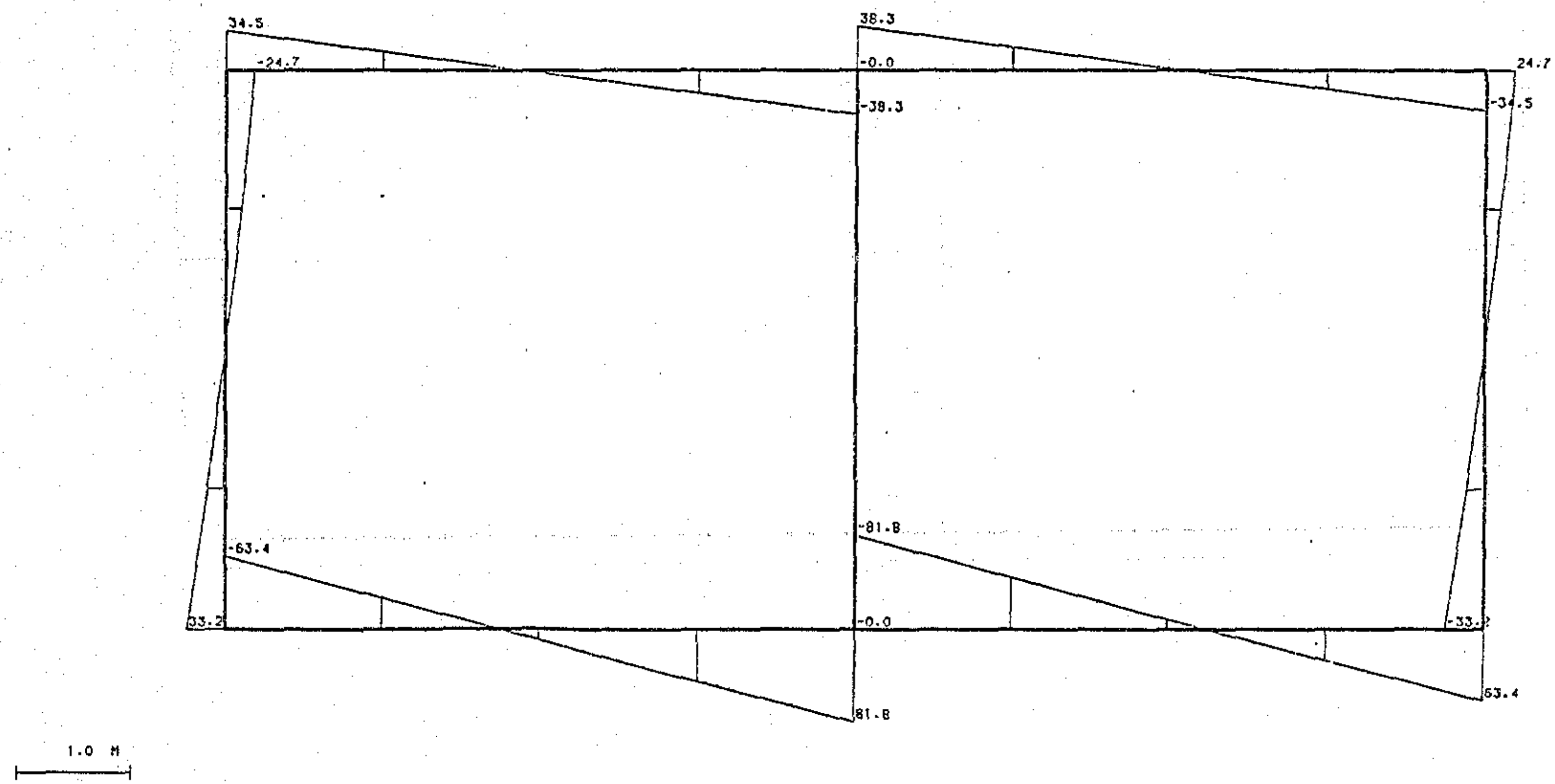

Fig 41. The shearing force diagram

CONNECTED CULVERT AT PUMP PIT CASE-2 (CONSTRUCTION) AXIAL FORCE

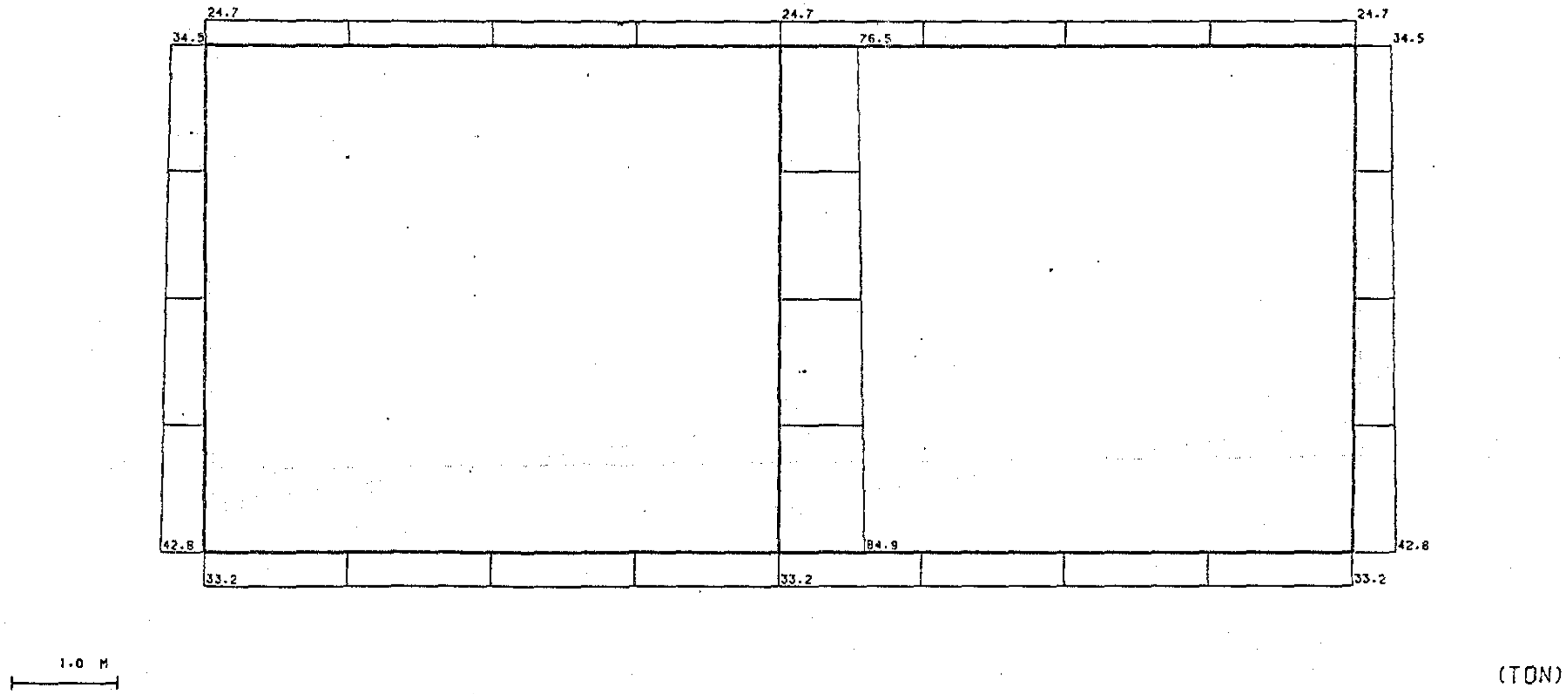

Fig 42. The axial force diagram

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Table 16. The calculation results of the sectional forces (Consyruction)

** ELEMENTAL FORCES **

ELEM	I-END	AXIAL	SHEAR	MOMENT	J-END	AXIAL	SHEAR	MOMENT
1	1	4.2793E+01	3.3236E+01	3.2796E+01	7	4.0708E+01	1.5566E+01	3.4676E+00
2	7	4.0708E+01	1.5566E+01	3.4246E+00	8	3.8622E+01	2.5160E-02	-5.7698E+00
3	8	3.8622E+01	2.5160E-02	-5.8128E+00	9	3.6537E+01	-1.3388E+01	2.5465E+00
4	9	3.6537E+01	-1.3388E+01	2.5035E+00	2	3.4451E+01	-2.4673E+01	2.5836E+01
5	2	2.4673E+01	3.4451E+01	2.5793E+01	10	2.4673E+01	1.6274E+01	-9.0799E+00
6	10	2.4673E+01	1.6274E+01	-9.0799E+00	11	2.4673E+01	-1.9039E+00	-1.8959E+01
7	11	2.4673E+01	-1.9039E+00	-1.8959E+01	12	2.4673E+01	-2.0081E+01	-3.8442E+00
8	12	2.4673E+01	-2.0181E+01	-3.8442E+00	3	2.4673E+01	-3.8259E+01	3.6265E+01
9	3	2.4673E+01	3.8259E+01	3.6265E+01	13	2.4673E+01	2.0081E+01	-3.8442E+00
10	13	2.4673E+01	2.0181E+01	-3.8442E+00	14	2.4673E+01	1.9039E+00	-1.8959E+01
11	14	2.4673E+01	1.9039E+00	-1.8959E+01	15	2.4673E+01	-1.6274E+01	-9.0799E+00
12	15	2.4673E+01	-1.6274E+01	-9.0799E+00	4	2.4673E+01	-3.4451E+01	2.5793E+01
13	4	3.4451E+01	2.4673E+01	2.5793E+01	16	3.6537E+01	1.3388E+01	2.4605E+00
14	16	3.6537E+01	1.3388E+01	2.5035E+00	17	3.8622E+01	-2.5160E-02	-5.8558E+00
15	17	3.8622E+01	-2.5160E-02	-5.8128E+00	18	4.0708E+01	-1.5566E+01	3.3816E+00
16	18	4.0708E+01	-1.5566E+01	3.4246E+00	5	4.2793E+01	-3.3236E+01	3.2753E+01
17	5	3.3236E+01	6.3394E+01	3.2796E+01	19	3.3236E+01	2.7094E+01	-2.9415E+01
18	19	3.3236E+01	2.7094E+01	-2.9415E+01	20	3.3236E+01	-9.2057E+00	-4.1714E+01
19	20	3.3236E+01	-9.2057E+00	-4.1714E+01	21	3.3236E+01	-4.5506E+01	-4.0995E+00
20	21	3.3236E+01	-4.5506E+01	-4.0995E+00	6	3.3236E+01	-8.1806E+01	8.3427E+01
21	6	3.3236E+01	8.1806E+01	8.3427E+01	22	3.3236E+01	4.5506E+01	-4.0995E+00
22	22	3.3236E+01	4.5506E+01	-4.0995E+00	23	3.3236E+01	9.2057E+00	-4.1714E+01
23	23	3.3236E+01	9.2057E+00	-4.1714E+01	24	3.3236E+01	-2.7094E+01	-2.9415E+01
24	24	3.3236E+01	-2.7094E+01	-2.9415E+01	1	3.3236E+01	-6.3394E+01	3.2796E+01
25	3	7.6518E+01	-1.4346E-14	-3.0336E-14	25	7.8603E+01	-1.4346E-14	-1.2941E-14
26	25	7.8603E+01	-1.4346E-14	-1.2941E-14	26	8.0689E+01	-1.4346E-14	4.4541E-15
27	26	8.0689E+01	-1.4346E-14	4.4541E-15	27	8.2774E+01	-1.4346E-14	2.1849E-14
28	27	8.2774E+01	-1.4346E-14	2.1849E-14	6	8.4860E+01	-1.4346E-14	3.9244E-14

1.5.5 The Structural Design Calculation of Case-3 (at Inspection)

1) Frame of the design structure

Frame of the design structure is the same structure as that of design case-1.

2) Load calculation (per 1m unit length)

Load calculations are the same calculations as those of case-1 excluding a part that the internal water loads are no considered(=0).

3) The load diagram

The load diagram is shown in Fig 43.

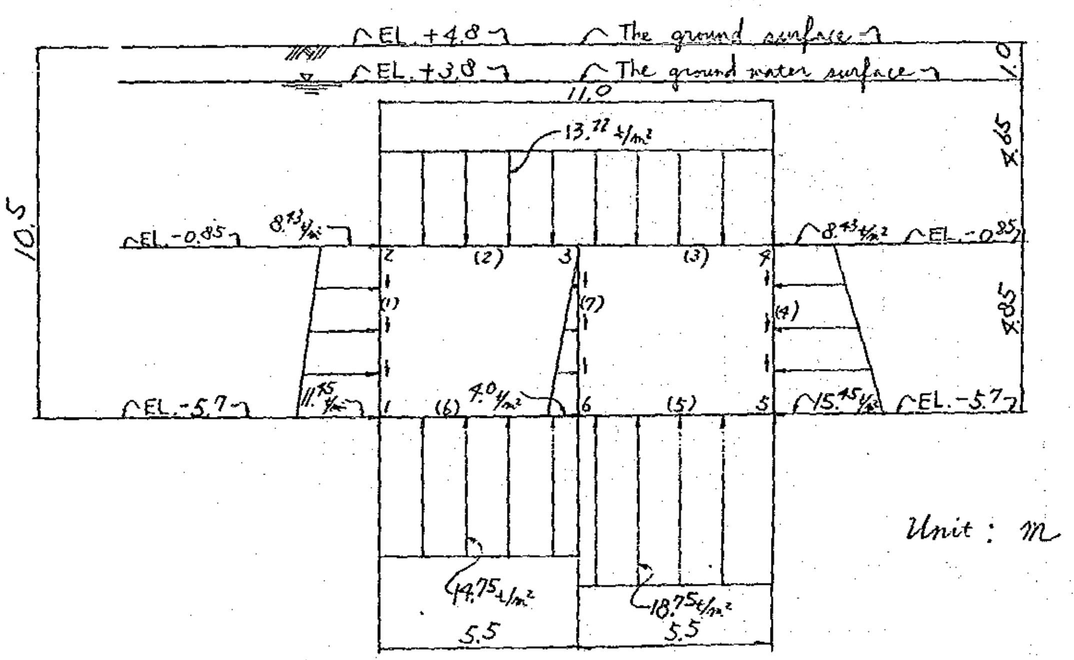


Fig 43. The load diagram

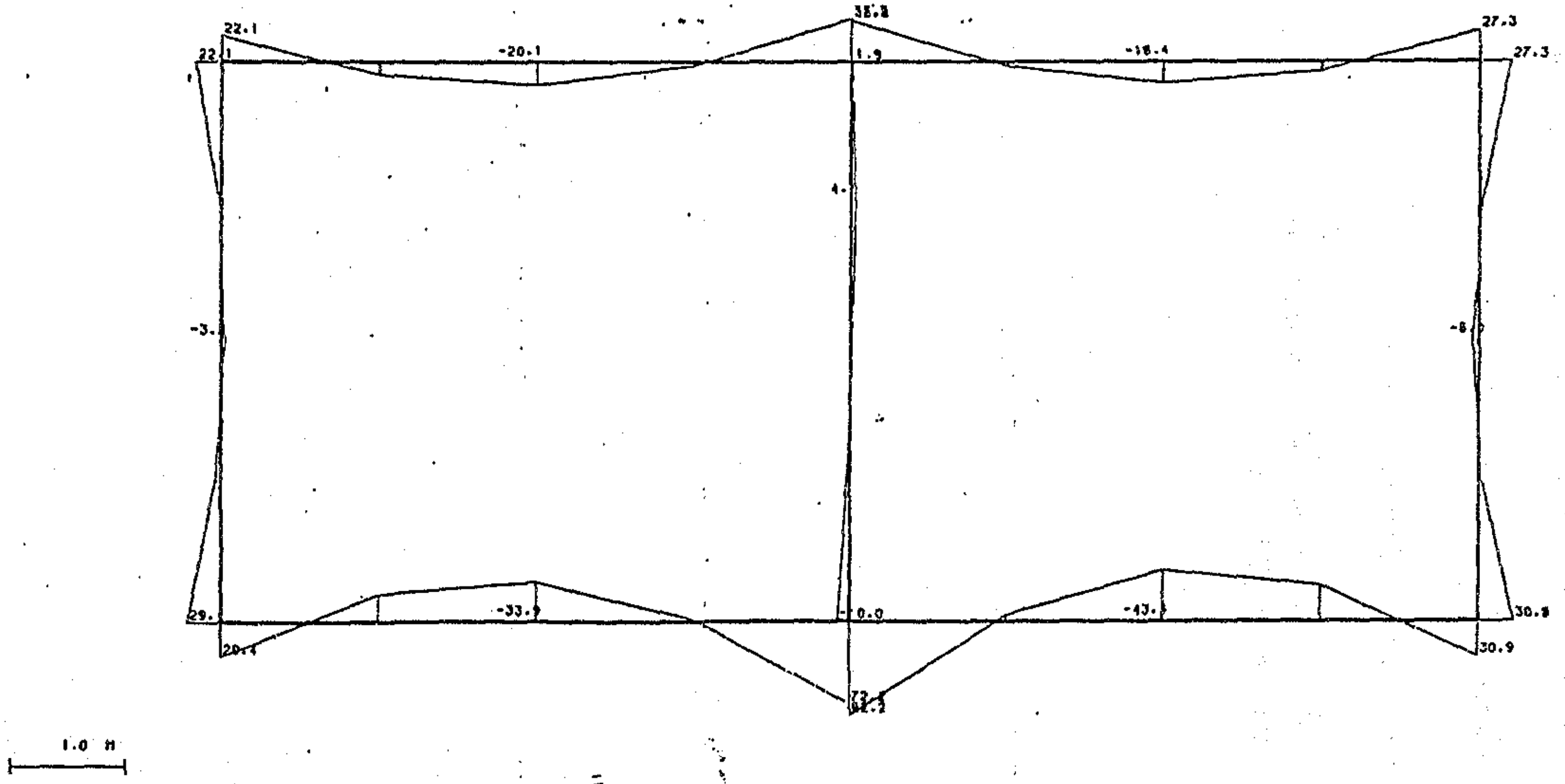
4) Input data for the sectional dimensions

Input data for the sectional dimensions are the same values as those of design case−1.

5) The coputer calculation results

The computer calculation results are shown in the following figures and Table (Fig 44−46, Table 17).

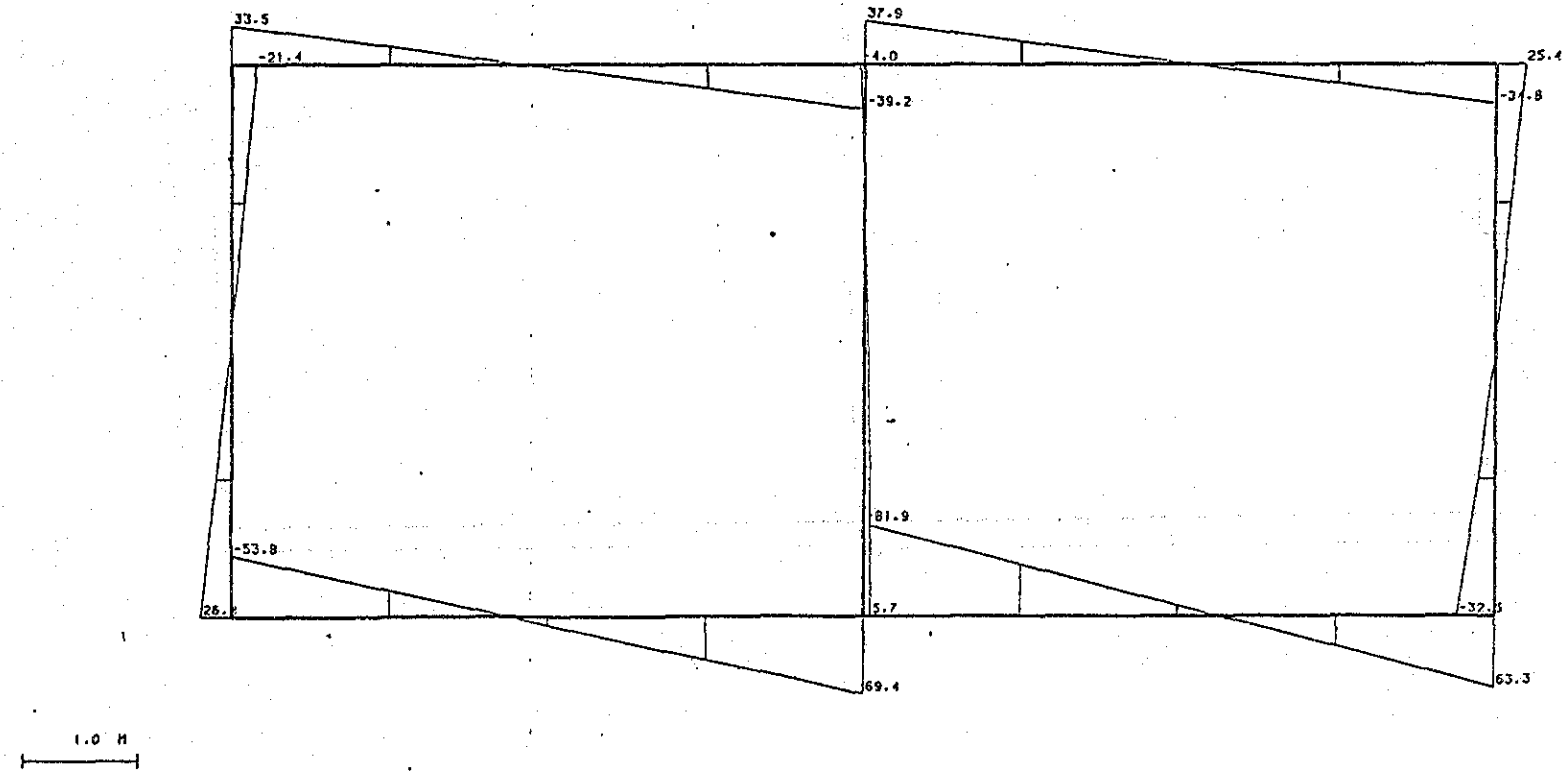
CONNECTED CULVERT AT PUMP PIT CASE-3 (INSPECTION) BENDING MOMENT



(TON*M)

Fig 44. The bending moment diagram

CONNECTED CULVERT AT PUMP PIT CASE-3(INSPECTION) SHEARING FORCE



(TON)

Fig 45. The shearing force diagram

CONNECTED CULVERT AT PUMP PIT CASE-3 (INSPECTION) AXIAL FORCE

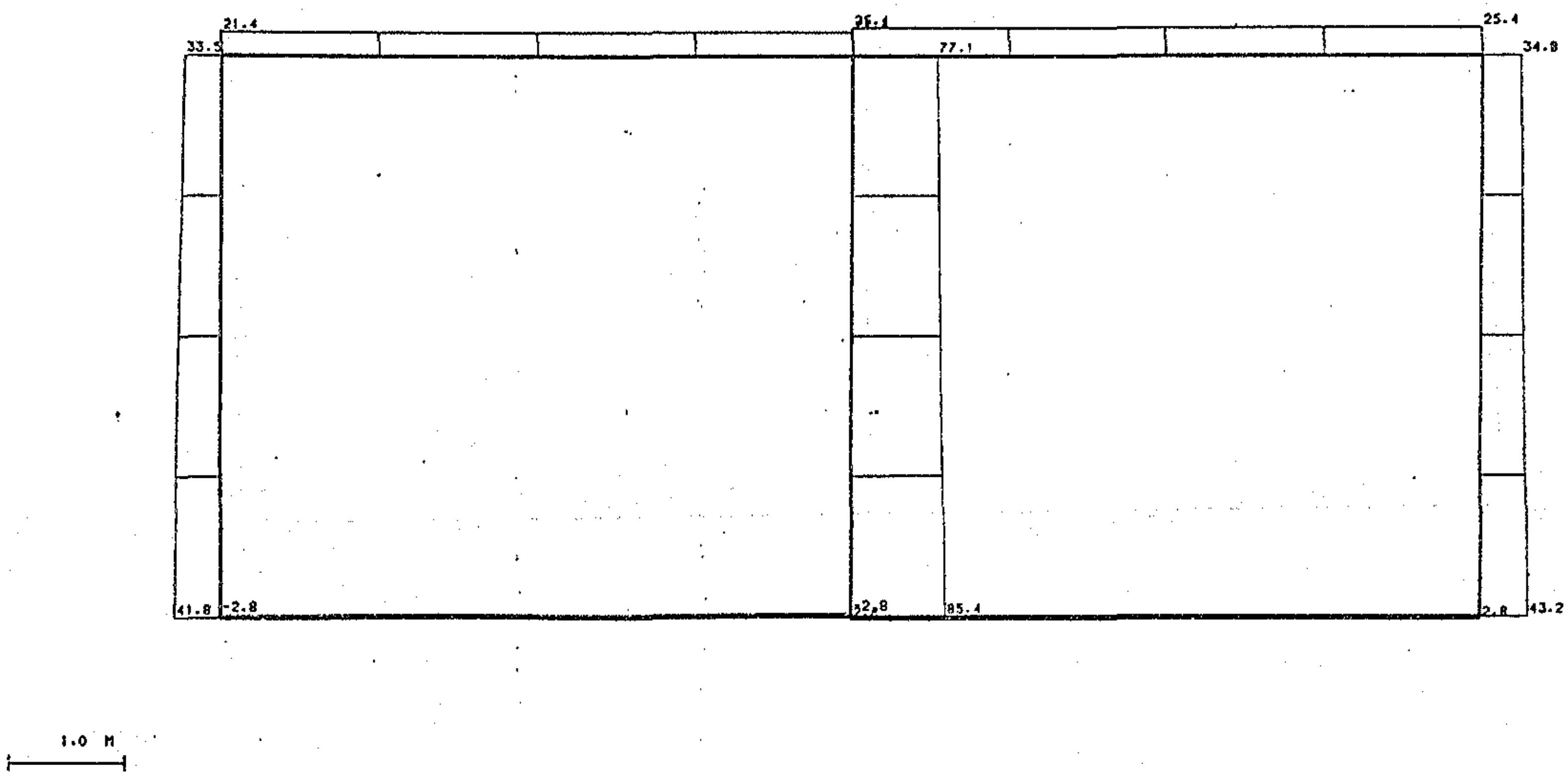


Fig 46. The axial force diagram

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Table 17. The calculation results of the sectional forces (Inspection)

** ELEMENTAL FORCES **

ELEM	I-END	AXIAL	SHEAR	MOMENT	J-END	AXIAL	SHEAR	MOMENT
1	1	4.1848E+01	2.6834E+01	2.9385E+01	7	3.9762E+01	1.3409E+01	5.0988E+00
2	7	3.9762E+01	1.3409E+01	5.0803E+00	8	3.7677E+01	8.9877E-01	-2.4826E+00
3	8	3.7677E+01	8.9877E-01	-3.5011E+00	9	3.5591E+01	-1.0696E+01	2.5493E+00
4	9	3.5591E+01	-1.0696E+01	2.5308E+00	2	3.3506E+01	-2.1375E+01	2.2085E+01
5	2	2.1375E+01	3.3506E+01	2.2066E+01	10	2.1375E+01	1.5328E+01	-1.1507E+01
6	10	2.1375E+01	1.5328E+01	-1.1507E+01	11	2.1375E+01	-2.8492E+00	-2.0087E+01
7	11	2.1375E+01	-2.8492E+00	-2.0087E+01	12	2.1375E+01	-2.1027E+01	-3.6721E+00
8	12	2.1375E+01	-2.1027E+01	-3.6721E+00	3	2.1375E+01	-3.9204E+01	3.7737E+01
9	3	2.5386E+01	3.7901E+01	3.5847E+01	13	2.5386E+01	1.9724E+01	-3.7700E+00
10	13	2.5386E+01	1.9724E+01	-3.7700E+00	14	2.5386E+01	1.5464E+00	-1.8393E+01
11	14	2.5386E+01	1.5464E+00	-1.8393E+01	15	2.5386E+01	-1.6631E+01	-8.0225E+00
12	15	2.5386E+01	-1.6631E+01	-8.0225E+00	4	2.5386E+01	-3.4809E+01	2.7342E+01
13	4	3.4809E+01	2.5386E+01	2.7342E+01	16	3.6894E+01	1.4100E+01	3.1459E+00
14	16	3.6894E+01	1.4100E+01	3.1889E+00	17	3.8980E+01	6.8711E-01	-6.0340E+00
15	17	3.8980E+01	6.8711E-01	-5.9910E+00	18	4.1065E+01	-1.4854E+01	2.3397E+00
16	18	4.1065E+01	-1.4854E+01	2.3827E+00	5	4.3151E+01	-3.2523E+01	3.0847E+01
17	5	2.8446E+00	6.3270E+01	3.0890E+01	19	2.8446E+00	2.6970E+01	-3.1150E+01
18	19	2.8446E+00	2.6970E+01	-3.1150E+01	20	2.8446E+00	-9.3298E+00	-4.3278E+01
19	20	2.8446E+00	-9.3298E+00	-4.3278E+01	21	2.8446E+00	-4.5630E+01	-5.4929E+00
20	21	2.8446E+00	-4.5630E+01	-5.4929E+00	6	2.8446E+00	-8.1930E+01	8.2204E+01
21	6	-2.8446E+00	6.9381E+01	7.2183E+01	22	-2.8446E+00	3.8581E+01	-2.0415E+00
22	22	-2.8446E+00	3.8581E+01	-2.0415E+00	23	-2.8446E+00	7.7814E+00	-3.3916E+01
23	23	-2.8446E+00	7.7814E+00	-3.3916E+01	24	-2.8446E+00	-2.3019E+01	-2.3440E+01
24	24	-2.8446E+00	-2.3019E+01	-2.3440E+01	1	-2.8446E+00	-5.3819E+01	2.9385E+01
25	3	7.7106E+01	-4.0109E+00	1.8892E+00	25	7.9191E+01	2.3287E-01	4.0226E+00
26	25	7.9191E+01	2.3287E-01	4.0571E+00	26	8.1277E+01	3.2641E+00	1.7901E+00
27	26	8.1277E+01	3.2641E+00	1.8146E+00	27	8.3362E+01	5.0829E+00	-3.3928E+00
28	27	8.3362E+01	5.0829E+00	-3.3683E+00	6	8.5448E+01	5.6891E+00	-1.0046E+01

MESSAGE SUMMARY: MESSAGE NUMBER - COUNT

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1.5.6 The Stress Calculation

Before calculating the stress, the sectional force for the structural design is determined by selecting one case among three design cases from a view point of the safety design, and the stress calculations are executed, so the stress calculation results are indicated in Table 18 and the arrangement of the reinforcing bars is shown in Fig 47.

〔Pump Pit〕

〔Section II〕
Connected Culvert

Table.18-1 The Calculation Results of The Stress

Member	Point	The Sectional Force: M [kg·cm]	The Sectional Force: N [kg]	The Sectional Force: S [kg]	The Sectional Dimensions: B [cm]	H [cm]	d [cm]	d' [cm]	The Arrangement of Reinforcing Bars: D [mm]	Pitch [mm]	As [cm²] A's [cm²]	The strees (kg/cm²): σ_b	σ_c	τ	Remarks
(1)	1	[Case-2] 3 280 000	[Case-2] 42 800	[Case-2] 33 200	100	80	70	20	D22 D19	150 300	25.8 9.54	1260	53.7	4.7	σ_{ba}=2000 kg/cm² σ_{ca}=87.5 kg/cm² τ_a=10.6 kg/cm²
	Center	[Case-2] -580 000	[Case-2] 38 700	0	100	70	60	10	D19 D22	300 150	9.54 25.8	135	10.7	0	DITTO
	2	[Case-1] 2 460 000	[Case-1] 34 100	[Case-1] 22 500	100	80	70	20	D22 D19	150 300	25.8 9.54	913	40.2	3.2	σ_{ba}=1600 kg/cm² σ_{ca}=70 kg/cm² τ_a=8.5 kg/cm²
(2)	2	[Case-1] 2 460 000	[Case-1] 22 500	[Case-1] 34 100	100	80	70	20	D22 D22	150 150	25.8 25.8	1113	39.7	4.9	DITTO
	Center	[Case-1] -1 930 000	[Case-1] 22 500	0	100	70	60	10	D22 D22	150 150	25.8 25.8	974	36.8	0	DITTO
	3	[Case-1] 3 690 000	[Case-1] 22 500	[Case-1] 38 600	100	80	70	20	D25 D22	150 150	33.8 25.8	1452	53.9	5.5	DITTO
(3)	3	[Case-1] 3 690 000	[Case-1] 22 500	[Case-1] 38 600	100	80	70	20	D25 D22	150 150	33.8 25.8	1452	53.9	5.5	DITTO
	Center	[Case-1] -1 930 000	[Case-1] 22 500	[Case-1] 0	100	70	60	10	D22 D22	150 150	25.8 25.8	974	36.8	0	DITTO
	4	[Case-1] 2 460 000	[Case-1] 22 500	[Case-1] 34 100	100	80	70	20	D22 D22	150 150	25.8 25.8	1113	39.7	4.9	DITTO
(4)	4	[Case-1] 2 460 000	[Case-1] 34 100	[Case-1] 22 500	100	80	70	20	D22 D19	150 300	25.8 9.54	913	40.2	3.2	DITTO
	Center	[Case-2] -580 000	[Case-2] 38 700	0	100	70	60	10	D19 D22	300 150	9.54 25.8	135	10.7	0	σ_{ba}=2000 kg/cm² σ_{ca}=87.5 kg/cm² τ_a=10.6 kg/cm²
	5	[Case-2] 3 280 000	[Case-2] 42 800	[Case-2] 33 200	100	80	70	20	D22 D19	150 300	25.8 9.54	1260	53.7	4.7	DITTO

Where
Mb : Bending moment
N : Axial force
S : Shearing force
B : The Width
H : The Height
d : The effective height
d' : The covering of compression bar
D : Diameter of bars
As : The area of tension bars
A's : The area of compression bars
σ_b : The bending stress
σ_c' : The compressive stress
τ : The shearing stress

[Pump Pit]

Table. 18-2 The Calculation Results of The Stress

(Section II)
Connected Culvert

Member	Point	The Sectional Force M [kg·cm]	The Sectional Force N [kg]	The Sectional Force S [kg]	The Sectional Dimensions B [cm]	The Sectional Dimensions H [cm]	The Sectional Dimensions d [cm]	The Sectional Dimensions d' [cm]	The Arrangement of Reinforcing Bars D [mm]	Pitch [mm]	As [cm²] A's [cm²]	The strees (kg/cm²) σb	σc	τ	Remarks
(5)	5	[Case-2] 3 280 000	[Case-2] 33 200	[Case-2] 63 400	100	110	100	10	Φ25 Φ25	150 150	33.8 33.8	648	26.0	6.3	σba=2000kg/cm² σca=87.5kg/cm² τa=10.6kg/cm²
	Center	[Case-1] -3 580 000	[Case-1] 25 700	[Case-1] 0	100	100	90	10	Φ25 Φ25	150 150	33.8 33.8	944	31.4	0	σba=1600kg/cm² σca=70.7kg/cm² τa=8.5kg/cm²
	6	[Case-1] 7 160 000	[Case-1] 25 700	[Case-1] 69 900	100	110	100	10	Φ29 Φ25	150 150	42.9 33.8	1565	78.2	7.0	DITTO
(6)	6	[Case-1] 7 160 000	[Case-1] 25 700	[Case-1] 69 900	100	110	100	10	Φ29 Φ25	150 150	42.9 33.8	1565	78.2	7.0	DITTO
	Center	[Case-1] -3 580 000	[Case-1] 25 700	[Case-1] 0	100	100	90	10	Φ25 Φ25	150 150	33.8 33.8	944	31.4	0	DITTO
	1	[Case-2] 3 280 000	[Case-2] 33 200	[Case-2] 63 400	100	110	100	20	Φ25 Φ25	150 150	33.8 33.8	648	26.0	6.3	σba=2000kg/cm² σca=87.5kg/cm² τa=10.6kg/cm²
(7)	3	[Case-3] 190 000	[Case-3] 77 100	[Case-3] 4 000	100	90	80	20	Φ25 Φ25	300 300	16.9 16.9	134	9.6	0.5	As+As' ≧0.004 B·H =28cm²
	Center	[Case-3] 410 000	[Case-3] 79 200	[Case-3] 200	100	70	60	10	Φ25 Φ25	300 300	16.9 16.9	207	15.1	0	DITTO
	6	[Case-3] -1 000 000	[Case-3] 85 400	[Case-3] 5 700	100	90	80	20	Φ25 Φ25	300 300	16.9 16.9	194	16.1	0.7	DITTO

Where
Mb : Bending moment
N : Axial force
S : Shearing force
B : The Width
H : The Height
d : The effective height
d' : The covering of compression bar
D : Diameter of bars
As : The area of tension bars
A's : The area of compression bars
σ_b : The bending stress
σ_c' : The compressive stress
τ : The shearing stress

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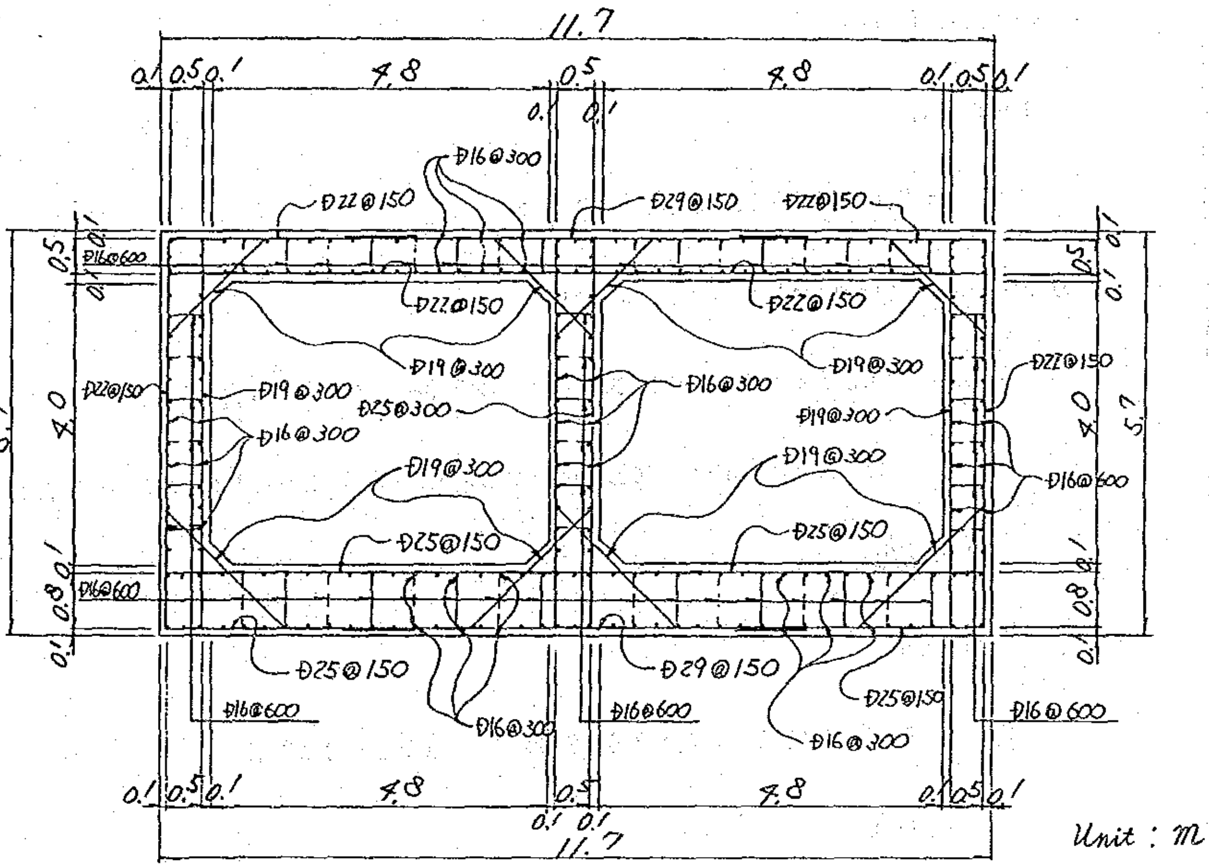

Fig 47. The arrangement of reinforcing bars