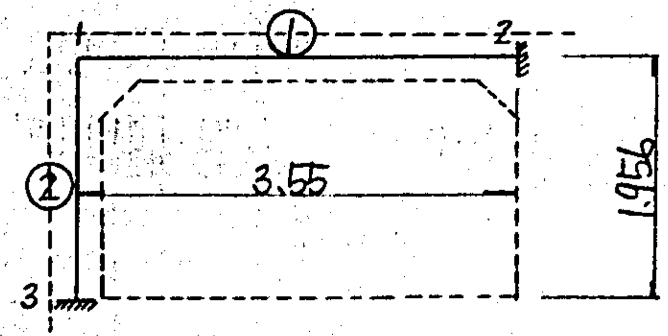
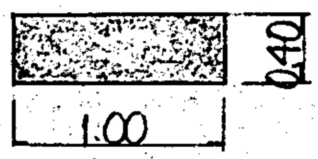
[2] FUNDAMENTAL CALCULATION

(1) FRAME



(2) AREA AND MOMENT OF INERTIA

UPPER SLAB (①)

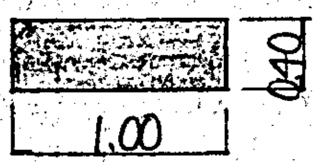


$A = 1.00 \times 0.40 = 0.400^{m^2}$

$I = 1/12 \times 1.00 \times 0.40^3$

$= 0.00533^{m^4}$

WALL (②)



$A = 1.00 \times 0.40 = 0.400^{m^2}$

$I = 1/12 \times 1.00 \times 0.40^3$

$= 0.00533^{m^4}$

(3) YOUNG'S MODULUS

$E_c = 2.55 \times 10^5 \ kg/cm^2 \quad (\sigma_{ck} = 210 \ kg/cm^2)$

3 CALCULATION OF LOADS

(1) DEAD LOAD

SURCHARGE $= 1.00^{t/m^2}$

WEIGHT OF UPPER SLAB $0.40 \times 2.5^{t/m^3} = 1.00$ 〃

$\omega_1 = 2.00^{t/m^2}$

WEIGHT OF HAUNCH $P = 0.30 \times 0.30 \times 1/2 \times 2.5^{t/m^3}$

$= 0.11^{t}$

WEIGHT OF WALL $\omega_2 = 0.40 \times 2.5^{t/m^3} = 1.00^{t/m^2}$

(2) EARTH PRESSURE

STATIC EARTH PRESSURE $K_0 = 0.5$

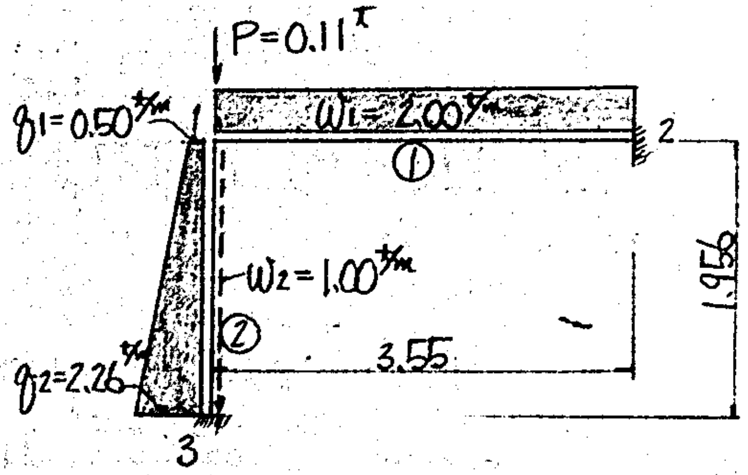
SURCHARGE $\omega = 1.00^{t/m^2}$

$q_1 = 1.00^{t/m^2} \times 0.5 = 0.50^{t/m^2}$

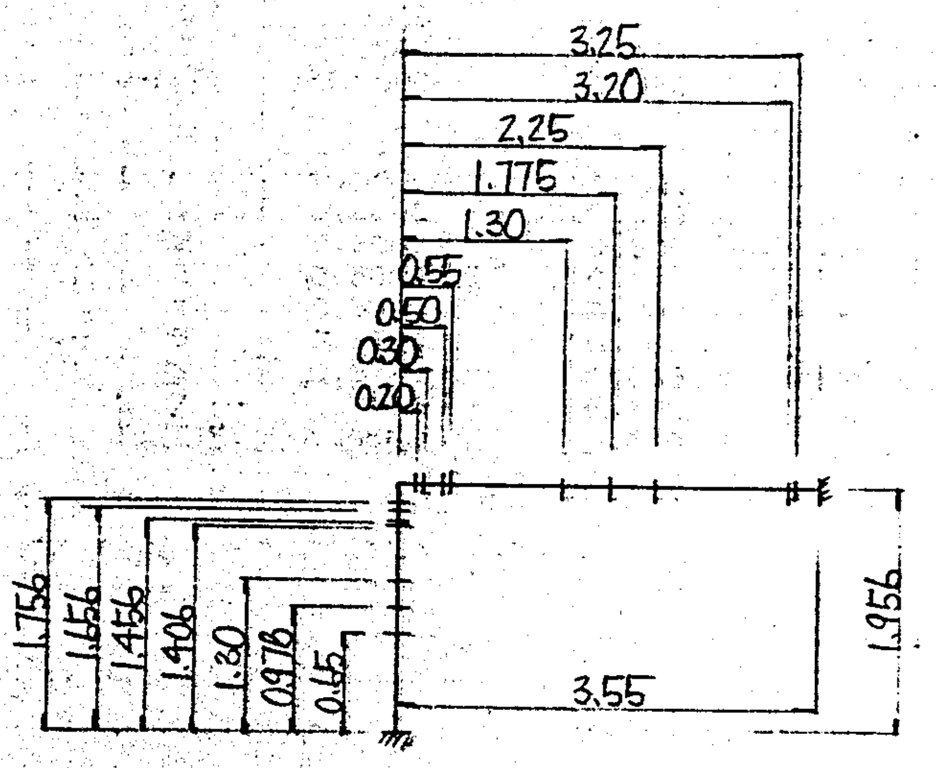
$q_2 = 0.50 + 1.956 \times 1.8^{t/m^2} \times 0.5$

$= 0.50 + 1.76 = 2.26^{t/m^2}$

(3) DIAGRAM OF LOADING



(4) POINTS OF CALCULATION



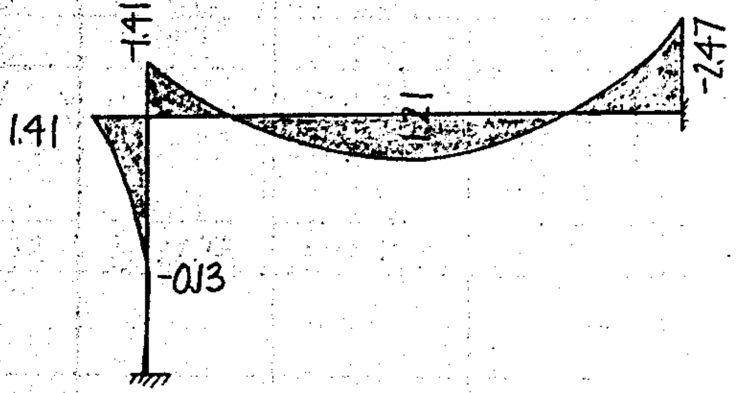
4 LIST OF MEMBER FORCE

UNIT : ton, ton·meter

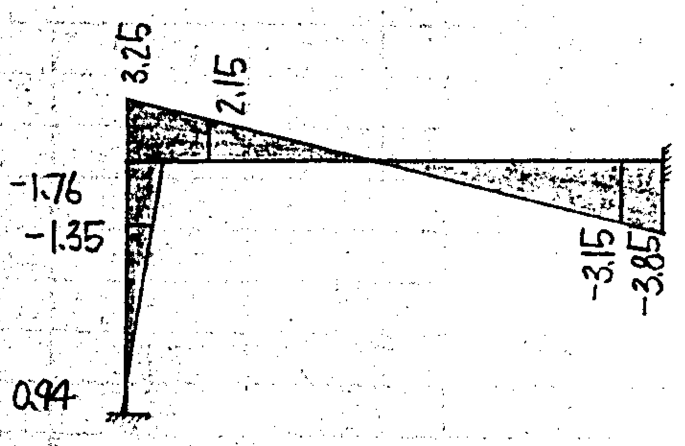
MEMBER	DISTANCE	M	S	N
1 [1-- 2]				
I-SIDE	0.0000	-1.409	3.250	-1.758
1	0.2000	-0.799	2.850	-1.758
2	0.3000	-0.524	2.650	-1.758
3	0.5000	-0.034	2.250	-1.758
4	0.5500	0.075	2.150	-1.758
5	1.3000	1.126	0.650	-1.758
6	1.7750	1.209	-0.299	-1.758
7	2.2500	0.841	-1.249	-1.758
8	3.2000	-1.247	-3.149	-1.758
9	3.2500	-1.407	-3.249	-1.758
J-SIDE	3.5500	-2.472	-3.849	-1.758
2 [1-- 3]				
I-	0.0000	1.409	-1.758	-3.360
1	0.2000	1.069	-1.640	-3.560
2	0.3000	0.908	-1.568	-3.660
3	0.5000	0.611	-1.396	-3.860
4	0.5500	0.542	-1.347	-3.910
5	0.6560	0.405	-1.236	-4.016
6	0.9780	0.069	-0.839	-4.338
7	1.3060	-0.126	-0.338	-4.666
J-SIDE	1.9560	0.048	0.940	-5.316

« DIAGRAM OF FORCES »

* MOMENT DIAGRAM (UNIT ; tm)



* SHEAR DIAGRAM (UNIT ; t)



5 EXAMINATION OF SAFETY

	UPPER SLAB			WALL		
	1	2	1~2	1		
M (tm)	1.41	2.47	1.21	1.41		
N (t)	1.76	1.76	1.76	3.36		
S (t)						
b (cm)	100	100	100	100		
h (cm)	50	50	40	50		
d (cm)	43	43	33	43		
d' (cm)	7	7	7	7		
As (cm²)	D13−3.33 4.21	D13−3.33 4.21	D13−3.33 4.21	D13−3.33 4.21		
p	0.00098	0.00098	0.00127	0.00098		
As' (cm²)						
p'						
e=M/N (cm)	80.1	140.3	68.7	41.9		
e=M/N+u (cm)	98.1	158.3	81.7	59.9		
e=M/N−u (cm)						
e/h						
d/e	0.438	0.271	0.403	0.717		
d'/h						
d'/d						
Ne/bd² (kg/cm²)	0.933	1.507	1.321	1.089		
k						
c	0.093	0.084	0.101	0.115		
j						
1/Lc						
1/Ls						
β=σs/σc	60.12	68.32	53.55	44.27		
σc (kg/cm²)	10.0	17.8	13.0	9.4		
σs (kg/cm²)	602	1217	697	416		
τ (kg/cm²)						
σsa (kg/cm²)	80	〃	〃	〃		
σca (kg/cm²)	1400	〃	〃	〃		
τa (kg/cm²)						

CALCULATION OF SHEARING STRESS

* UPPER SLAB (AT POINT OF H/2)

$$\tau = \frac{S}{b\,d}$$

$$= \frac{3.15 \times 10^3}{100 \times 33.0} = 0.95 \ kg/cm^2$$

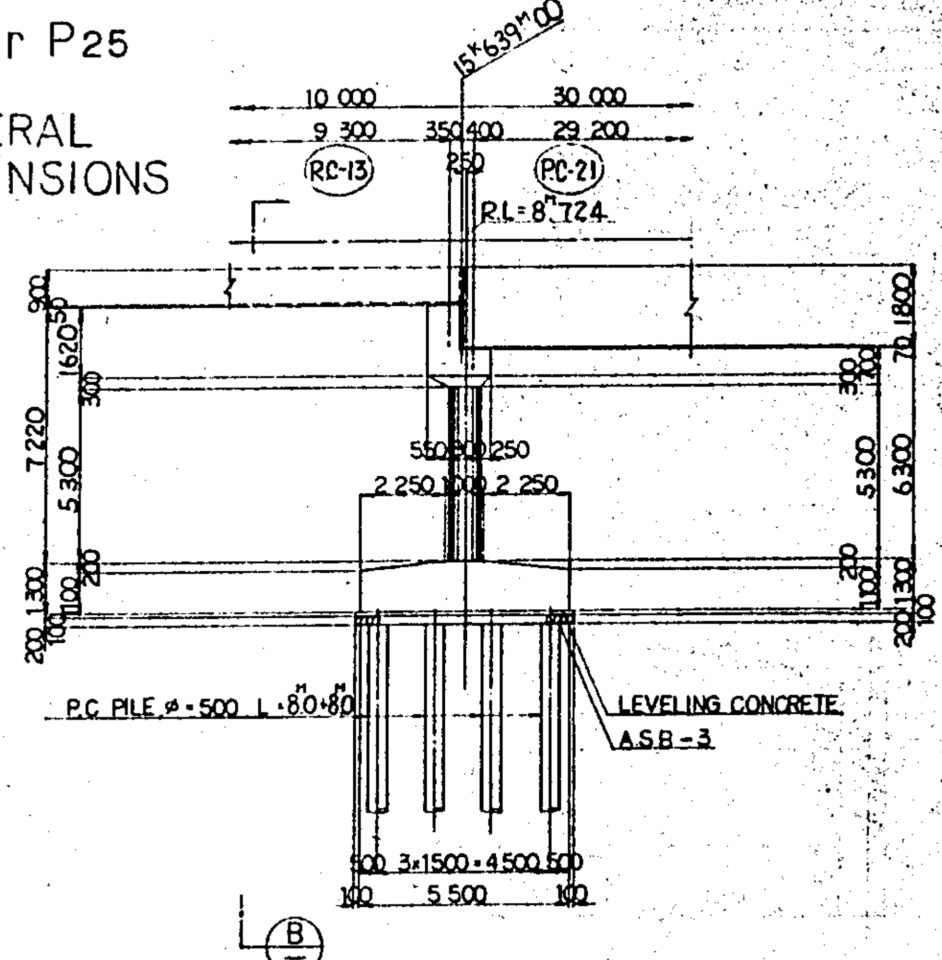
$$< \tau_{a1} = 3.7 \ ''$$

* WALL (AT POINT OF H/2)

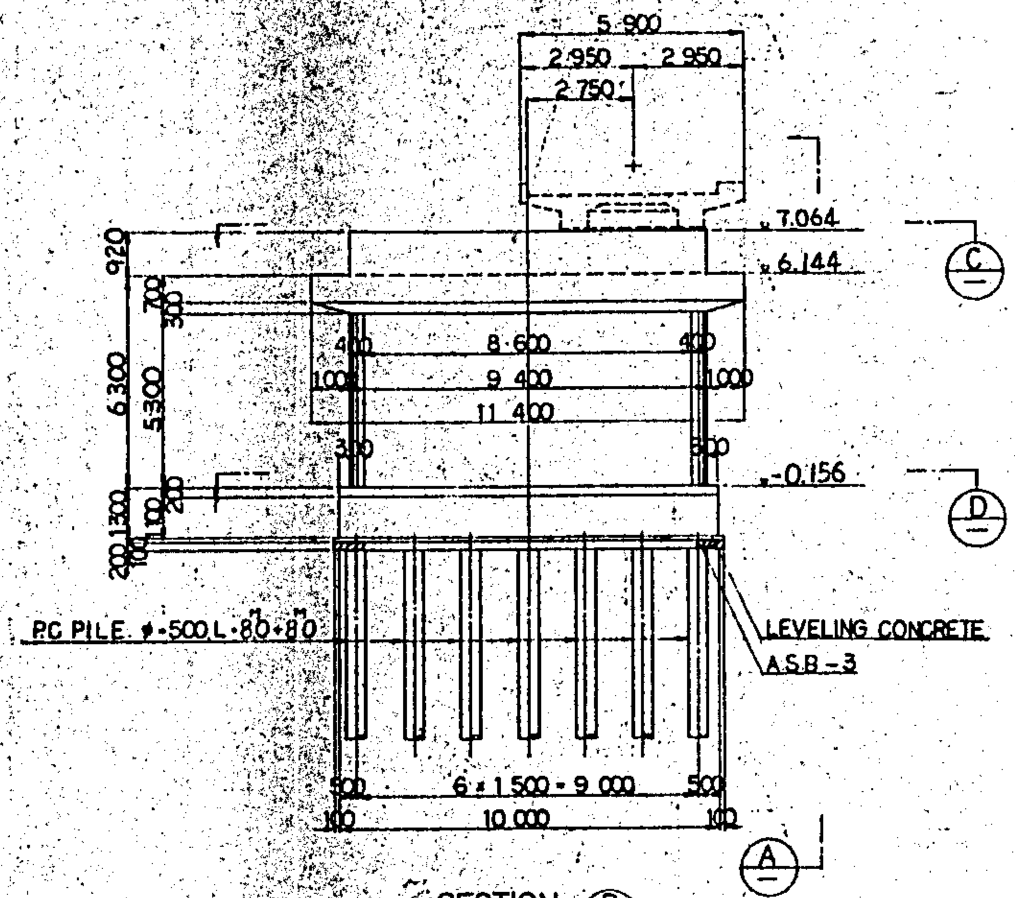
$$\tau = \frac{1.35 \times 10^3}{100 \times 33.0} = 0.41 \ kg/cm^2 < \tau_{a1}$$

§8. Pier P25

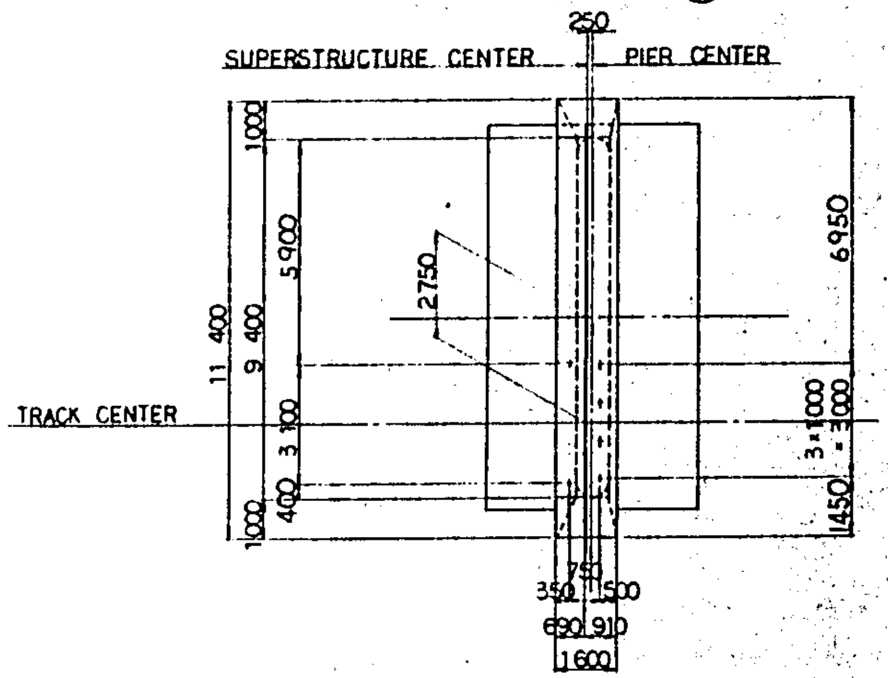
1 GENERAL DIMENSIONS



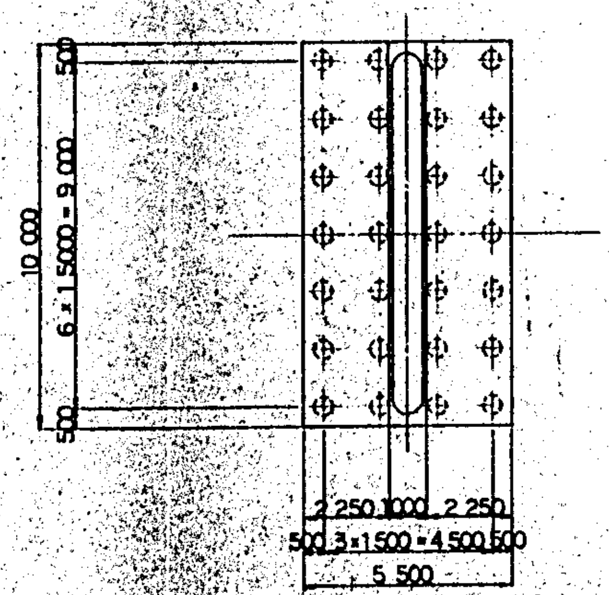
SECTION (A)



SECTION (B)

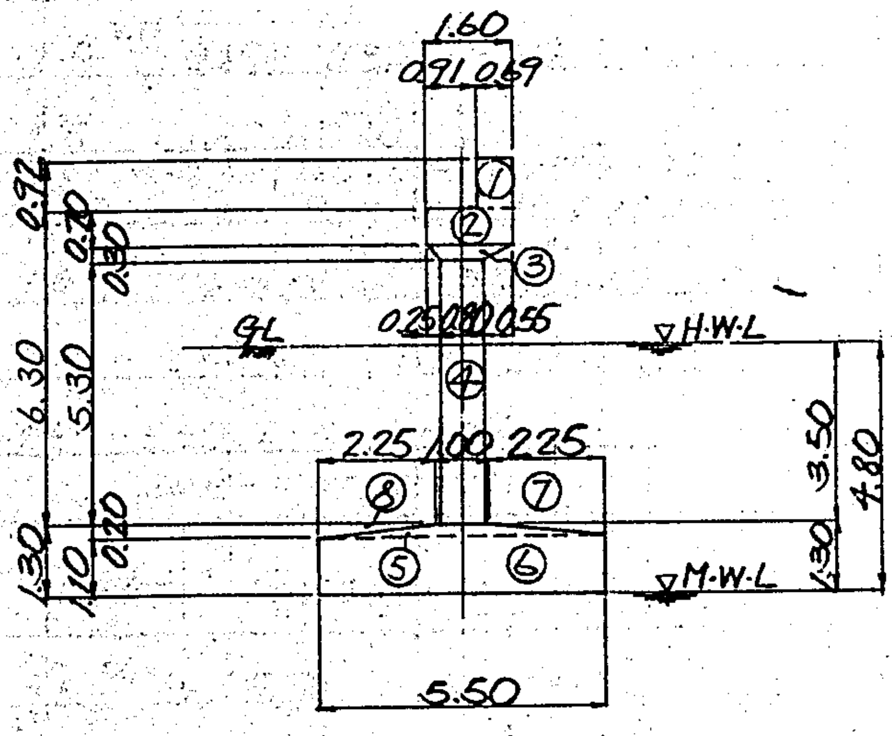


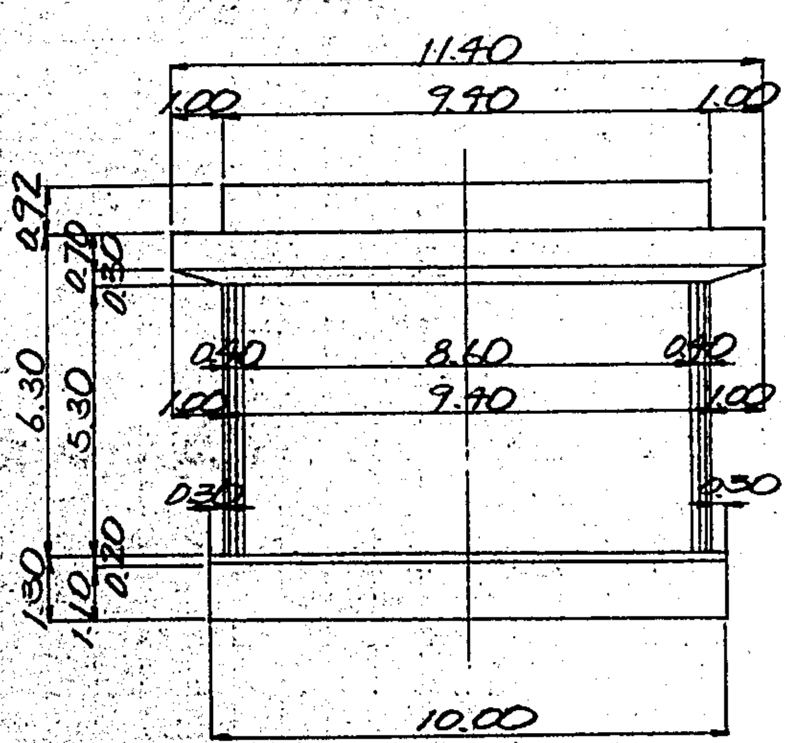
SECTION (C)



SECTION (D)

[2] OWN WEIGHT OF SUBSTRUCTURE AND WEIGHT OF EARTH COVER.





1. OWN WEIGHT OF SUBSTRUCTURE AND WEIGHT OF EARTH COVER

SUBSTRUCTURE

		t
①	$2.5^{t/m^3} \times 0.69 \times 0.92 \times 9.40$	14.92
②	$2.5'' \times 1.60 \times 0.70 \times 11.40$	" 31.92
③	$2.5'' \times 0.30/6 \times \{1.60 \times 11.40 + 0.80 \times 9.40 + (1.60 + 0.80)(11.40 + 9.40)\}$	" 9.46
④	$2.5'' \times (1/4 \times \pi \times 0.80^2 + 0.80 \times 8.60) \times 5.30$ (ς 7.383)	" 97.82
⑤	$2.5'' \times 1/2 \times (1.00 + 5.50) \times 0.20 \times 10.00$	" 16.25
⑥	$2.5'' \times 5.50 \times 1.10 \times 10.00$	" 151.25
	SUB-TOTAL	321.62 t

EARTH COVER

		t
⑦	$1.8^{t/m^3} \times (5.50 \times 10.00 - 7.383) \times 3.50$	299.99
⑧	$1.8'' \times 1/2 \times 2.25 \times 0.20 \times 10.00 \times 2$	" 8.10
	SUB-TOTAL	308.09 t

TOTAL

$$321.62 + 308.09 = 629.71^{t}$$

2. BUOYANCY

$$1.0^{t/m^3} \times 5.50 \times 10.00 \times 4.80 = 264.00^{t}$$

3. HORIZONTAL FORCES DUE TO EARTHQUAKE LOAD

	N (t)	y (m)	N·y (t·m)
①	14.92	8.06	120.26
②	31.92	7.25	231.42
③	9.46	6.767	64.02
④	97.82	3.95	386.39
⑤	16.25	1.177	19.13
⑥	151.25	0.55	83.19
Σ	321.62	———	904.41

NOTE N: AXIAL FORCE

y: DISTANCE FROM THE BOTTOM OF FOOTING TO GRAVITY CENTER

4. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

$$y_e = \frac{N \cdot y}{N} = \frac{904.41}{321.62} = 2.812 \ ^{m}$$

$$P_E = 321.62 \times 0.10 = 32.16 \ ^{t}$$

$$M_o = 32.16 \times 2.812 = 90.43 \ ^{tm}$$

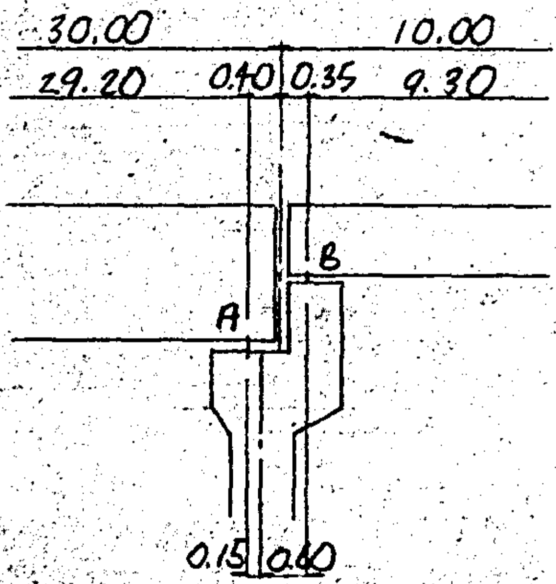
NOTE y_e : DISTANCE FROM THE BOTTOM OF FOOTING TO THE CENTER OF SUBSTRUCTURE.

P_E : HORIZONTAL FORCE DUE TO EARTHQUAKE LOAD

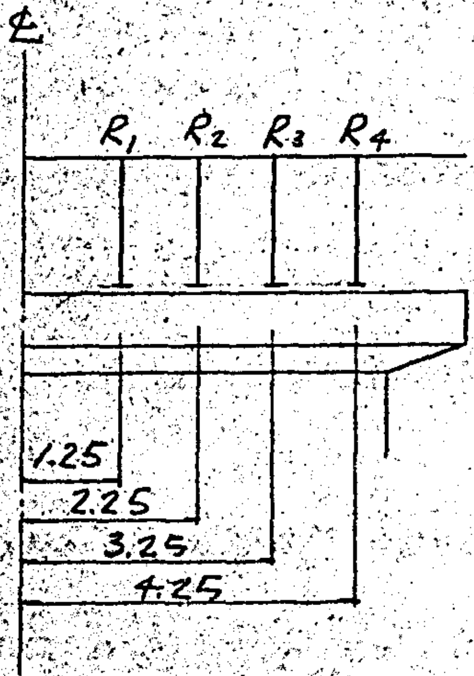
M_o : OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

3 REACTION FORCES TRANSMITTED FROM SUPERSTRUCTURE

1. REACTION FORCES DUE TO DEAD WEIGHT OF SUPERSTRUCTURE



1-1. REACTION FORCES ACTING AT BEARINGS - A



$R_1 = 70.17^t$

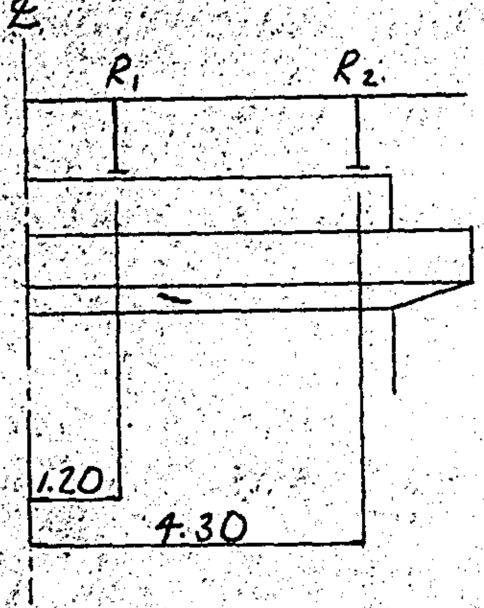
$R_2 = 70.17$ "

$R_3 = 70.17$ "

$R_4 = 73.36$ "

TOTAL $= 283.87^t$

1-2. REACTION FORCES ACTING AT BEARINGS-B



$R_1 = 34.00^t$
$R_2 = 34.00$ "
TOTAL $= 68.00^t$

1-3. SECTIONAL MOMENT AT THE CENTER OF PIER SHAFT DUE TO DEAD WEIGHT OF SUPERSTRUCTURE

SINGLE-TRACK LOADING FOR CALCULATION OF TRANSVERSAL STABILITY. DOUBLE-TRACK LOADING FOR CALCULATION OF LONGITUDINAL STABILITY

TRANSVERSAL DIRECTION

$M_1 = 70.17 \times (1.25 + 2.25 + 3.25) + 73.36 \times 4.25$
$+ 34.00 \times (1.20 + 4.30) = 972.43^{tm}$

LONGITUDINAL DIRECTION

$M_2 = (68.00 \times 0.60 - 283.87 \times 0.15) \times 2 = -3.56^{tm}$

1-4. HORIZONTAL FORCES DUE TO EARTHQUAKE ACTING ON DEAD WEIGHT OF SUPERSTRUCTURE

a) LONGITUDINAL DIRECTION

9.30 m - SPAN SIDE

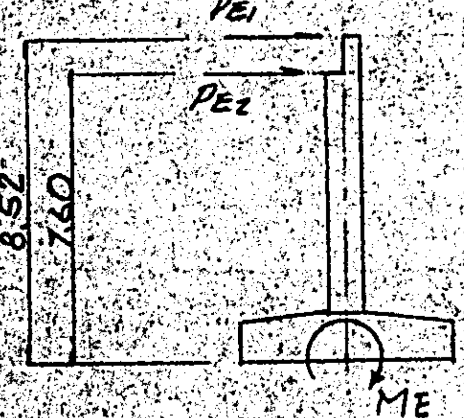
$P_{E_1} = 68.0 \times 2 \times 0.1 \times 0.55 = 7.48^t$

29.20 m - SPAN SIDE

$P_{E_2} = 283.87 \times 2 \times 0.1 - \frac{1}{2} \times 283.87 \times 0.1 = 42.58^t$

$\Sigma P_E = 7.48 + 42.58 = 50.06^t$

OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING



$M_E = 7.48 \times 8.52 + 42.58 \times 7.60 = 387.34^t$

b) TRANSVERSAL DIRECTION

9.30^m - SPAN SIDE

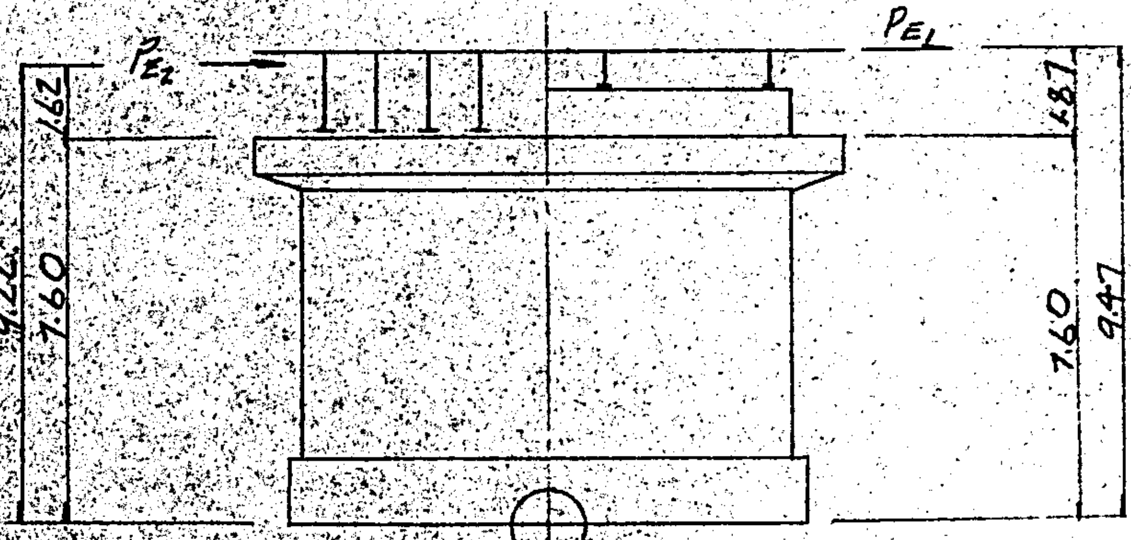
$P_{E1} = 68.00 \times 0.10 = 6.80^t$

29.20^m - SPAN SIDE

$P_{E2} = 283.87 \times 0.10 = 28.39^t$

$\Sigma P_E = 6.80 + 28.39 = 35.19^t$

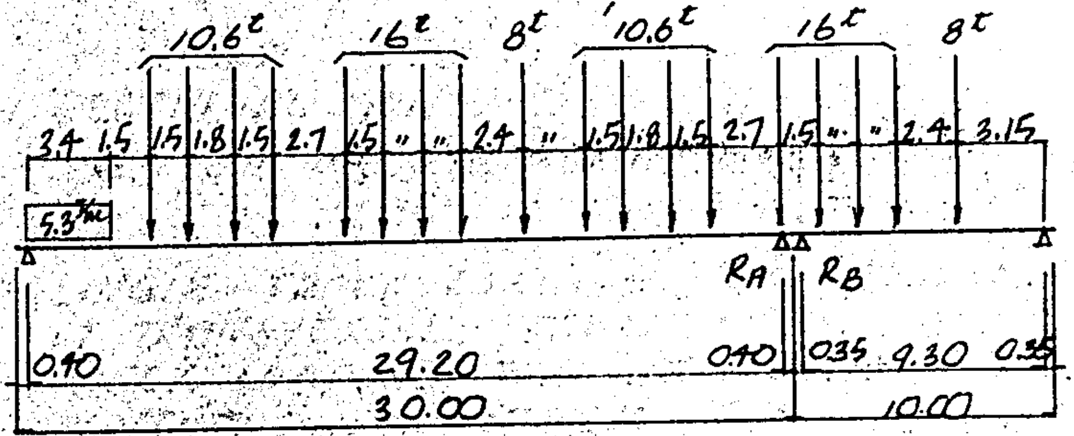
OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING



$M_E = 6.80 \times 9.47 + 28.39 \times 9.22 = 326.15^{tm}$

2. REACTION FORCES DUE TO LIVE LOAD PLUS IMPACT.

EQUIVALENT TO KS-16 LOADING.
CALCULATION IS CARRIED OUT UNDER THE LOADING CONDITION OF PRODUCING MAXIMUM REACTION FORCE ON PIER.



$$R_A = \frac{1}{29.20} \times (16 \times 29.20 + 10.6 \times 4 \times 24.10 + 8 \times 19.30 + 16 \times 4 \times 14.65 + 10.6 \times 4 \times 7.30 + 5.3 \times 3.40^2 \times 1/2)$$

$$= 100.04^t$$

$$R_B = \frac{1}{9.30} \times (16 \times 3 \times 7.05 + 8 \times 3.15) = 39.10''$$

$$139.14^t$$

IMPACT COEFFICIENT

29.20m - SPAN SIDE --- $i = 0.342$

9.30 - SPAN SIDE --- $i = 0.437$

LIVE LOAD PLUS IMPACT

$R(A+L) = 100.04 \times 1.342 = 134.25^{t}$

$R(B+L) = 39.10 \times 1.437 = 56.19$ "

TOTAL $= 190.44^{t}$

2-1. SECTIONAL MOMENT ACTING AT THE CENTER OF PIER SHAFT

SINGLE-TRACK LOADING FOR CALCULATION OF TRANSVERSAL STABILITY. DOUBLE-TRACK LOADING FOR CALCULATION OF LONGITUDINAL STABILITY,

TRANSVERSAL DIRECTION

$M_1 = 134.25 \times 1/4 \times (1.25 + 2.25 + 3.25 + 4.25)$

$+ 56.19 \times 1/2 \times (1.20 + 4.30)$

$= 523.71^{tm}$

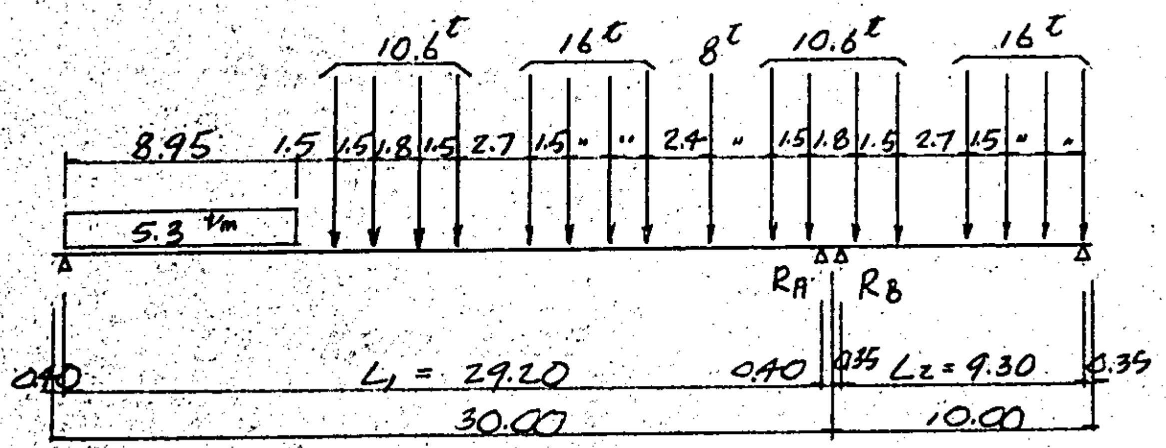
LONGITUDINAL DIRECTION

$M_2 = (56.19 \times 0.60 - 134.25 \times 0.15) \times 2$

$= 27.15^{tm}$

3. BRAKE LOAD AND TRACTION LOAD

UNDER THE LOADING CONDITION AS SHOWN BELOW



3-1. BRAKE LOAD

15% OF KS LOADING.

L1 - SPAN SIDE

$P_{B-1} = (16 \times 4 + 10.6 \times 6 + 8 \times 1 + 5.3 \times 8.95) \times 0.15 \times 1/2$

$= 13.73^t$

L2 - SPAN SIDE

$P_{B-2} = (16 \times 4 + 10.6 \times 2) \times 0.15 \times 0.55$

$= 7.03$

$\Sigma P_B = 13.73 + 7.03 = 20.76^t$

3-2. TRACTION LOAD

25% OF MOVING WHEEL AXLE LOAD OF KS LOADING

L1 - SPAN SIDE

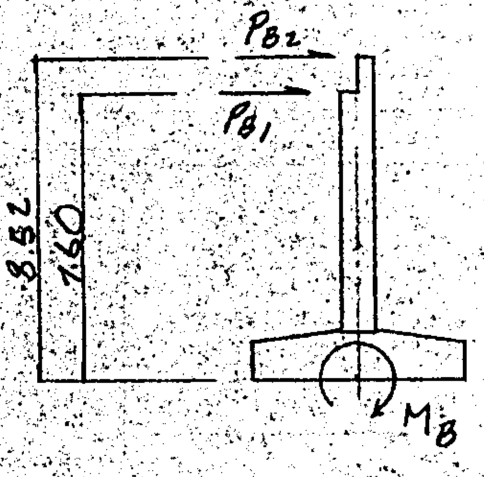
$P_{T-1} = 16 \times 4 \times 0.25 \times 1/2 = 8.00^t$

L2 - SPAN SIDE

$P_{T-2} = 16 \times 4 \times 0.25 \times 0.55 = 8.80^t$

$\Sigma P_T = 8.00 + 8.80 = 16.80^t < \Sigma P_B = 20.76^t$

3-3. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING



$M_B = 13.73 \times 7.60 + 7.03 \times 8.52 = 164.24^{tm}$

4. CENTRIFUGAL LOAD

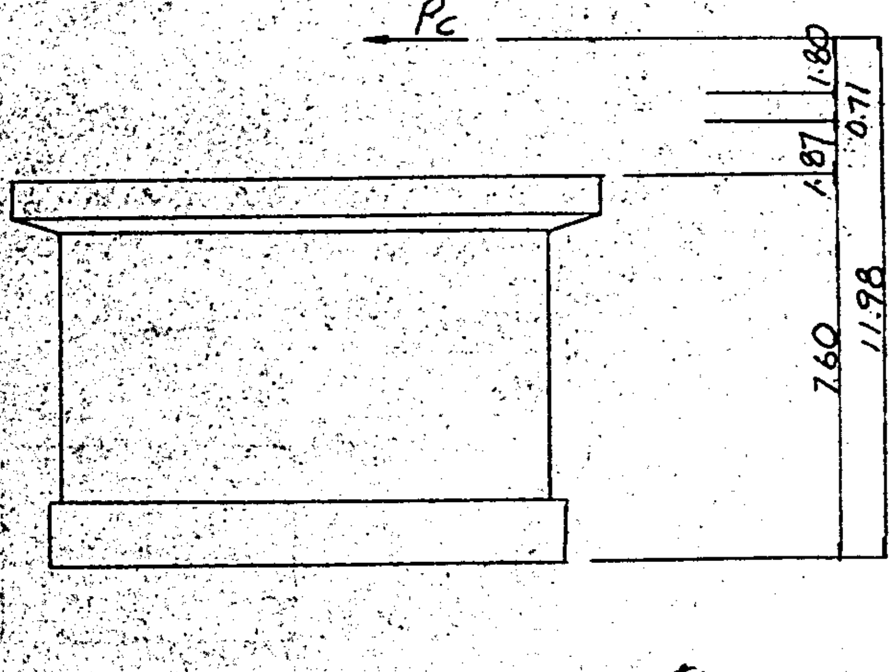
ASSUMED THAT THE LOAD IS EQUIVALENT TO THE LIVE (TRAIN) LOAD MULTIPLIED BY α AND IS ACTING TRASVERSALLY ON 1,8 m ABOVE THE TRACK LEVEL.

REFERENCE IS MADE TO THE LOADING CALCULATION OF LIVE (TRAIN) LOAD PLUS IMPACT.

$$R = 500^{m} \text{ - - - - } \alpha = 0.12$$

$$P_c = (100.04 + 39.10) \times 0.12 = 16.70^{t}$$

4-1. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.

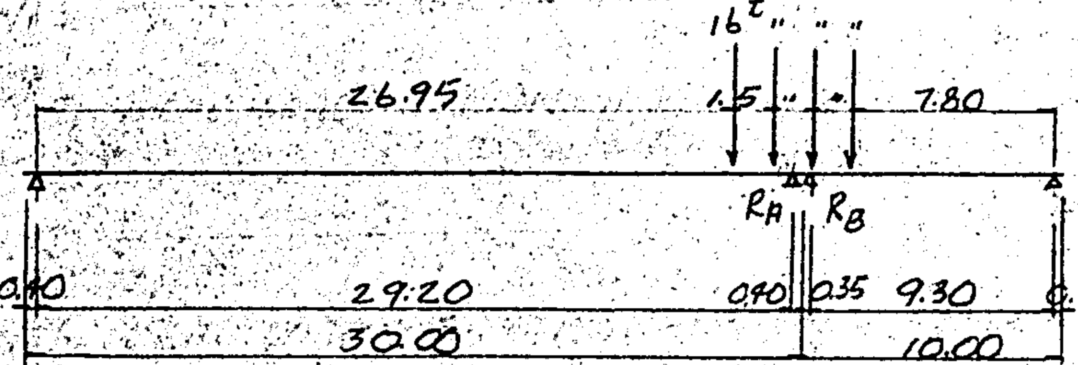


$$M_c = 16.70 \times 11.98 = 200.07^{tm}$$

5. TRAIN LATERAL LOAD

TRANSVERSAL FORCE DUE TO LIVE (TRAIN) LOAD IS ASSUMED TO BE EQUIVALENT TO THE SERIES OF CONCENTRATED LOADS CONSISTED OF 15% OF MOVING WHEEL AXLE LOAD ACTING TRANSVERSALLY AT THE TRACK LEVEL.

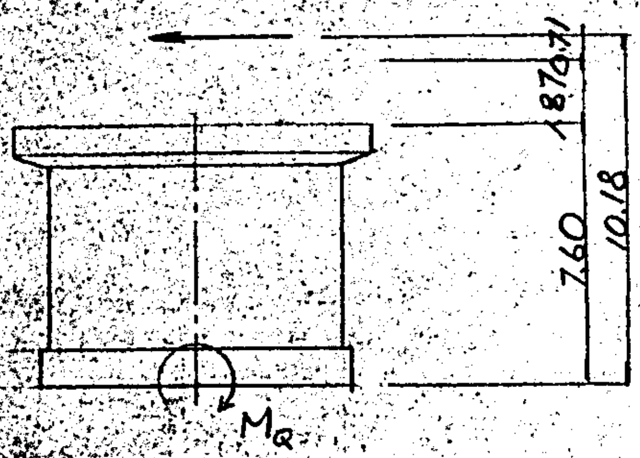
CALCULATION IS MADE UNDER THE SINGLE-TRACK LOADING



$$R_A + R_B = \frac{16}{29.20} \times (26.95 + 28.45) + \frac{16}{9.30} \times (7.80 + 9.30) = 59.78^t$$

$$P_Q = 59.78 \times 0.15 = 8.97^t$$

5-1 OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.



$$M_Q = 8.97 \times 10.18 = 91.31^{tm}$$

4 CALCULATION ON STABILITY

1. COMBINATION OF LOADS

1-1 TRANSVERSAL DIRECTION

No1. DEAD LOAD (M.W.L)

No2. DEAD LOAD + (TRAIN + IMPACT) LOAD (M.W.L)

No3. ―――――― 〃 ―――――― (H.W.L)

No4. DEAD LOAD + (TRAIN + IMPACT) LOAD + TRAIN LATERAL LOAD (M.W.L)

No5. ―――――― 〃 ―――――― (H.W.L)

No6. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

No7. DEAD LOAD (M.W.L)

No8. DEAD LOAD + (TRAIN + IMPACT) LOAD + CENTRIFUGAL LOAD (M.W.L)

No9. ―――――― 〃 ―――――― (H.W.L)

No10. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

THE ABOVE LOADING COMBINATIONS ARE APPLIED No. 1 THRU No. 6 FOR SINGLE-TRACK LOADING AND No. 7 THRU No. 10 FOR DOUBLE-TRACK LOADING.

1-2. LONGITUDINAL DIRECTION.

No.1. DEAD LOAD (M.W.L)

No.2. DEAD LOAD + (TRAIN + IMPACT) LOAD (M.W.L)

No.3. ——————— " ——————— (H.W.L)

No.4. DEAD LOAD + (TRAIN + IMPACT) LOAD + BREAKING LOAD or TRACTION LOAD (M.W.L)

No.5. ——————— " ——————— (H.W.L)

No.6. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

ALL OF THE ABOVE LOADING COMBINATIONS ARE APPLIED FOR DOUBLE-TRACK LOADING.

2. TABLE OF FORCE AND MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

2-1. TRANSVERSAL DIRECTION

SINGLE-TRACK LOADING

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No1	629.71 + 283.87 + 68.00 = 981.58	972.43	—
No2	981.58 + 190.44 = 1172.02	972.43 + 523.71 = 1496.14	—
No3	1172.02 − 264.00 = 908.02	1496.14	—
No4	1172.02	1496.14 + 91.31 = 1587.45	8.97
No5	908.02	1587.45	8.97
No6	981.58	90.43 + 972.43 + 326.15 = 1389.01	32.16 + 35.19 = 67.35

DOUBLE-TRACK LOADING

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No7	629.71 + (283.87 + 68.00) × 2 = 1333.45	———	———
No8	1333.45 + 190.44 × 2 = 1714.33	200.07 × 2 = 400.14	16.70 × 2 = 33.40
No9	1714.33 − 264.00 = 1450.33	400.14	33.40
No10	1333.45	90.43 + 326.15 × 2 = 742.73	32.16 + 35.19 × 2 = 102.54

2-2. LONGITUDINAL DIRECTION

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No 1	1333.45	3.56	———
No 2	1714.33	27.15 − 3.56 = 23.59	———
No 3	1450.33	23.59	———
No 4	1714.33	23.59 + 164.24 = 187.83	20.76
No 5	1450.33	187.83	20.76
No 6	1333.45	90.43 + 387.34 × 2 = 865.11	32.16 + 50.06 × 2 = 132.28

3. REACTION FORCE ACTING ON PILES

$$P = \frac{N}{n} \pm \frac{M}{I} \times x$$

WHERE: P REACTION FORCE

n NUMBER OF PILES

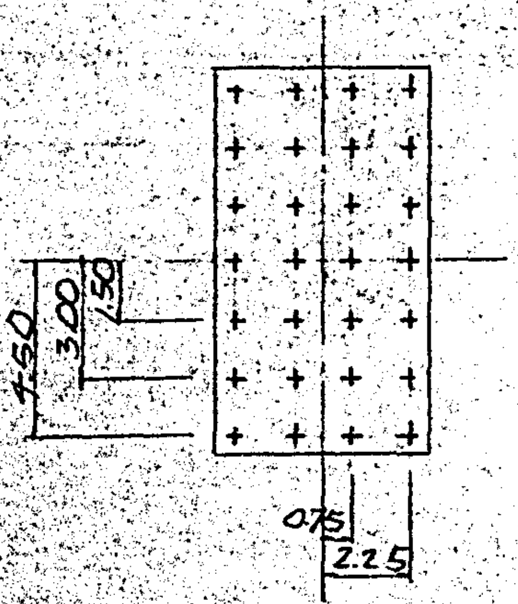
N AXIAL FORCE ACTING AT THE CENTER OF THE BOTTOM OF FOOTING

M MOMENT ACTING AT THE CENTER OF THE BOTTOM OF FOOTING

I MOMENT OF INERTIA OF THE GROUP OF PILES WITH RESPECT TO THE GEOMETRICAL CENTER

x DISTANCE FROM THE GEOMETRICAL CENTER OF THE GROUP OF PILES TO THE CENTER OF THE PILE TO BE CALCULATED

3-1. ARRANGEMENT OF PILES



LONGITUDINAL

$n = 28$

3-2 REACTION FORCE ACTING ON PILES DUE TO TRANSVERSAL LOAD

	N (t)	M (t·m)	$\frac{N}{n}$ (t)	$\frac{M}{I}$ ($\frac{t}{m}$)	Pmax (t)	Pmin (t)
No 1	981.58	972.43	35.06	3.86	52.43	17.69
No 2	1172.02	1496.14	41.86	5.94	68.59	15.13
No 3	908.02	1496.14	32.43	5.94	59.16	5.70
No 4	1172.02	1587.45	41.86	6.30	70.21	13.51
No 5	908.02	1587.45	32.43	6.30	60.78	4.08
No 6	981.58	1389.01	35.06	5.51	59.86	10.27
No 7	1333.45	—	47.62	0	47.62	47.62
No 8	1714.33	400.14	61.23	1.59	68.39	54.08
No 9	1450.33	400.14	51.80	1.59	58.96	44.65
No 10	1333.45	742.73	47.62	2.95	60.90	34.35

$$I = (4.50^2 + 3.00^2 + 1.50^2) \times 4 \times 2 = 252.00^{m^2}$$

$$x = 4.50^{m}$$

3-3 REACTION FORCE ACTING ON PILES DUE TO LONGITUDINAL LOAD

	N (t)	M (t·m)	$\frac{N}{n}$ (t)	$\frac{M}{I}$ ($\frac{t}{m}$)	x (m)	Pmax (t)	Pmin (t)
No1	1,333.45	3.56	47.62	0.05	x_1	47.66	47.58
					x_2	47.73	47.51
					x_3	—	—
No2	1,714.33	23.59	61.23	0.30	x_1	61.46	61.01
					x_2	61.91	60.56
					x_3	—	—
No3	1,450.33	23.59	51.80	0.30	x_1	52.03	51.58
					x_2	52.48	51.13
					x_3	—	—
No4	1,714.33	187.83	61.23	2.39	x_1	63.02	59.44
					x_2	66.61	55.85
					x_3	—	—
No5	1,450.33	187.83	51.80	2.39	x_1	53.59	50.00
					x_2	57.18	46.42
					x_3	—	—
No6	1,333.45	865.11	47.62	10.99	x_1	55.86	39.38
					x_2	72.35	22.89
					x_3	—	—

$$I = (2.25^2 + 0.75^2) \times 7 \times 2 = 78.75\ m^2$$

$$x_1 = 0.75\ m$$

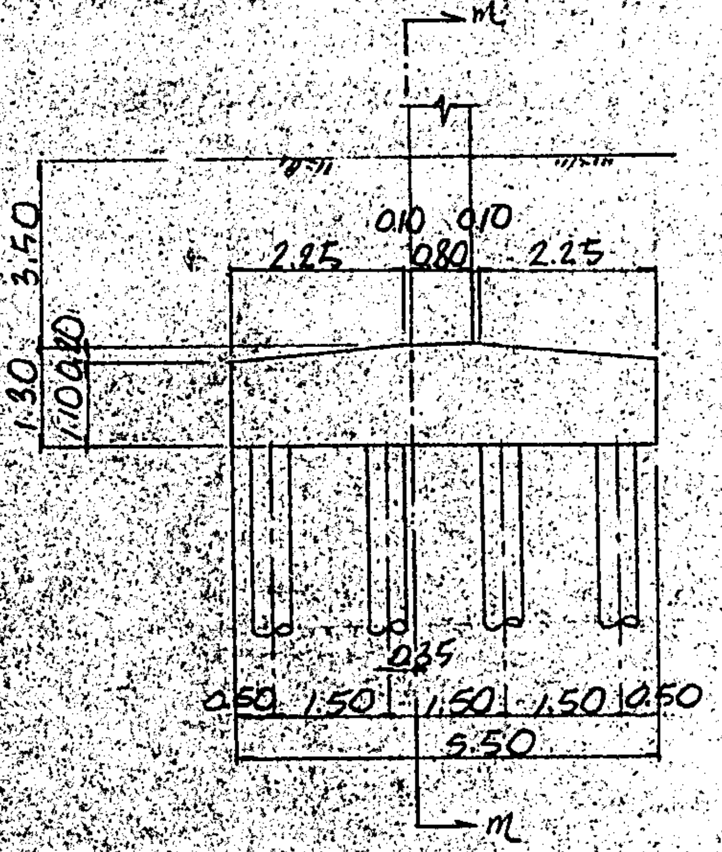
$$x_2 = 2.25\ m$$

5 DESIGN OF FOOTING

CALCULATION IS MADE ONLY THE CASE OF LONGITUDINAL LOADING, BECAUSE NO STRESS OCCURS UNDER THE TRANSVERSAL LOADING DUE TO REACTION FORCES ON PILES WITHIN THE WALL SHAFT

1. EXAMINATION OF SAFETY AGAINST BENDING MOMENT

1-1. BENDING MOMENT DUE TO OWN WEIGHT OF FOOTING AND WEIGHT OF EARTH COVER



WHERE: m SECTION WHERE MOMENT IS CALCULATED

M: BENDING MOMENT AT SECTION m

BENDING MOMENT AT SECTION m

i) THE CASE NO BUOYANCY IS CONSIDERED

$M_m = (2.5 \times 1.30 + 1.8 \times 3.50) \times 2.35^2 \times 1/2$
$- 1/2 \times 2.25 \times 0.20 \times 1.60 \times (2.5-1.8) = 26.12$ tm

ii) THE CASE BUOYANCY IS CONSIDERED

$M_m = 26.12 - 1/2 \times 2.35^2 \times 4.80 \times 1.00 = 12.87$ tm

1-2, STRESS DUE TO REACTION FORCE ON PILES

BENDING MOMENT AT SECTION m

No.1. $M_m = (47.73 \times 1.95 + 47.66 \times 0.45) \times \frac{7}{10.00} = 80.16$ tm/m

No.2. $M_m = (61.91 \times$ " $+ 61.46 \times$ " $) \times$ " $= 103.87$ "

No.3 $M_m = (52.48 \times$ " $+ 52.03 \times$ " $) \times$ " $= 88.02$ "

No.4 $M_m = (66.61 \times$ " $+ 63.02 \times$ " $) \times$ " $= 110.77$ "

No.5 $M_m = (57.18 \times$ " $+ 53.59 \times$ " $) \times$ " $= 94.93$ "

No.6 $M_m = (72.35 \times$ " $+ 55.86 \times$ " $) \times$ " $= 116.35$ "

1-3. SUMMARY OF BENDING MOMENT ON FOOTING

No1 : $M_u = (80.16 - 26.12) \times 1.8/1.4 = 69.48$ tm/m

No2 : $M_u = (103.87 - 26.12) \times 1.00 = 77.75$ "

No3 : $M_u = (88.02 - 12.87) \times 1.00 = 75.15$ "

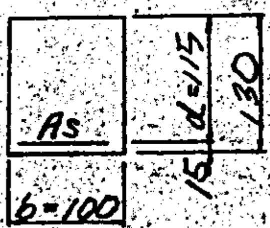
No4 : $M_u = (110.77 - 26.12) \times 1/1.15 = 73.61$ "

No5 : $M_u = (94.93 - 12.87) \times 1/1.15 = 71.36$ "

No6 : $M_u = (116.35 - 26.12) \times 1/1.50 = 60.15$ "

1-4. EXAMINATION OF SAFETY

$M_u = 77.75$ tm/m



$As = 6 \phi 7 - D29 = 42.83$ cm²

$p = \frac{As}{b \cdot d} = \frac{42.83}{100 \times 115} = 0.00372$

$\frac{1}{Lc} = 7.81 \qquad \frac{1}{Ls} = 297$

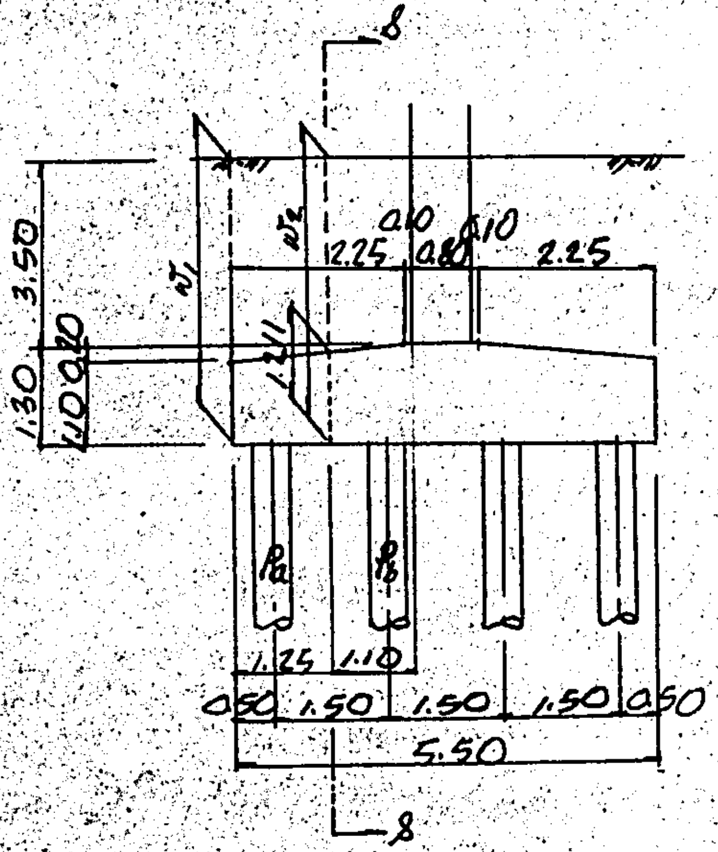
$\sigma_c = \frac{M}{b \cdot d^2} \times \frac{1}{Lc} = \frac{77.75 \times 10^5}{100 \times 115^2} \times 7.81 = 45.9$ kg/cm² < 80 kg/cm²

$\sigma_s = \frac{M}{b \cdot d^2} \times \frac{1}{Ls} =$ —— " —— $\times 297 = 1746$ " < 1800 "

2. EXAMINATION OF SAFETY AGAINST SHEARING FORCE

EXAMINATION ON THE COMBINATION No.6

2-1. SHEARING FORCE DUE TO OWN WEIGHT OF FOOTING AND WEIGHT OF EARTH COVER



WHERE: s SECTION WHERE SHEARING FORCE IS CALCULATED

S_s SHEARING FORCE AT SECTION s

SHEARING FORCE AT SECTION s

$W_1 = 2.5^{t/m^3} \times 1.10 + 1.8^{t/m^3} \times 3.70 = 9.41^{ton}$

$W_2 = (2.5'' \times 1.211 + 1.8'' \times 3.589) \times \frac{1.10}{2 \times (1.211 - 0.15)} = 4.92''$

$S_s = 1/2 \times (9.41 + 4.92) \times 1.25 = 8.96^t$

2-2. STRESS DUE TO REACTION FORCE ON PILES

SHEARING FORCE AT SECTION s

$P_a = 72.35 \times \frac{1.85}{2 \times (1.211 - 0.15)} = 63.08^t$

$S_s = 63.08 \times \frac{7}{10.00} = 44.16^t$

2-3. SUMMARY OF SHEARING FORCES ON FOOTING

$\Sigma S_s = 44.16 - 8.96 = 35.20^t$

2-4. EXAMINATION OF SAFETY,

$\tau = \frac{35.20 \times 10^3}{100 \times (121.1 - 15)} = 3.32^{kg/cm^2} < 3.7^{kg/cm^2}$

6 DESIGN OF SUBSTRUCTURE.

EXAMINATION IS MADE ONLY THE CASE OF LONGITUDINAL LOADING.

1. COMBINATION OF LOADS

No.6 DEAD LOAD + EARTHQUAKE LOAD

2. BENDING MOMENT AND AXIAL FORCE ACTING AT THE BOTTOM OF WALL

THE FOLLOWING FIGURES ARE REFERRED TO THE CALCULATION OF THE REACTION FORCES TRANSMITTED FROM THE SUPERSTRUCTURE.

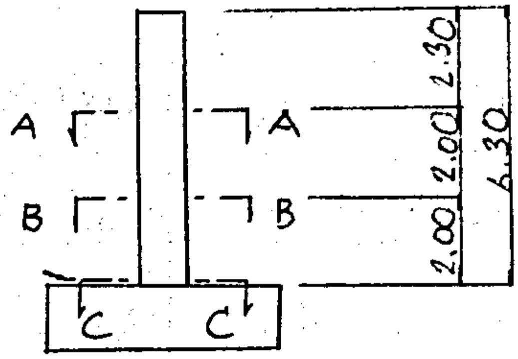
$$M = (14.91 \times 6.76 + 31.92 \times 5.95 + 9.46 \times 5.467 + 97.82 \times 2.65) \times 0.10 + 3.56 + (7.48 \times 7.22 + 42.58 \times 6.30) \times 2 = 708.24^{\,tm}$$

$$N = 14.92 + 31.92 + 9.46 + 97.82 + (283.87 + 68.00) \times 2 = 857.86^{\,t}$$

3. EXAMINATION OF SAFETY

M (tm)	708.24
N (t)	857.86
S (t)	
b (cm)	860
h (cm)	80
d (cm)	
d' (cm)	8
As (cm²)	D25-59 = 298.95
p	0.00434
As' (cm²)	= As
p'	= P
e=M/N (cm)	82.5
e=M/N+u (cm)	
e=M/N−u (cm)	
e/h	1.031
d/e	
d'/h	0.100
d'/d	
Ne/bd² (kg/cm²)	12.468
k	0.353
c	0.122
j	
1/Lc	
1/Ls	
β=σs/σc	
σc (kg/cm²)	101.6
σs (kg/cm²)	2358
τ (kg/cm²)	
σsa (kg/cm²)	2700
σca (kg/cm²)	120
τa (kg/cm²)	

4. DEDUCTION OF REINFORCING BARS



4-1 BENDING MOMENT AND AXIAL FORCE ACTING AT THE SECTION A AND B

$M_A = 3.56 + (14.91 \times 2.76 + 31.92 \times 1.95 + 9.46 \times 1.467$
$+ 2.5 \times 7.383 \times 1.30^2 \times 1/2) \times 0.1$
$+ (7.48 \times 3.12 + 42.58 \times 2.30) \times 2 = 259.39^{tm}$

$N_A = 14.91 + 31.92 + 9.46 + 2.5 \times 7.386 \times 1.30$
$+ (283.87 + 68.00) \times 2 = 784.03^{t}$

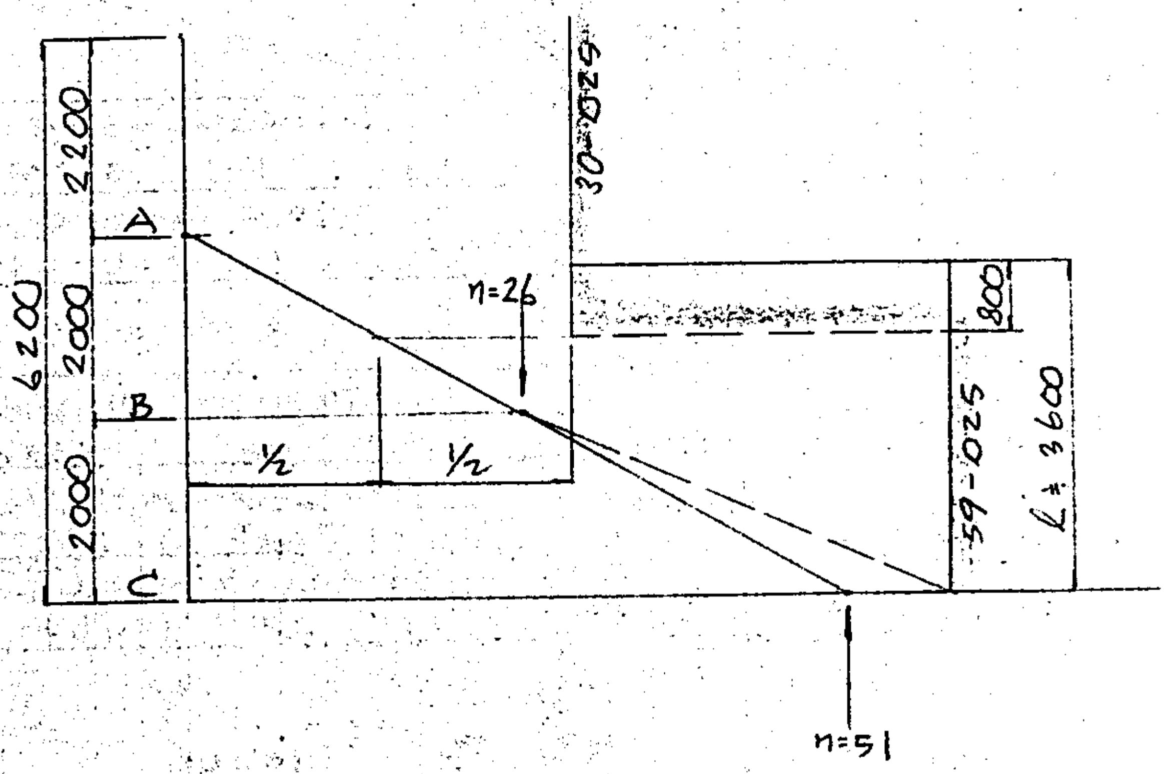
$M_B = 3.56 + (14.91 \times 4.76 + 31.92 \times 3.95 + 9.46 \times 3.467$
$+ 2.5 \times 7.383 \times 3.30^2 \times 1/2) \times 0.1$
$+ (7.48 + 5.12 + 42.58 \times 4.30) \times 2 = 479.38^{tm}$

$N_B = 784.03 + 2.5 \times 7.386 \times 2.00 = 820.96^{t}$

4-2. THE LEAST REINFORCING BARS REQUIRED AT THE SECTION A AND B

SECTION	A	B	C
M (tm)	259.39	479.38	708.24
N (t)	184.03	820.96	857.86
b (cm)	860	"	"
h (")	80	"	"
d' (")	8	"	"
As	D25 - 1	D25 - 26	D25 - 51
σc (kg/cm²)	77.7	95.1	108.3
σs (")	2376	2625	2699

4-3. MOMENT DIAGRAM



[7] DESIGN OF PILE

1. REACTION FORCES ACTING ON PILES

EXAMINATION IS MADE ONLY TO THE EARTHQUAKE LOADING.

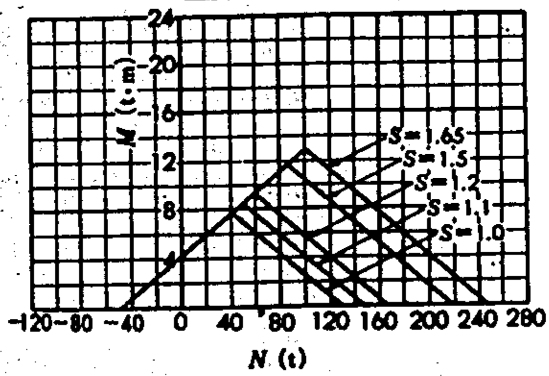
	LONGITUDINAL DIRECTION ①	TRANSVERSAL DIRECTION	
		② SINGLE TRACK	③ DOUBLE TRACK
WHOLE HORIZONTAL FORCE, ΣH (t)	132.28	67.35	102.54
HORIZONTAL FORCE PER PILE, H (t)	4.72	2.41	3.66
VALUE OF β (m^{-1})	0.214	"	"
MAXIMUM MOMENT PER PILE, Mmax (tm)	7.10	3.63	5.51
MAXIMUM AXIAL FORCE PER PILE, Pmax (t)	72.35	59.86	60.90
MINIMUM AXIAL FORCE PER PILE, Pmin (t)	22.89	10.27	34.35

WHERE $H = \Sigma H / n$, n …… NUMBER OF PILE
$n = 28$

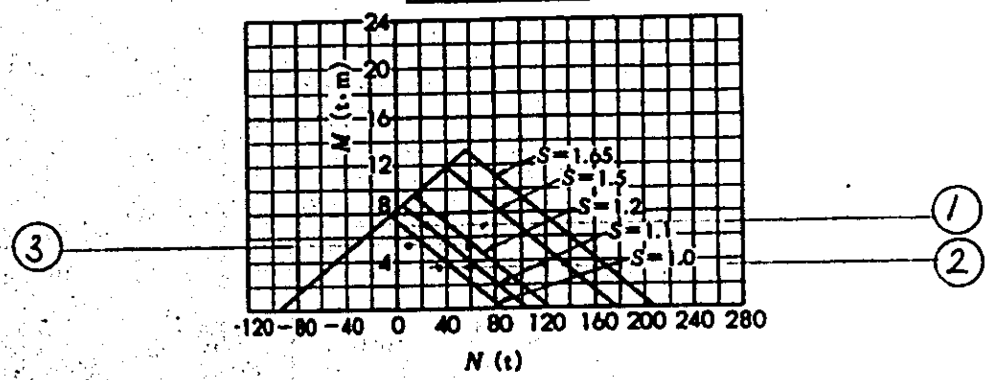
$M_{max} = \frac{0.322 \cdot H}{\beta}$

2. EXAMINATION OF SAFETY

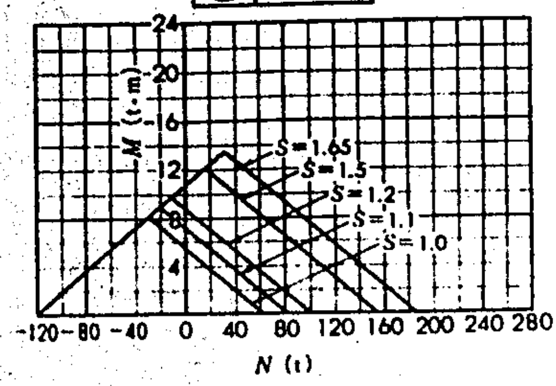
(13) D500-A



(14) D500-B

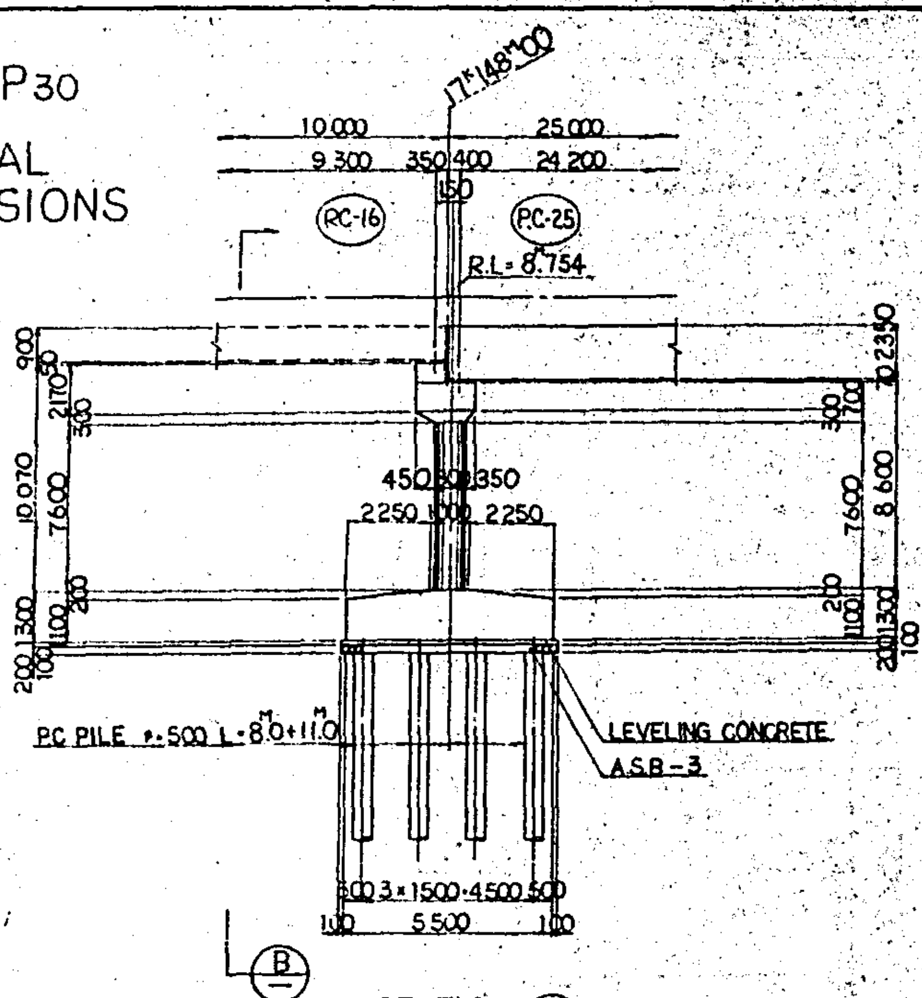


(15) D500-C

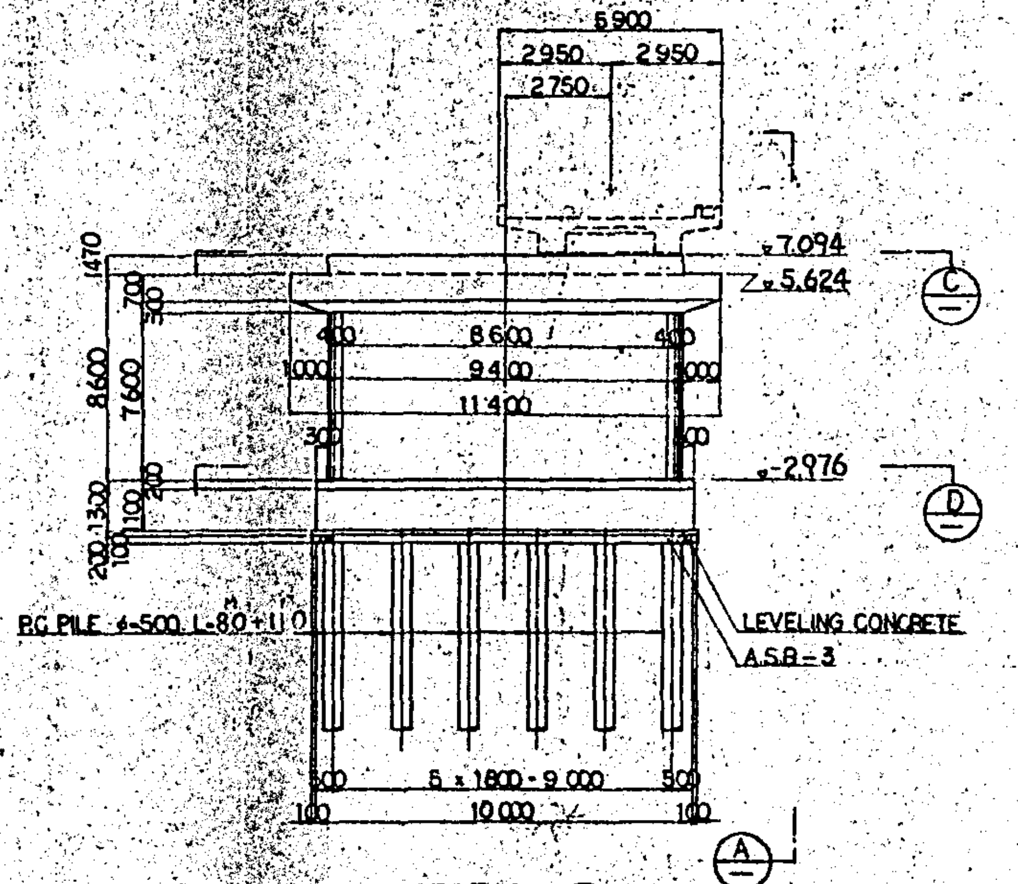


§9. Pier P30

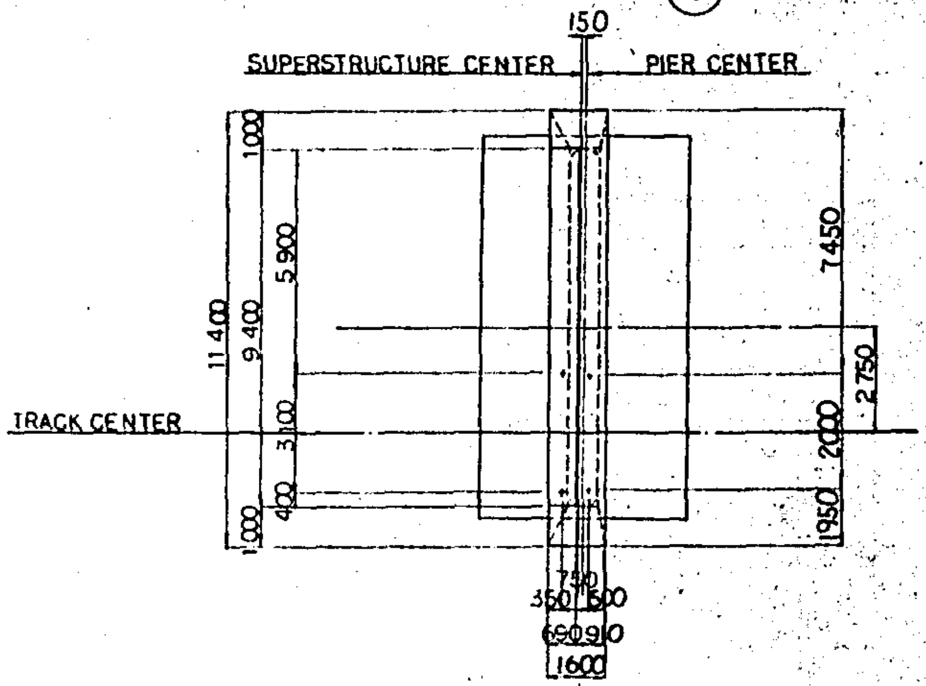
1 GENERAL DIMENSIONS



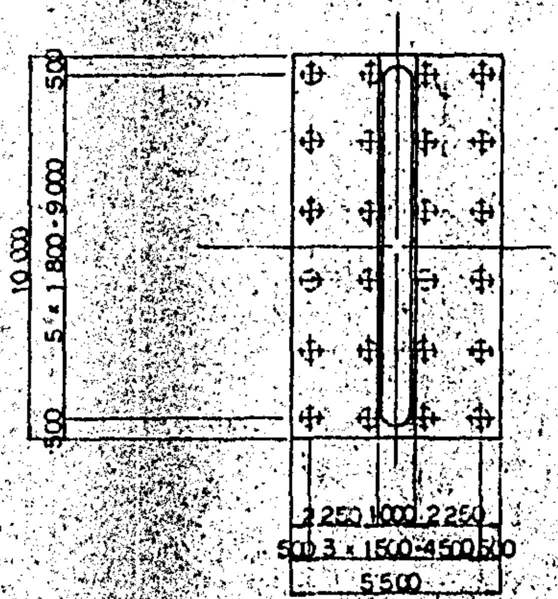
SECTION (A)



SECTION (B)

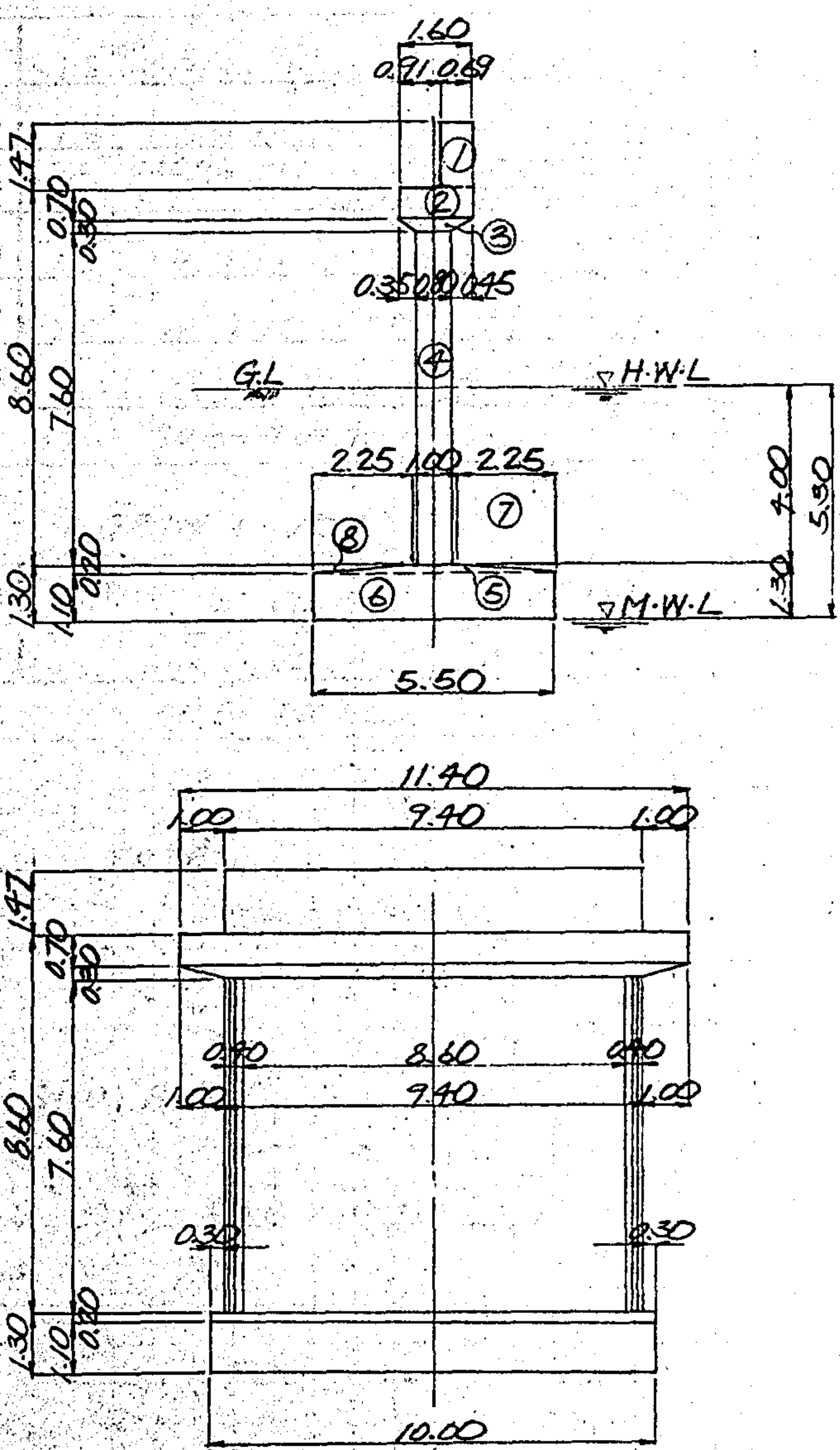


SECTION (C)



SECTION (D)

2 OWN WEIGHT OF SUBSTRUCTURE AND WEIGHT OF EARTH COVER



1. OWN WEIGHT OF SUBSTRUCTURE AND WEIGHT OF EARTH COVER

SUBSTRUCTURE

①	$2.5^{t/m^3} \times 0.69 \times 1.47 \times 9.40$	23.84^{t}
②	$2.5'' \times 1.60 \times 0.70 \times 11.40$	$31.92''$
③	$2.5'' \times 0.30/6 \times \{1.60 \times 11.40 + 0.80 \times 9.40 + (1.60 + 0.80)\cdot(11.40 + 9.40)\}$	$9.46''$
④	$2.5'' \times (1/4 \times \pi \times 0.80^2 + 0.80 \times 8.60)^{7.383} \times 7.60$	$140.28''$
⑤	$2.5'' \times 1/2 \times (1.00 + 5.50) \times 0.20 \times 10.00$	$16.25''$
⑥	$2.5'' \times 5.50 \times 1.10 \times 10.00$	$151.25''$
	SUB-TOTAL	373.00^{t}

EARTH COVER

⑦	$1.8^{t/m^3} \times (5.50 \times 10.00 - 7.383) \times 4.00$	342.84^{t}
⑧	$1.8'' \times 1/2 \times 2.25 \times 0.20 \times 10.00 \times 2$	$8.10''$
	SUB-TOTAL	350.94^{t}

TOTAL

$$373.00 + 350.94 = 723.94^{t}$$

2. BUOYANCY

$$1.0^{t/m^3} \times 5.50 \times 10.00 \times 5.30 = 291.50^{t}$$

3. HORIZONTAL FORCES DUE TO EARTHQUAKE LOAD

	N (t)	y (m)	N·y (t·m)
①	23.84	10.635	253.54
②	31.92	9.55	304.84
③	9.46	9.067	85.77
④	140.28	5.10	715.43
⑤	16.25	1.177	19.13
⑥	151.25	0.55	83.19
Σ	373.00	―――	1461.90

NOTE N: AXIAL FORCE.

y: DISTANCE FROM THE BOTTOM OF FOOTING TO GRAVITY CENTER

4. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

$$y_e = \frac{N \cdot y}{N} = \frac{1461.90}{373.00} = 3.919^m$$

$$\tilde{P}_E = 373.00 \times 0.10 = 37.30^t$$

$$M_o = 37.30 \times 3.919 = 146.18^{tm}$$

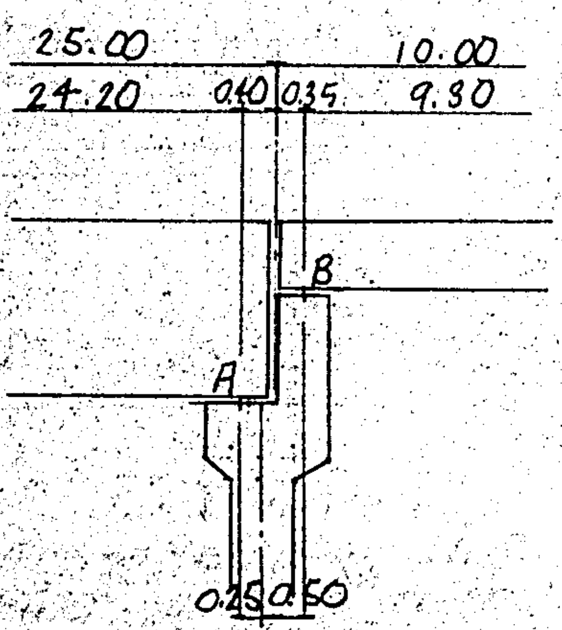
NOTE y_e : DISTANCE FROM THE BOTTOM OF FOOTING TO THE CENTER OF SUBSTRUCTURE.

P_E : HORIZONTAL FORCE DUE TO EARTHQUAKE LOAD

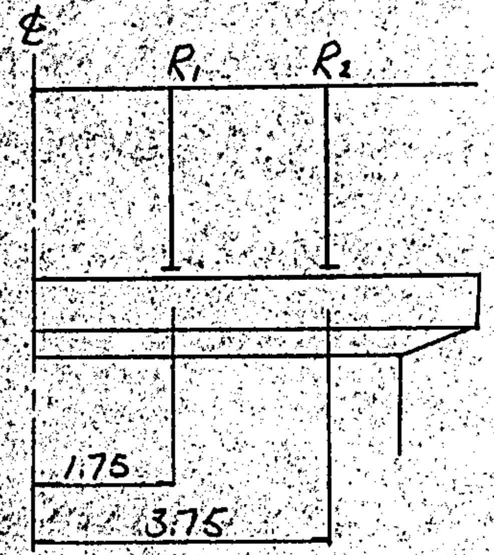
M_o : OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

[3] REACTION FORCES TRANSMITTED FROM SUPERSTRUCTURE

1. REACTION FORCES DUE TO DEAD WEIGHT OF SUPERSTRUCTURE



1-1. REACTION FORCES ACTING AT BEARINGS-A

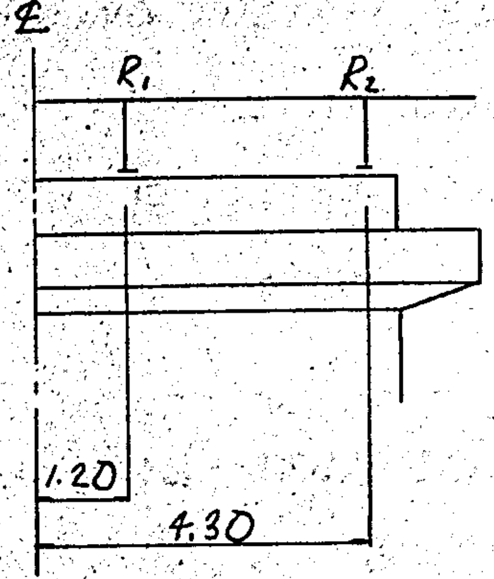


R_1 = 87.83 t

R_2 = 96.10 "

TOTAL = 183.93 t

1-2. REACTION FORCES ACTING AT BEARINGS-B



$R_1 = 34.00^t$

$R_2 = 34.00$ "

TOTAL $= 68.00^t$

1-3. SECTIONAL MOMENT AT THE CENTER OF PIER SHAFT DUE TO DEAD WEIGHT OF SUPERSTRUCTURE

SINGLE-TRACK LOADING FOR CALCULATION OF TRANSVERSAL STABILITY. DOUBLE-TRACK LOADING FOR CALCULATION OF LONGITUDINAL STABILITY

TRANSVERSAL DIRECTION

$$M_1 = 87.83 \times 1.75 + 96.10 \times 3.75 + 34.00 \times (1.20 + 4.30) = 701.08^{tm}$$

LONGITUDINAL DIRECTION

$$M_2 = (-183.93 \times 0.25 + 68.00 \times 0.50) \times 2 = -23.97^{tm}$$

1-4. HORIZONTAL FORCES DUE TO EARTHQUAKE ACTING ON DEAD WEIGHT OF SUPERSTRUCTURE

a) LONGITUDINAL DIRECTION

24.20^m - SPAN SIDE

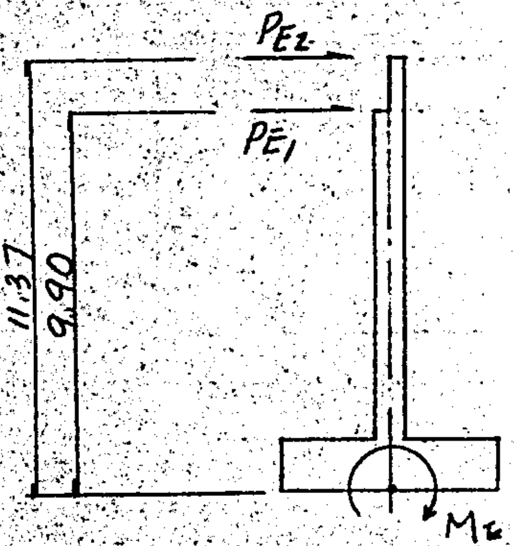
$$P_{E_1} = 183.93 \times 2 \times 0.10 - \frac{1}{2} \times 183.93 \times 0.10$$
$$= 27.59^t$$

9.30^m - SPAN SIDE

$$P_{E_2} = 68.00 \times 2 \times 0.10 \times 0.55 = 7.48^t$$

$$\therefore \Sigma P_E = 27.59 + 7.48 = 35.07^t$$

OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING



$$M_E = 27.59 \times 9.90 + 7.48 \times 11.37 = 358.19^{tm}$$

b) TRANSVERSAL DIRECTION

24.20^m - SPAN SIDE

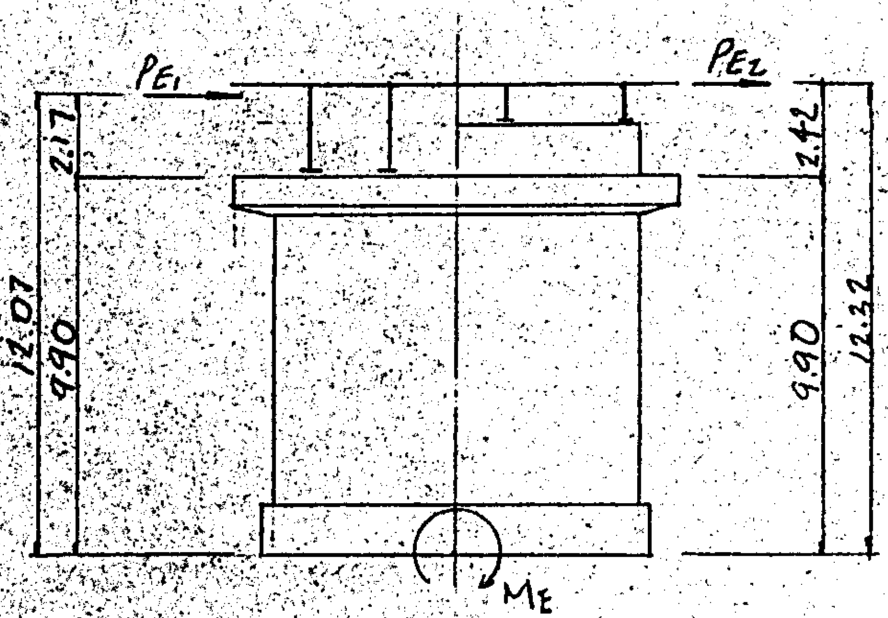
$P_{E1} = 183.93 \times 0.10 = 18.39^t$

9.30^m - SPAN SIDE

$P_{E2} = 68.00 \times 0.10 = 6.80^t$

$\Sigma P_E = 18.39 + 6.80 = 25.19^t$

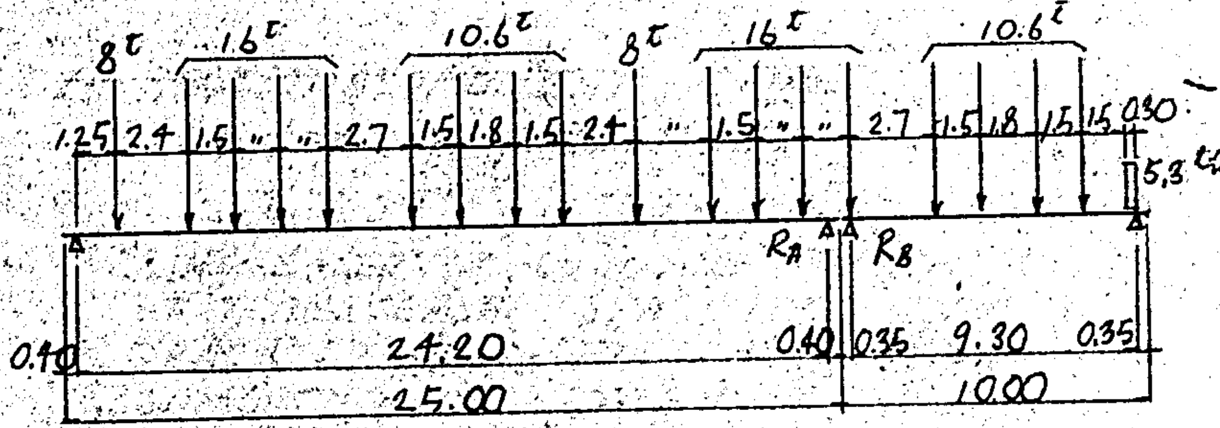
OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING



$M_E = 18.39 \times 12.07 + 6.80 \times 12.32 = 305.74^{tm}$

2. REACTION FORCES DUE TO LIVE LOAD PLUS IMPACT

EQUIVALENT TO KS-16 LOADING.
CALCULATION IS CARRIED OUT UNDER THE LOADING CONDITION OF PRODUCING MAXIMUM REACTION FORCE ON PIER.



$$R_A = \frac{1}{24.20} \times (8 \times 1.25 + 16 \times 4 \times 5.90 + 10.6 \times 4 \times 13.25$$

$$+ 8 \times 18.05 + 16 \times 3 \times 21.95) \qquad = 88.74^t$$

$$R_B = \frac{1}{9.30} \times (16 \times 9.30 + 10.6 \times 4 \times 4.20$$

$$+ 5.3 \times 0.30^2 \times 1/2) \qquad = 35.17''$$

TOTAL $= 123.91^t$

IMPACT COEFFICIENT

24.20^m - SPAN SIDE --- $i = 0.357$

9.30^m - SPAN SIDE --- $i = 0.437$

LIVE LOAD PLUS IMPACT

$R(A+L) = 88.74 \times 1.357 = 120.42^t$

$R(B+L) = 35.17 \times 1.437 = 50.54$ "

TOTAL $= 170.96^t$

2-1. SECTIONAL MOMENT ACTING AT THE CENTER OF PIER SHAFT

SINGLE-TRACK LOADING FOR CALCULATION OF TRANSVERSAL STABILITY. DOUBLE-TRACK LOADING FOR CALCULATION OF LONGITUDINAL STABILITY.

TRANSVERSAL DIRECTION

$M_1 = 50.54 \times \frac{1}{2} \times (1.20 + 4.30)$

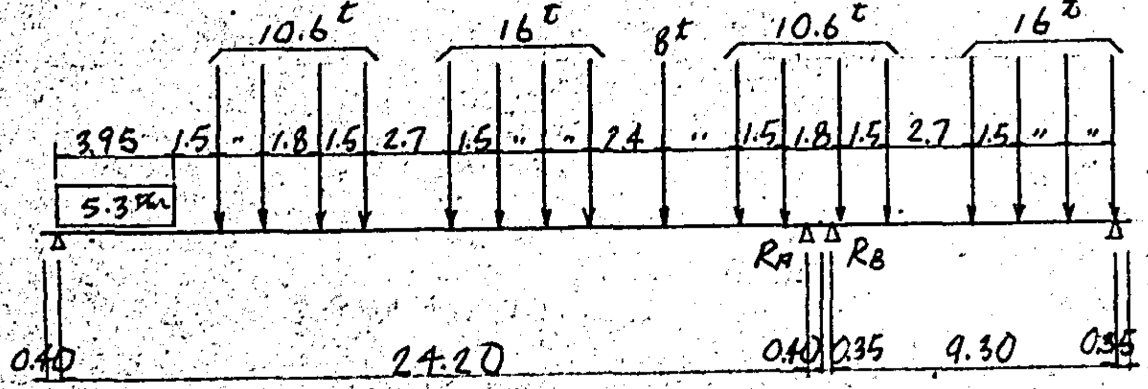
$+ 120.42 \times \frac{1}{2} \times (1.75 + 3.75) = 470.14^{tm}$

LONGITUDINAL DIRECTION

$M_2 = (-120.42 \times 0.25 + 50.54 \times 0.50) \times 2 = -9.67^{tm}$

3. BRAKE LOAD AND TRACTION LOAD

UNDER THE LOADING CONDITION AS SHOWN BELOW



3-1. BRAKE LOAD

15% OF KS LOADING.

L1 - SPAN SIDE

$P_{B-1} = (5.3 \times 3.95 + 10.6 \times 6 + 16 \times 4 + 8) \times 0.15 \times 1/2$

$= 11.74^{t}$

L2 - SPAN SIDE

$P_{B-2} = (10.6 \times 2 + 16 \times 4) \times 0.15 \times 0.55 = 7.03^{t}$

$\Sigma P_B = 11.74 + 7.03 = 18.77^{t}$

3-2. TRACTION LOAD

25% OF MOVING WHEEL AXLE LOAD OF KS LOADING

L1 - SPAN SIDE

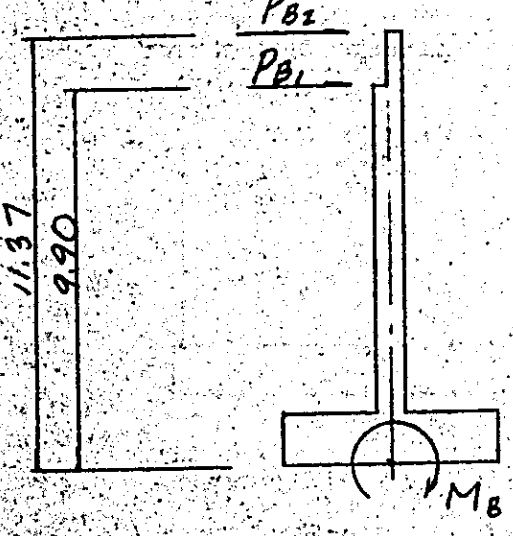
$P_{T-1} = 16 \times 4 \times 0.25 \times 1/2 = 8.00^t$

L2 - SPAN SIDE

$P_{T-2} = 16 \times 4 \times 0.25 \times 0.55 = 8.80^t$

$\therefore \Sigma P_T = 8.00 + 8.80 = 16.80^t < \Sigma P_B = 18.77^t$

3-3. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING



$M_B = 11.74 \times 9.90 + 7.03 \times 11.37 = 196.16^{tm}$

4. CENTRIFUGAL LOAD

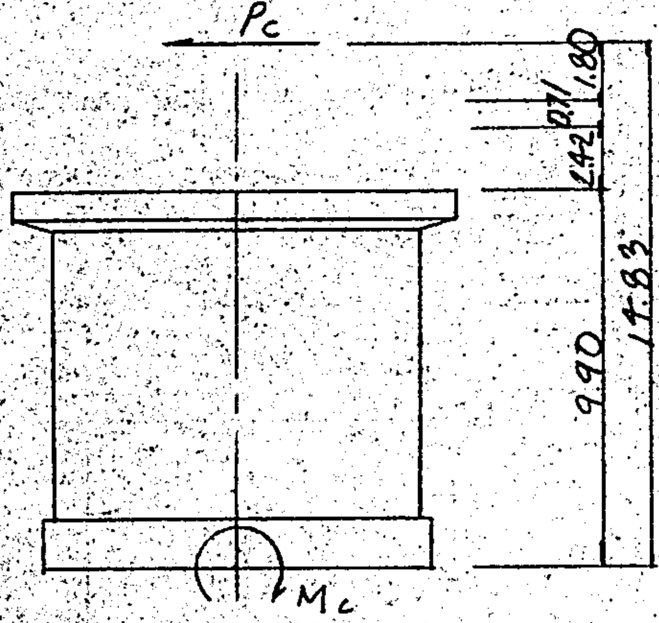
ASSUMED THAT THE LOAD IS EQUIVALENT TO THE LIVE (TRAIN) LOAD MULTIPLIED BY α AND IS ACTING TRANSVERSALLY ON 1.8m ABOVE THE TRACK LEVEL.

REFERENCE IS MADE TO THE LOADING CALCULATION OF LIVE (TRAIN) LOAD PLUS IMPACT

$$R = 500 \quad ---- \quad \alpha = 0.12$$

$$P_c = 123.91 \times 0.12 = 14.87^t$$

4-1. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.

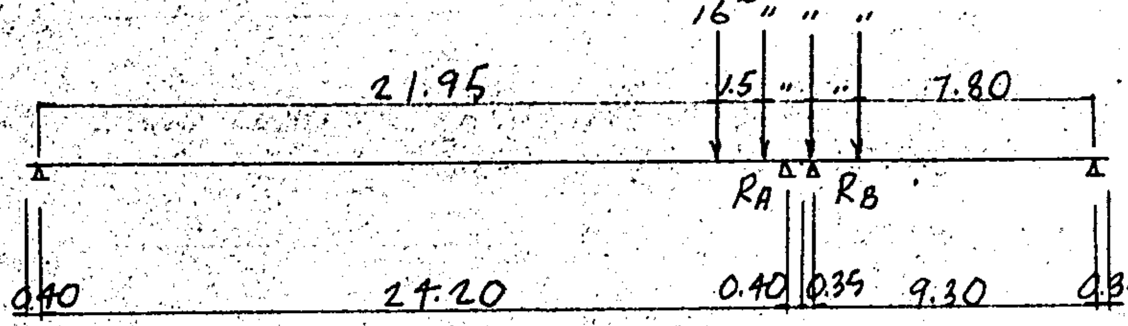


$$M_c = 14.87 \times 14.83 = 220.52^{tm}$$

5. TRAIN LATERAL LOAD

TRANSVERSAL FORCE DUE TO LIVE (TRAIN) LOAD IS ASSUMED TO BE EQUIVALENT TO THE SERIES OF CONCENTRATED LOADS CONSISTED OF 15% OF MOVING WHEEL AXLE LOAD ACTING TRANSVERSALLY AT THE TRACK LEVEL.

CALCULATION IS MADE UNDER THE SINGLE-TRACK LOADING

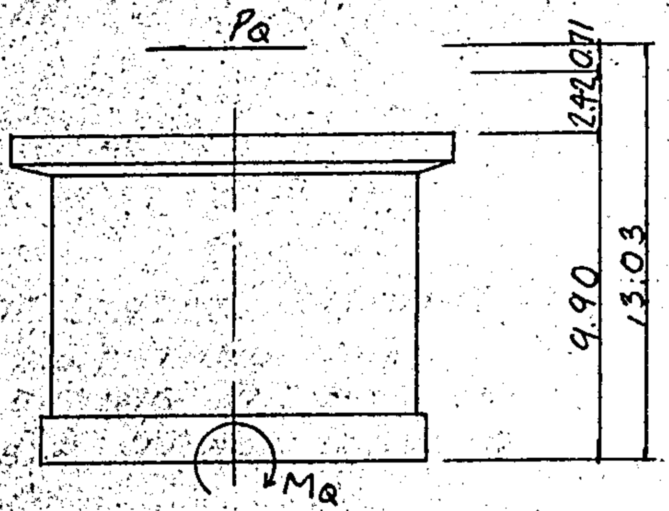


$$R_A + R_B = \frac{16}{24.20} \times (21.95 + 23.45) + \frac{16}{9.30} \times (7.80 + 9.30)$$

$$= 59.44^t$$

$$P_Q = 59.44 \times 0.15 = 8.92^t$$

5-1. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.



$$M_Q = 8.92 \times 13.03 = 116.23^{tm}$$

4 CALCULATION ON STABILITY

1. COMBINATION OF LOADS

1-1 TRANSVERSAL DIRECTION

No1. DEAD LOAD (M.W.L)

No2. DEAD LOAD + (TRAIN + IMPACT) LOAD (M.W.L)

No3. ———— 〃 ———— (H.W.L)

No4. DEAD LOAD + (TRAIN + IMPACT) LOAD + TRAIN LATERAL LOAD (M.W.L)

No5. ———— 〃 ———— (H.W.L)

No6. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

No7. DEAD LOAD (M.W.L)

No8. DEAD LOAD + (TRAIN + IMPACT) LOAD + CENTRIFUGAL LOAD (M.W.L)

No9. ———— 〃 ———— (H.W.L)

No10. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

THE ABOVE LOADING COMBINATIONS ARE APPLIED No. 1 THRU No. 6 FOR SINGLE-TRACK LOADING AND NO. 7 THRU NO. 10 FOR DOUBLE-TRACK LOADING.

1-2. LONGITUDINAL DIRECTION.

No.1. DEAD LOAD (M.W.L)

No.2. DEAD LOAD + (TRAIN + IMPACT) LOAD (M.W.L)

No.3. ——————— " ——————— (H.W.L)

No.4. DEAD LOAD + (TRAIN + IMPACT) LOAD

+ BREAKING LOAD or TRACTION LOAD (M.W.L)

No.5. ——————— " ——————— (H.W.L)

No.6. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

ALL OF THE ABOVE LOADING COMBINATIONS ARE APPLIED FOR DOUBLE-TRACK LOADING.

2. TABLE OF FORCE AND MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

2-1. TRANSVERSAL DIRECTION

SINGLE-TRACK LOADING

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No1	723.94 + 183.93 + 68.00 = 975.87	701.08	—
No2	975.87 + 170.96 = 1146.83	701.08 + 470.14 = 1171.22	—
No3	1146.83 - 291.50 = 855.33	1171.22	—
No4	1146.83	1171.22 + 116.23 = 1287.45	8.92
No5	855.33	1287.45	8.92
No6	975.87	146.18 + 305.74 + 701.08 = 1153.00	37.30 + 25.19 = 62.49

DOUBLE-TRACK LOADING

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No7	723.94 + 183.93×2 +68.00×2 = 1227.80	———	———
No8	1227.80+170.96×2 = 1569.72	220.52×2 = 441.04	14.87×2 = 29.74
No9	1569.72 −291.50 = 1,278.22	441.04	29.74
No10	1227.80	146.18 + 305.74×2 = 757.66	37.30 + 25.19×2 = 87.68

2-2, LONGITUDINAL DIRECTION

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No 1	1227.80	— 23.97	———
No 2	1569.72	23.97 + 9.67 = 33.64	———
No 3	1278.22	33.64	———
No 4	1569.72	33.64 + 196.16 = 229.80	18.77
No 5	1278.22	229.80	18.77
No 6	1227.80	146.18 + 358.19 × 2 + 23.97 = 886.53	37.30 + 35.07 × 2 = 107.44

3. REACTION FORCE ACTING ON PILES

$$P = \frac{N}{n} \pm \frac{M}{I} \times x$$

WHERE: P REACTION FORCE

n NUMBER OF PILES

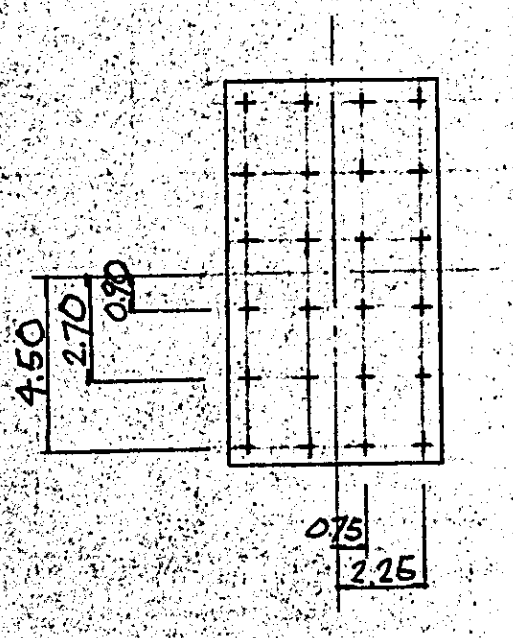
N AXIAL FORCE ACTING AT THE CENTER OF THE BOTTOM OF FOOTING

M MOMENT ACTING AT THE CENTER OF THE BOTTOM OF FOOTING

I MOMENT OF INERTIA OF THE GROUP OF PILES WITH RESPECT TO THE GEOMETRICAL CENTER

x DISTANCE FROM THE GEOMETRICAL CENTER OF THE GROUP OF PILES TO THE CENTER OF THE PILE TO BE CALCULATED

3-1. ARRANGEMENT OF PILES



LONGITUDINAL

$n = 24$

3-2 REACTION FORCE ACTING ON PILES DUE TO TRANSVERSAL LOAD

	N (t)	M (t·m)	N/n (t)	M/I (t/m)	Pmax (t)	Pmin (t)
No 1	975.87	701.08	40.66	3.09	54.57	26.76
No 2	1146.83	1171.22	47.78	5.16	71.00	24.56
No 3	855.33	1171.22	35.64	5.16	58.86	12.42
No 4	1146.83	1287.45	47.78	5.68	73.34	22.22
No 5	855.33	1287.45	35.64	5.68	61.20	10.08
No 6	975.87	1153.00	40.66	5.08	63.52	17.80
No 7	1227.80	—	51.16	—	51.16	51.16
No 8	1569.72	441.04	65.41	1.94	74.14	56.68
No 9	1278.22	441.04	53.26	1.94	61.99	44.53
No 10	1227.80	757.66	51.16	3.34	66.19	36.13

$I = (4.50^2 + 2.70^2 + 0.90^2) \times 4 \times 2 = 226.80\ m^2$

$x = 4.50^m$

3-3. REACTION FORCE ACTING ON PILES DUE TO LONGITUDINAL LOAD

	N (t)	M (tm)	$\frac{N}{n}$ (t)	$\frac{M}{I}$ ($\frac{t}{m}$)	$x_{(m)}$	P_{max} (t)	P_{min} (t)
No1	1227.80	23.97	51.16	0.27 0.81 0.36	x_1	51.43	50.89
					x_2	51.97	50.35
					x_3	—	—
No2	1569.72	33.64	65.41	0.38 1.13 0.50	x_1	65.79	65.04
					x_2	66.54	64.29
					x_3	—	—
No3	1278.22	33.64	53.26	0.50	x_1	53.64	52.89
					x_2	54.39	52.14
					x_3	—	—
No4	1569.72	229.80	65.41	2.55 7.65 3.40	x_1	67.96	62.86
					x_2	73.06	57.76
					x_3	—	—
No5	1278.22	229.80	53.26	3.40	x_1	55.81	50.71
					x_2	60.91	45.61
					x_3	—	—
No6	1227.80	886.53	51.16	9.85 29.54 13.13	x_1	61.01	41.31
					x_2	80.70	21.62
					x_3	—	—

$$I = (2.25^2 + 0.75^2) \times 6 \times 2 = 67.50\ m^2$$

$$x_1 = 0.75^m$$

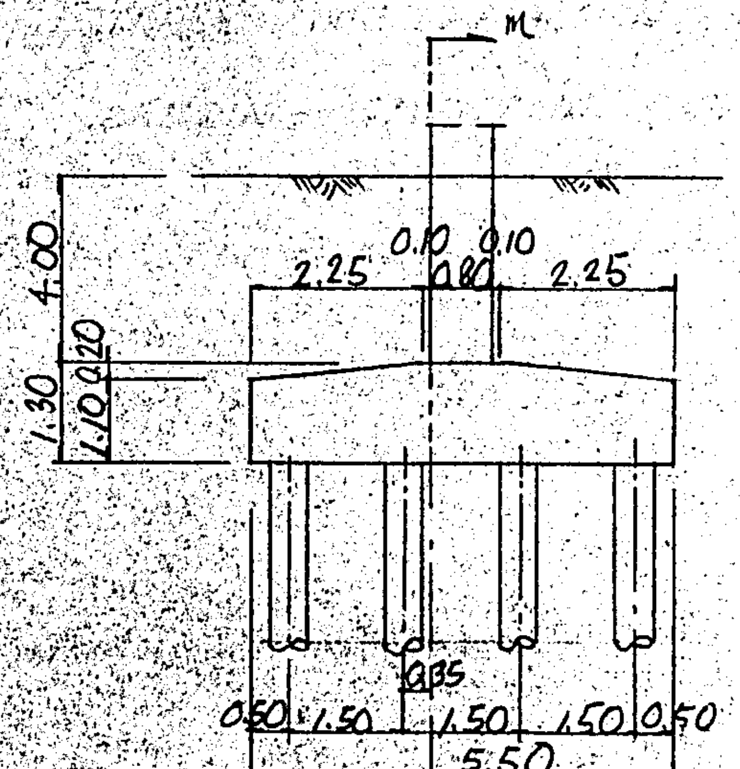
$$x_2 = 2.25^m$$

5 DESIGN OF FOOTING

CALCULATION IS MADE ONLY THE CASE OF LONGITUDINAL LOADING, BECAUSE NO STRESS OCCURS UNDER THE TRANSVERSAL LOADING DUE TO REACTION FORCES ON PILES WITHIN THE WALL SHAFT.

1. EXAMINATION OF SAFETY AGAINST BENDING MOMENT

1-1. BENDING MOMENT DUE TO OWN WEIGHT OF FOOTING AND WEIGHT OF EARTH COVER



WHERE: m SECTION WHERE MOMENT IS CALCULATED

M: BENDING MOMENT AT SECTION m

BENDING MOMENT AT SECTION m

i) THE CASE NO BUOYANCY IS CONSIDERED

$M_m = (2.5^{T/m^3} \times 1.30 + 1.8^{T/m^3} \times 4.00) \times 2.35^2 \times 1/2$

$- 1/2 \times 2.25 \times 0.20 \times 1.60 \times (2.5^{T/m^3} - 1.8^{T/m^3}) = 28.60^{tm}$

ii) THE CASE BUOYANCY IS CONSIDERED

$M_m = 28.60 - 1/2 \times 2.35^2 \times 5.30 \times 1.00 = 13.97^{tm}$

1-2, STRESS DUE TO REACTION FORCE ON PILES

BENDING MOMENT AT SECTION m

No.1 $M_m = (51.97 \times 1.95 + 51.43 \times 0.45) \times \frac{6}{10.00} = 74.69^{Tm/m}$

No.2 $M_m = (86.54 \times$ " $+ 65.79 \times$ " $) \times$ " $= 95.62$ "

No.3 $M_m = (54.39 \times$ " $+ 53.64 \times$ " $) \times$ " $= 78.12$ "

No.4 $M_m = (73.06 \times$ " $+ 67.96 \times$ " $) \times$ " $= 103.83$ "

No.5 $M_m = (60.91 \times$ " $+ 55.81 \times$ " $) \times$ " $= 86.33$ "

No.6 $M_m = (80.70 \times$ " $+ 61.01 \times$ " $) \times$ " $= 110.89$ "

1-3. SUMMARY OF BENDING MOMENT ON FOOTING

No1 : $M_m = (74.69 - 28.60) \times {}^{1.8}/_{1.4} = 59.26^{t\cdot m/m}$

No2 : $M_m = (95.62 - 28.60) \times 1.00 = 67.02$ "

No3 : $M_m = (78.12 - 13.97) \times 1.00 = 64.15$ "

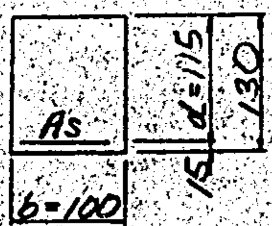
No4 : $M_m = (103.83 - 28.60) \times {}^{1}/_{1.15} = 65.42$ "

No5 : $M_m = (86.33 - 13.97) \times {}^{1}/_{1.15} = 62.92$ "

No6 : $M_m = (110.89 - 28.60) \times {}^{1}/_{1.50} = 54.86$ "

1-4. EXAMINATION OF SAFETY

$$M_m = 67.02^{t\cdot m/m}$$



$As = 6.67 - D29 = 42.83^{cm^2}$

$$P = \frac{As}{b \cdot d} = \frac{42.83}{100 \times 115} = 0.00372$$

$$\frac{1}{Lc} = 7.81 \qquad \frac{1}{Ls} = 297$$

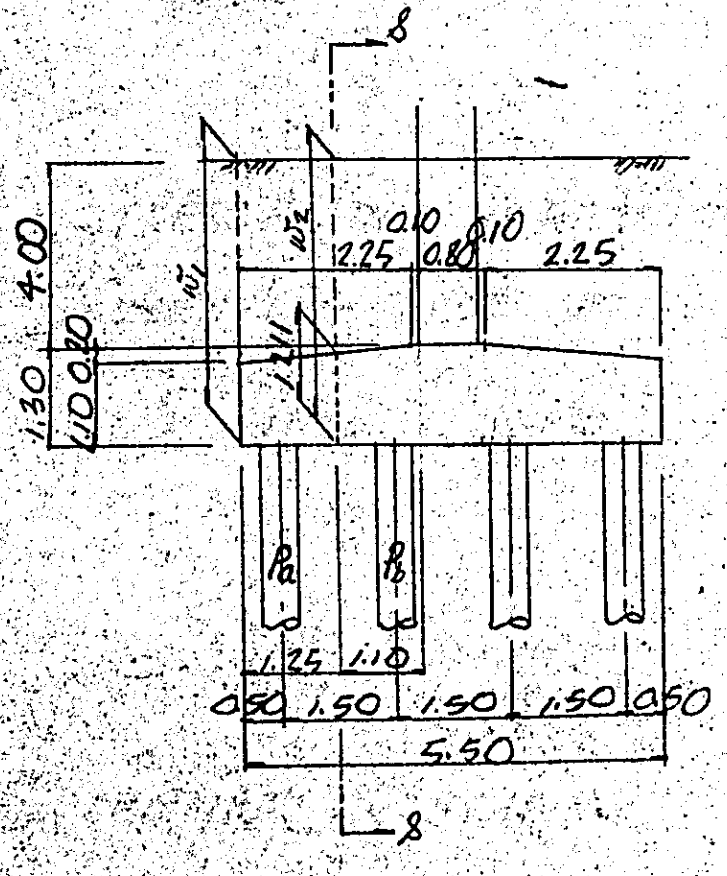
$$\sigma_c = \frac{M}{b \cdot d^2} \times \frac{1}{Lc} = \frac{67.02 \times 10^5}{100 \times 115^2} \times 7.81 = 39.6^{kg/cm^2} < 80^{kg/cm^2}$$

$$\sigma_s = \frac{M}{b \cdot d^2} \times \frac{1}{Ls} = \text{———〃———} \times 297 = 1505 \text{ "} < 1800 \text{"}$$

2. EXAMINATION OF SAFETY AGAINST SHEARING FORCE

EXAMINATION ON THE COMBINATION No.6

2-1. SHEARING FORCE DUE TO OWN WEIGHT OF FOOTING AND WEIGHT OF EARTH COVER



WHERE: s SECTION WHERE SHEARING FORCE IS CALCULATED

S_s SHEARING FORCE AT SECTION s

SHEARING FORCE AT SECTION S

$w_1 = 2.5^{t/m^3} \times 1.10 + 1.8^{t/m^3} \times 4.20 = 10.31^{t/m}$

$w_2 = (2.5'' \times 1.211 + 1.8'' \times 4.089) \times \dfrac{1.10}{2 \times (1.211 - 0.15)} = 5.38''$

$S_s = \frac{1}{2} \times (10.31 + 5.38) \times 1.25 = 9.81^t$

2-2. STRESS DUE TO REACTION FORCE ON PILES

SHEARING FORCE AT SECTION S

$P_a = 80.10 \times \dfrac{1.85}{2 \times (1.211 - 0.15)} = 70.36^t$

$S_s = 70.36 \times \dfrac{6}{10.00} = 42.22^t$

2-3. SUMMARY OF SHEARING FORCES ON FOOTING

$\Sigma S_s = 42.22 - 9.81 = 32.41^t$

2-4. EXAMINATION OF SAFETY,

$\tau = \dfrac{32.41 \times 10^3}{100 \times (121.1 - 15)} = 3.05^{kg/cm^2} < 3.7^{kg/cm^2}$

6 DESIGN OF SUBSTRUCTURE.

EXAMINATION IS MADE ONLY THE CASE OF LONGITUDINAL LOADING.

1. COMBINATION OF LOADS

No.6 DEAD LOAD + EARTHQUAKE LOAD

2. BENDING MOMENT AND AXIAL FORCE ACTING AT THE BOTTOM OF WALL

THE FOLLOWING FIGURES ARE REFERRED TO THE CALCULATION OF THE REACTION FORCES TRANSMITTED FROM THE SUPERSTRUCTURE.

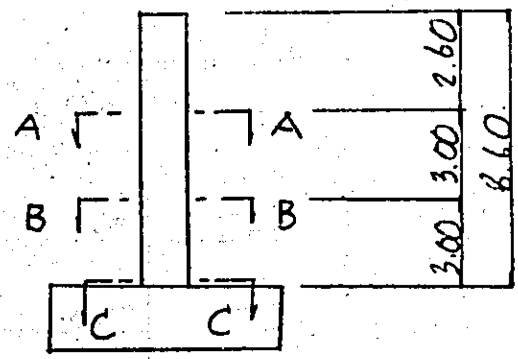
$$M = (23.84 \times 9.335 + 31.92 \times 8.25 + 9.46 \times 7.767 + 140.28 \times 3.80) \times 0.10 + 23.97 + (27.59 \times 8.60 + 7.48 \times 10.07) \times 2 = 758.41^{tm}$$

$$N = 23.84 + 31.92 + 9.46 + 140.28 + (183.93 + 68.00) \times 2 = 709.36^{t}$$

3. EXAMINATION OF SAFETY

M (tm)	758.41
N (t)	709.36
S (t)	
b (cm)	860
h (cm)	80
d (cm)	
d' (cm)	8
As (cm²)	D29 - 59 = 379.01
p	0.00550
As' (cm²)	= As
p'	= p
e = M/N (cm)	106.9
e = M/N + u (cm)	
e = M/N − u (cm)	
e/h	1.336
d/e	
d'/h	0.100
d'/d	
Ne/bd² (kg/cm²)	10.310
k	0.352
c	0.106
j	
I/Lc	
I/Ls	
β = σs/σc	
σc (kg/cm²)	96.7
σs (kg/cm²)	2157
τ (kg/cm²)	
σsa (kg/cm²)	2700
σcd (kg/cm²)	120
τa (kg/cm²)	

4. DEDUCTION OF REINFORCING BARS



4-1 BENDING MOMENT AND AXIAL FORCE ACTING AT THE SECTION A AND B.

$M_A = 23.97 + (23.84 \times 3.335 + 31.92 \times 2.25 + 9.46 \times 1.767$
$+ 2.5 \times 1.383 \times 1.60^2 \times 1/2) \times 0.1$
$+ (27.59 \times 2.60 + 7.48 \times 4.07) \times 2 = 247.49^{tm}$

$N_A = 23.84 + 31.92 + 9.46 + 2.5 \times 1.383 \times 1.60$
$+ (183.93 + 68.00) \times 2 = 598.63^{t}$

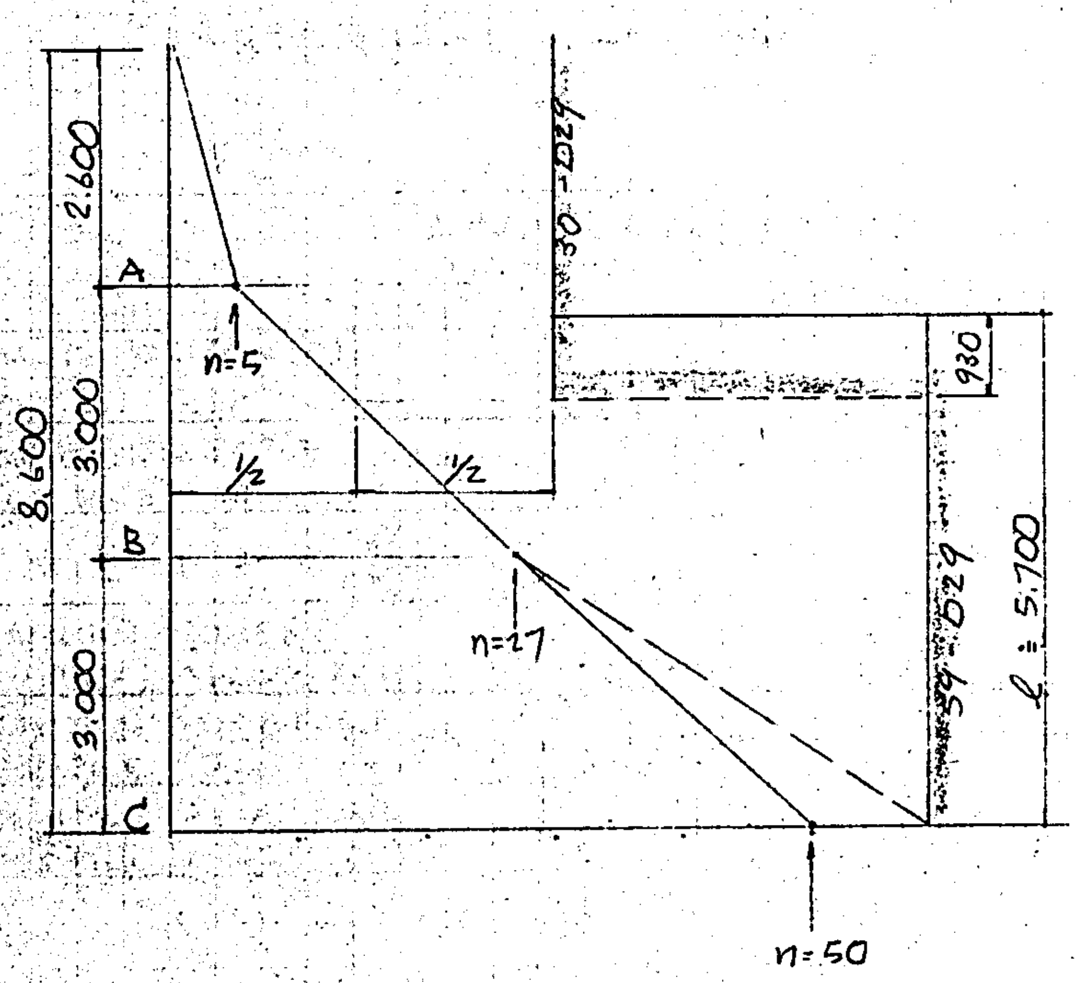
$M_B = 23.97 + (23.84 \times 6.335 + 31.92 \times 5.25 + 9.46 \times 3.767$
$+ 2.5 \times 1.383 \times 4.60^2 \times 1/2) \times 0.1$
$(27.59 \times 5.60 + 7.48 \times 7.07) \times 2 = 493.70^{tm}$

$N_B = 598.63 + 2.5 \times 1.383 \times 3.00 = 654.00^{t}$

4-2. THE LEAST REINFORCING BARS REQUIRED AT THE SECTION A AND B

SECTION	A	B	C
M (tm)	247.49	493.70	758.41
N (t)	598.63	654.00	709.36
b (cm)	860	"	"
h (")	80	"	"
d' (")	8	"	"
As	D29 - 5	D29 - 27	D29 - 50
σ_c (kg/cm²)	70.6	90.6	104.4
σ_s (")	2467	2669	2640

4-3. MOMENT DIAGRAM



7 DESIGN OF PILE

1. REACTION FORCES ACTING ON PILES

EXAMINATION IS MADE ONLY TO THE EARTHQUAKE LOADING.

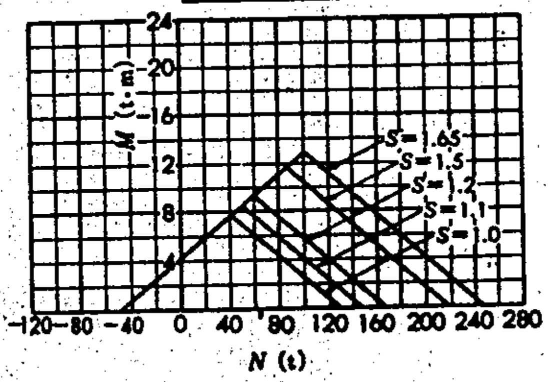
	LONGITUDINAL DIRECTION ①	TRANSVERSAL DIRECTION	
		② SINGLE TRACK	③ DOUBLE TRACK
WHOLE HORIZONTAL FORCE, ΣH (t)	107.44	62.49	87.68
HORIZONTAL FORCE PER PILE, H (t)	4.48	2.60	3.65
VALUE OF β (m^{-1})	0.214	〃	〃
MAXIMUM MOMENT PER PILE, M_{max} (tm)	6.74	3.91	5.49
MAXIMUM AXIAL FORCE PER PILE, P_{max} (t)	80.70	63.52	66.19
MINIMUM AXIAL FORCE PER PILE, P_{min} (t)	21.62	17.80	36.13

WHERE, $H = \Sigma H / n$, n …… NUMBER OF PILE, $n = 24$

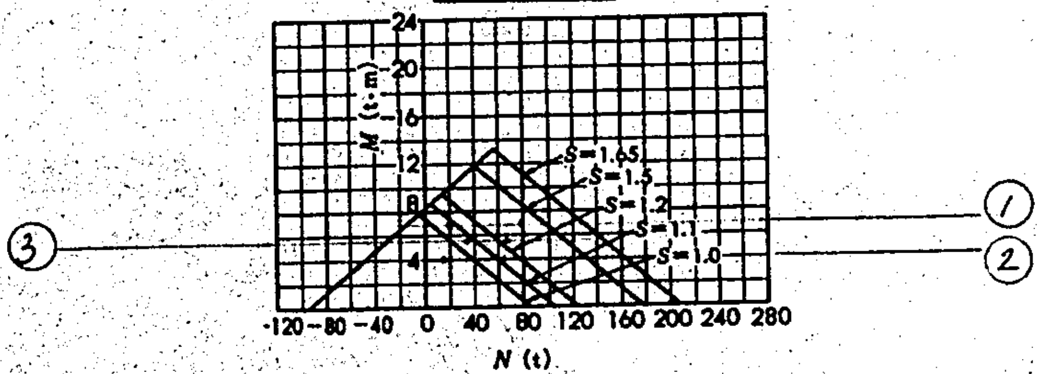
$$M_{max} = \frac{0.322 \cdot H}{\beta}$$

2. EXAMINATION OF SAFETY

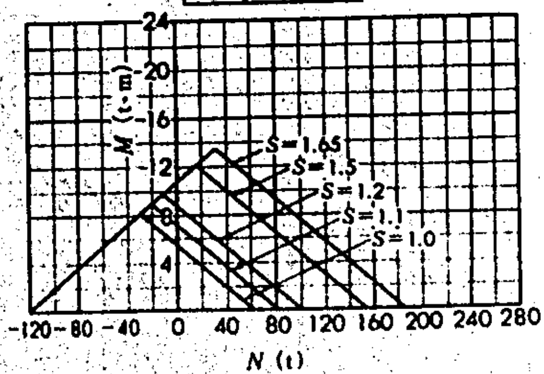
(13) D500-A



(14) D500-B

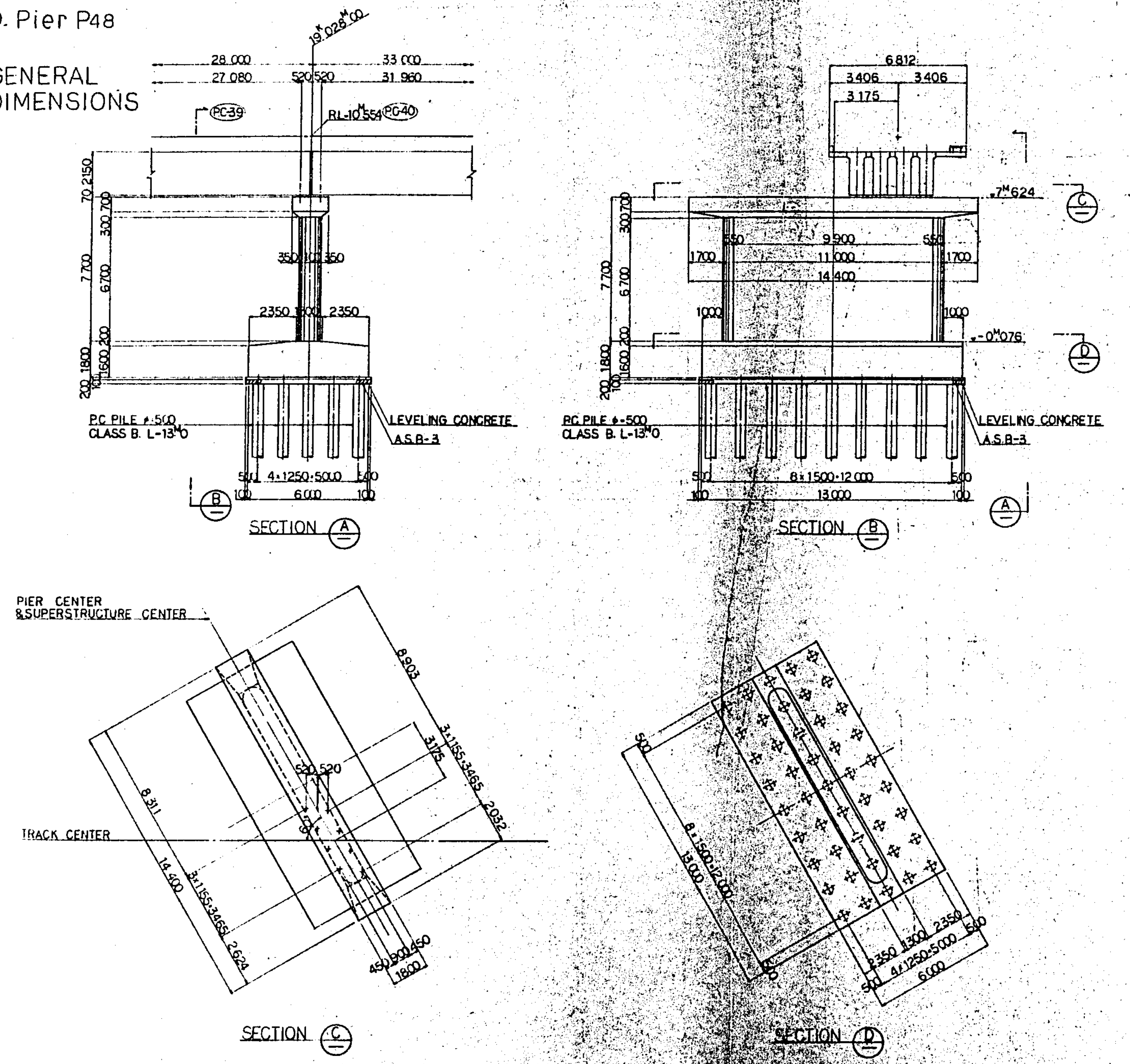


(15) D500-C

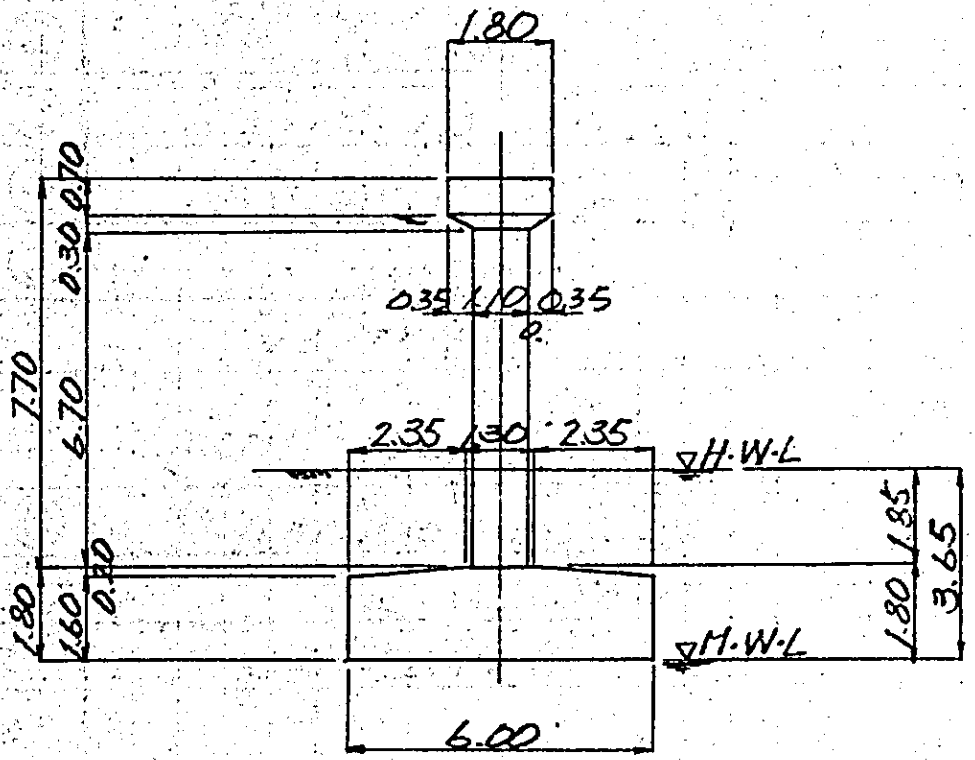


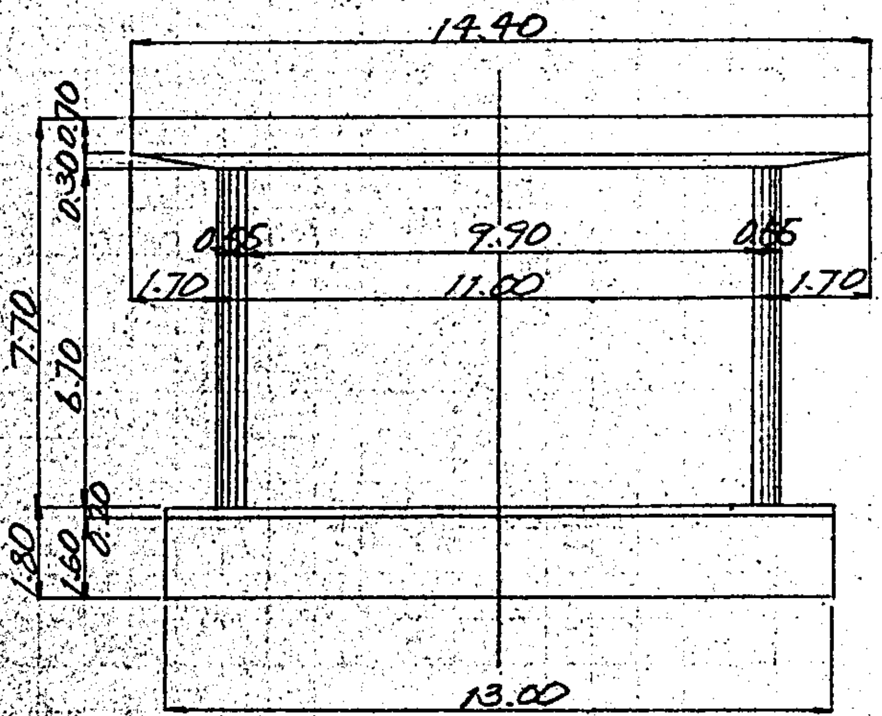
§10. Pier P48

GENERAL DIMENSIONS



2 OWN WEIGHT OF SUBSTRUCTURE - AND WEIGHT OF EARTH COVER





1. OWN WEIGHT OF SUBSTRUCTURE AND WEIGHT OF EARTH COVER

SUBSTRUCTURE

①	$2.5^{t/m^3} \times 1.80 \times 0.70 \times 14.40$	45.36^{t}
②	$2.5'' \times \frac{0.30}{6} \times \{14.40 \times 1.80 + 11.00 \times 1.10 + (14.40 + 11.00) \times (1.80 + 1.10)\}$	13.96
③	$2.5'' \times (\frac{\pi}{4} \times 1.10^2 + 9.90 \times 1.10)$ (11.840) $\times 6.70$	198.32"
④	$2.5'' \times 1/2 \times (1.30 + 6.00) \times 0.20 \times 13.00$	23.73
⑤	$2.5'' \times 6.00 \times 1.60 \times 13.00$	312.00
	SUB-TOTAL	593.37^{t}

EARTH COVER

⑥	$1.8^{t/m^3} \times (6.00 \times 13.00 - 11.840) \times 1.85$	220.31^{t}
⑦	$1.8'' \times 1/2 \times 2.35 \times 0.20 \times 13.00 \times 2$	11.00
	SUB-TOTAL	231.31^{t}

TOTAL

$$593.37 + 231.31 = 824.68^{t}$$

2. BUOYANCY

$$1.0^{t/m^3} \times 6.00 \times 13.00 \times 3.65 = 284.70^{t}$$

3. HORIZONTAL FORCES DUE TO EARTHQUAKE LOAD

	N (t)	y (m)	N×y (t·m)
①	45.36	9.15	415.04
②	13.96	8.662	120.92
③	198.32	5.15	1021.35
④	23.73	1.679	39.84
⑤	312.00	0.80	249.60
Σ	593.37		1846.75

NOTE N: AXIAL FORCE

y: DISTANCE FROM THE BOTTOM OF FOOTING TO GRAVITY CENTER

4. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

$$y_e = \frac{N \cdot y}{N} = \frac{1846.75}{593.37} = 3.112^{m}$$

$$P_E = 593.37 \times 0.1 = 59.34^{t}$$

$$M_o = 59.34 \times 3.112 = 184.67^{tm}$$

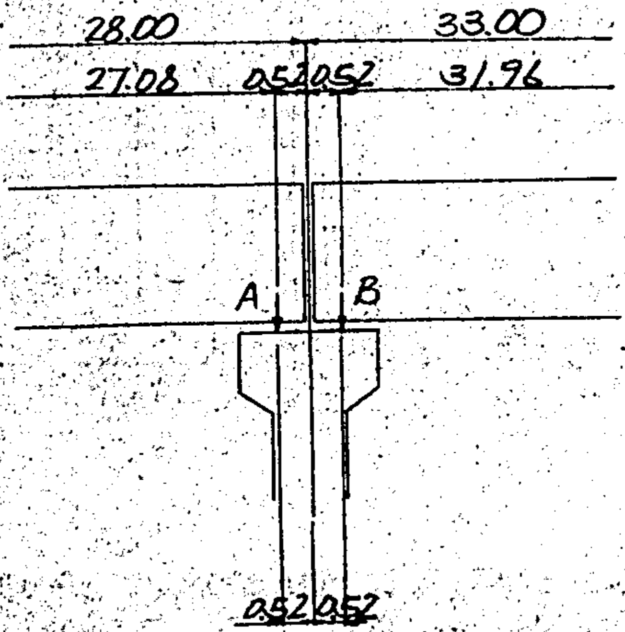
NOTE y_e : DISTANCE FROM THE BOTTOM OF FOOTING TO THE CENTER OF SUBSTRUCTURE.

P_E : HORIZONTAL FORCE DUE TO EARTHQUAKE LOAD

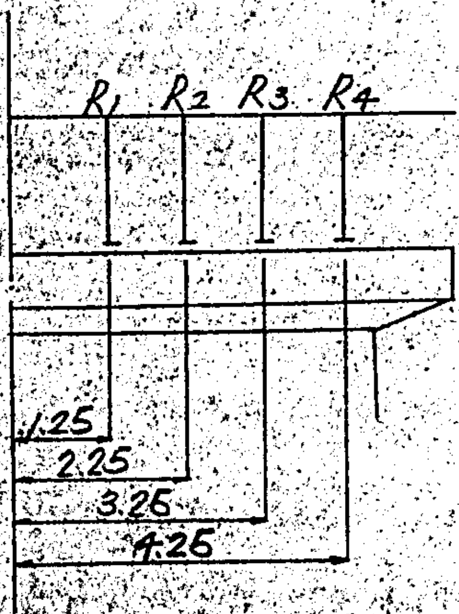
M_o : OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

[3] REACTION FORCES TRANSMITTED FROM SUPERSTRUCTURE

1. REACTION FORCES DUE TO DEAD WEIGHT OF SUPERSTRUCTURE



1-1. REACTION FORCES ACTING AT BEARINGS - A



$R_1 = 64.52^t$

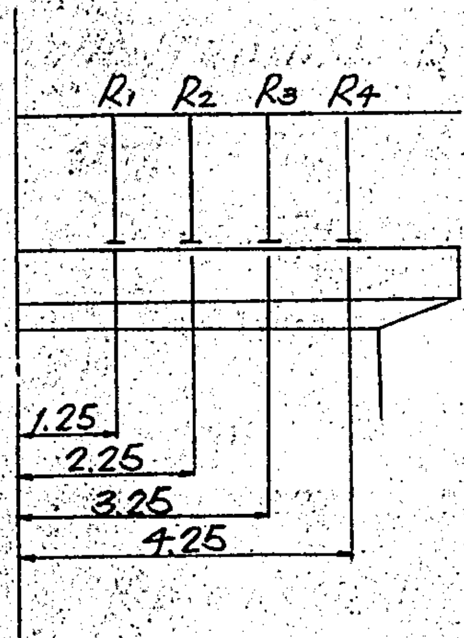
$R_2 = 63.40$ "

$R_3 = 62.19$ "

$R_4 = 64.05$ "

TOTAL $= 254.16^t$

1-2. REACTION FORCES ACTING AT BEARINGS-B



$R_1 = 76.04^t$

$R_2 = 74.72$ "

$R_3 = 73.29$ "

$R_4 = 75.49$ "

TOTAL $= 299.54^t$

1-3. SECTIONAL MOMENT AT THE CENTER OF PIER SHAFT DUE TO DEAD WEIGHT OF SUPERSTRUCTURE

SINGLE-TRACK LOADING FOR CALCULATION OF TRANSVERSAL STABILITY. DOUBLE-TRACK LOADING FOR CALCULATION OF LONGITUDINAL STABILITY

TRANSVERSAL DIRECTION

$$M_1 = (64.52 \times 1.25 + 63.40 \times 2.25 + 62.19 \times 3.25$$
$$+ 64.05 \times 4.25 + 76.04 \times 1.25 + 74.72 \times 2.25$$
$$+ 73.29 \times 3.25 + 75.49 \times 4.25) \times \frac{1}{\sin 60^\circ} = 1754.94^{tm}$$

LONGITUDINAL DIRECTION

$$M_2 = (299.54 - 254.16) \times 0.52 \times 2 \times \sin 60^\circ = 40.87^{tm}$$

1-4. HORIZONTAL FORCES DUE TO EARTHQUAKE ACTING ON DEAD-WEIGHT OF SUPERSTRUCTURE

a) LONGITUDINAL DIRECTION

31.96^{m} - SPAN SIDE

$P_{E1} = 299.54 \times 2 \times 0.1 - \frac{1}{2} \times 0.1 \times 299.54$

$= 44.93^{t}$

27.08^{m} - SPAN SIDE

$P_{E2} = 0.1 \times 254.16 = 25.42^{t}$

$\Sigma P_E = P_{E1} + P_{E2} = 44.93 + 25.42 = 70.35^{t}$

OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

COMPONENT OF ΣP_E VERTICAL TO THE WALL

$H_L = 70.35 \times \sin 60° = 60.92^{t}$

COMPONENT OF ΣP_E PARALLEL TO THE WALL

$H_T = 70.35 \times \cos 60° = 35.18^{t}$

$M_L = 60.92 \times 11.47 = 698.75^{tm}$

$M_T = 35.18 \times 11.47 = 403.51$ "

b) TRANSVERSAL DIRECTION

27.08^{m} - SPAN SIDE

$P_{E1} = 254.16 \times 0.1 = 25.42^{t}$

31.96^{m} - SPAN SIDE

$P_{E2} = 299.54 \times 0.1 = 29.95^{t}$

$\Sigma P_E = P_{E1} + P_{E2} = 25.42 + 29.95 = 55.37^{t}$

OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

COMPONENT OF ΣP_E VERTICAL TO THE WALL

$H_L = 55.37 \times \cos 60° = 27.69^{t}$

COMPONENT OF ΣP_E PARALLEL TO THE WALL

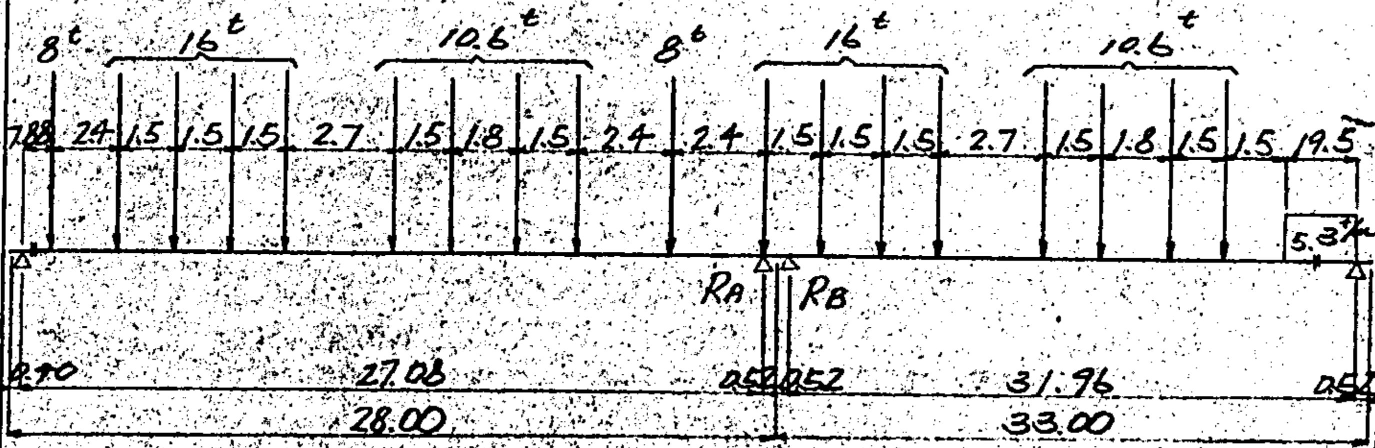
$H_T = 55.37 \times \sin 60° = 47.95^{t}$

$M_L = 27.69 \times 11.47 = 317.60^{tm}$

$M_T = 47.95 \times 11.47 = 549.99$ ″

2. REACTION FORCES DUE TO LIVE LOAD PLUS IMPACT

EQUIVALENT TO KS-16 LOADING.
CALCULATION IS CARRIED OUT UNDER THE LOADING CONDITION OF PRODUCING MAXIMUM REACTION FORCE ON PIER



$$R_A = \frac{1}{27.08} \times (8 \times 7.88 + 16 \times 4 \times 12.63 + 10.6 \times 4 \times 19.88 + 8 \times 24.68 + 16 \times 27.08) = 86.36^t$$

$$R_B = \frac{1}{31.96} \times (5.3 \times 19.50 \times 9.75 + 10.6 \times 4 \times 23.40 + 16 \times 3 \times 30.00) = 107.63^t$$

IMPACT COEFFICIENT

27.08^m - SPAN SIDE --- $i = 0.349$

31.96^m - SPAN SIDE --- $i = 0.336$

LIVE LOAD PLUS IMPACT

$R(A+L) = 86.36 \times 1.349 = 116.60^{t}$

$R(B+L) = 107.63 \times 1.336 = 143.79$ "

TOTAL $= 260.29^{t}$

2-1. SECTIONAL MOMENT ACTING AT THE CENTER OF PIER SHAFT

SINGLE-TRACK LOADING FOR CALCULATION OF TRANSVERSAL STABILITY. DOUBLE-TRACK LOADING FOR CALCULATION OF LONGITUDINAL STABILITY.

TRANSVERSAL DIRECTION

$M_1 = 260.29 \times 2.75 \times \frac{1}{\sin 60}$

$= 826.53^{tm}$

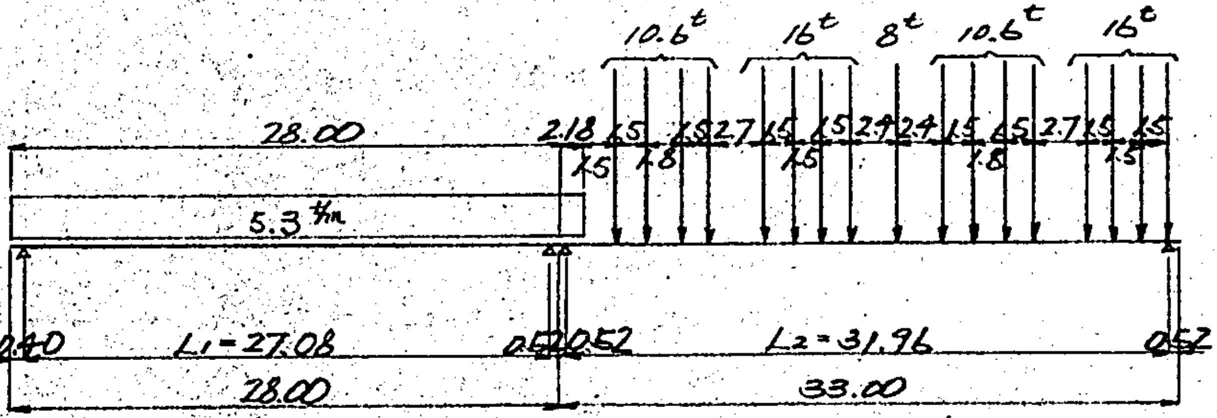
LONGITUDINAL DIRECTION

$M_2 = (143.79 - 116.50) \times 0.52 \times 2 \times \sin 60^{\circ}$

$= 24.58^{tm}$

3. BRAKE LOAD AND TRACTION LOAD

UNDER THE LOADING CONDITION AS SHOWN BELOW



3-1. BRAKE LOAD

15% OF KS LOADING

L1 - SPAN SIDE

$$P_{B-1} = 5.3^{t/m} \times 28.00 \times 0.15 \times \frac{1}{2}$$

$$= 11.13^{t}$$

L2 - SPAN SIDE

$$P_{B-2} = (5.3^{t/m} \times 2.18 + 16 \times 8 + 10.6 \times 8 + 8)$$

$$\times 0.15 \times \frac{1}{2} = 17.43^{t}$$

$$\Sigma P_B = P_{B-1} + P_{B-2} = 11.13 + 17.43 = 28.56^{t}$$

3-2. TRACTION LOAD

25% OF MOVING WHEEL AXLE LOAD
OF KS LOADING

L_2 - SPAN SIDE

$P_T = 16 \times 8 \times 0.25 \times \frac{1}{2} = 16.00^t$

3-3. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

COMPONENT OF ΣPB VERTICAL TO THE WALL

$H_L = 28.56 \times \sin 60° = 24.73^t$

COMPONENT OF ΣPB PARALLEL TO THE WALL

$H_T = 28.56 \times \cos 60° = 14.28^t$

$M_L = 24.73 \times 14.23 = 351.91^{tm}$

$M_T = 14.28 \times 14.23 = 203.20$ "

4. CENTRIFUGAL LOAD

ASSUMED THAT THE LOAD IS EQUIVALENT TO THE LIVE (TRAIN) LOAD MULTIPLIED BY α AND IS ACTING TRANSVERSALLY ON 1.8 m ABOVE THE TRACK LEVEL.

REFERENCE IS MADE TO THE LOADING CALCULATION OF LIVE (TRAIN) LOAD PLUS IMPACT.

$$R = 500^{m} \text{ ---- } \alpha = 0.12$$

$$\Sigma P_c = (86.36 + 107.63) \times 0.12 = 23.28^{t}$$

4-1. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.

COMPONENT OF ΣP_c VERTICAL TO THE WALL

$$H_L = 23.28 \times \cos 60^{\circ} = 11.64^{t}$$

COMPONENT OF ΣP_c PARALLEL TO THE WALL

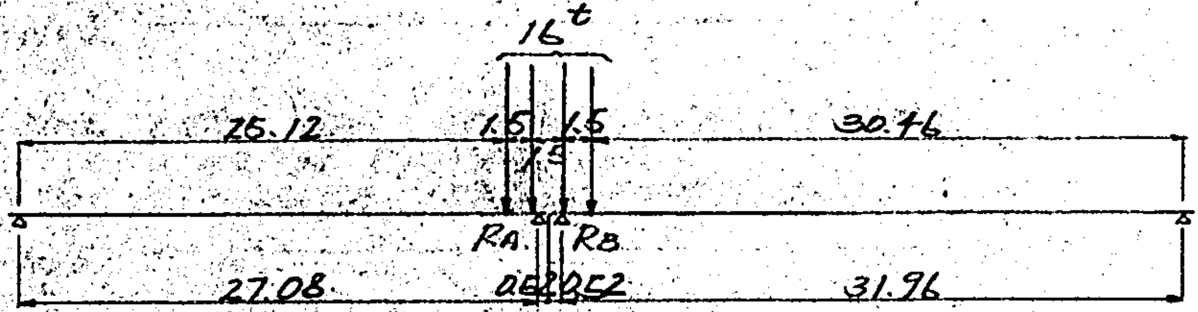
$$H_T = 23.28 \times \sin 60^{\circ} = 20.16^{t}$$

$$M_L = 11.64 \times 14.23 = 165.64^{tm}$$

$$M_T = 20.16 \times 14.23 = 286.88 \text{ "}$$

5. TRAIN LATERAL LOAD

TRANSVERSAL FORCE DUE TO LIVE (TRAIN) LOAD IS ASSUMED TO BE EQUIVALENT TO THE SERIES OF CONCENTRATED LOADS CONSISTED OF 15% OF MOVING WHEEL AXLE LOAD ACTING TRANSVERSALLY AT THE TRACK LEVEL.
CALCULATION IS MADE UNDER THE SINGLE-TRACK LOADING



$$R_A + R_B = \frac{16}{27.08} \times (25.12 + 26.62 + \frac{16}{31.96} \times (30.46 + 31.96) = 61.55^t$$

$$\Sigma P_T = 61.82 \times 0.15 = 9.27^t$$

5-1. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.

COMPONENT OF ΣP_T VERTICAL TO THE WALL

$$H_C = 9.27 \times \cos 60° = 4.64^t$$

COMPONENT OF ΣP_T PARALLEL TO THE WALL

$$H_T = 9.27 \times \sin 60° = 8.03^t$$

$$M_L = 4.64 \times 12.43 = 57.68^t$$

$$M_T = 8.03 \times 12.43 = 99.81$$

4 CALCULATION ON STABILITY

1. COMBINATION OF LOADS

1-1. TRANSVERSAL DIRECTION

No.1. DEAD LOAD (M.W.L)

No.2. DEAD LOAD + (TRAIN + IMPACT) LOAD (M.W.L)

No.3. ——— 〃 ——— (H.W.L)

No.4. DEAD LOAD + (TRAIN + IMPACT) LOAD
+ TRAIN LATERAL LOAD
+ BRAKE LOAD OR TRACTION LOAD (M.W.L)

No.5. ——— 〃 ——— (H.W.L)

No.6. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

No.7. DEAD LOAD (M.W.L)

No.8. DEAD LOAD + (TRAIN + IMPACT) LOAD
+ CENTRIFUGAL LOAD (M.W.L)

No.9. ——— 〃 ——— (H.W.L)

No.10. DEAD LOAD + (TRAIN + IMPACT) LOAD
+ CENTRIFUGAL LOAD
+ BRAKE LOAD OR TRACTION LOAD (M.W.L)

No.11 ——— 〃 ——— (H.W.L)

No.12 DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

THE ABOVE LOADING COMBINATIONS ARE APPLIED NO. 1 THRU NO. 6 FOR SINGLE-TRACK LOADING AND NO. 7 THRU NO. 12 FOR DOUBLE-TRACK LOADING.

1-2. LONGITUDINAL DIRECTION.

No.1. DEAD LOAD (M.W.L)

No.2. DEAD LOAD + (TRAIN + IMPACT) LOAD + CENTRIFUGAL LOAD (M.W.L)

No.3. ———— " ———— (H.W.L)

No.4. DEAD LOAD + (TRAIN + IMPACT) LOAD
+ CENTRIFUGAL LOAD
+ BRAKE LOAD or TRACTION LOAD (M.W.L)

No.5. ———— " ———— (H.W.L)

No.6. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

ALL OF THE ABOVE LOADING COMBINATIONS ARE APPLIED FOR DOUBLE-TRACK LOADING.

2. TABLE OF FORCE AND MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.

2-1. TRANSVERSAL DIRECTION

SINGLE-TRACK LOADING

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No1	824.68 + 254.16 +299.54 = 1378.38	1754.94	————
No2	1378.38 + 260.29 = 1638.67	1754.94 + 826.53 = 2581.47	————
No3	1638.67 − 284.70 = 1353.97	2581.47	————
No4	1638.67	2581.47 + 99.81 + 203.20 = 2884.48	8.03 + 14.28 = 22.31
No5	1353.97	2884.48	22.31
No6	1378.38	184.67 + 1754.94 + 403.51 + 549.99 = 2893.11	59.34 + 35.18 + 47.95 = 142.47

DOUBLE-TRACK LOADING

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No7	324.68+(254.16 +299.54)×2 =1932.08	———	———
No8	1932.08+260.29 ×2 = 2452.66	286.88 × 2 = 573.76	20.16 × 2 = 40.32
No9	2452.66-284.70 = 2167.96	573.76	40.32
No10	2452.66	573.76 + 203.20 = 776.96	40.32 + 14.28 = 54.60
No11	2167.96	776.96	54.60
No12	1932.08	184.67+(403.51 +549.99)×2 = 2091.67	59.34+(35.18 +47.95)×2 = 225.60

2-2, LONGITUDINAL DIRECTION

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No 1	1932.08	40.87	
No 2	2452.66	165.64 × 2 + 24.58 + 40.87 = 396.73	11.64 × 2 = 23.28
No 3	2167.96	396.73	23.28
No 4	2452.66	396.73 + 351.91 = 748.64	23.28 + 24.73 = 48.01
No 5	2167.96	748.64	48.01
No 6	1932.08	184.67 + 40.87 + (698.75 + 317.60) × 2 = 2258.24	59.34 + (60.92 + 27.69) × 2 = 236.56

3. REACTION FORCE ACTING ON PILES

$$P = \frac{N}{n} \pm \frac{M}{I} \times x$$

WHERE: P REACTION FORCE

n NUMBER OF PILES

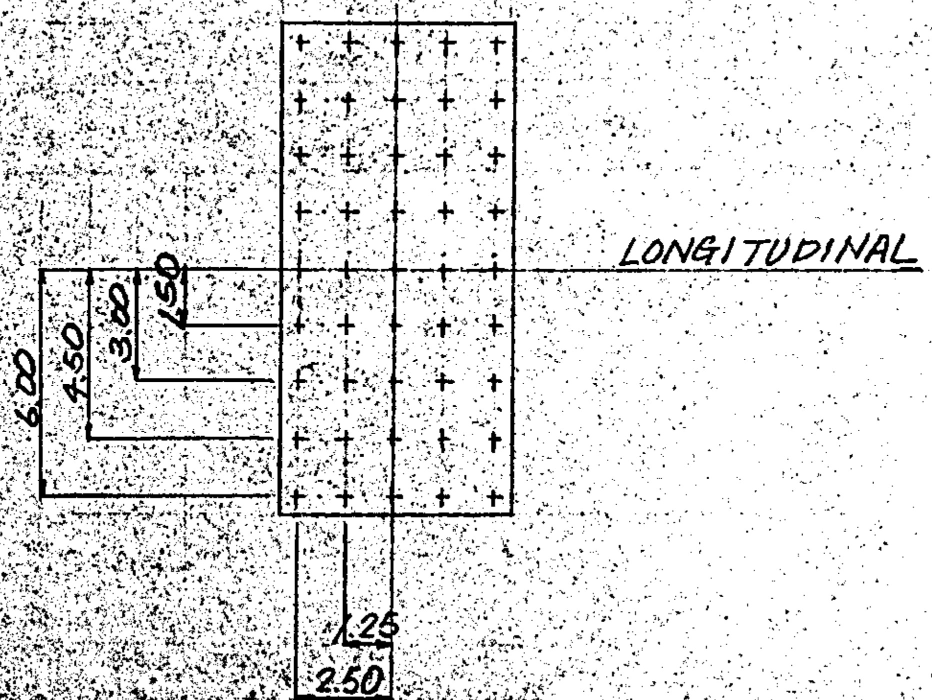
N AXIAL FORCE ACTING AT THE CENTER OF THE BOTTOM OF FOOTING

M MOMENT ACTING AT THE CENTER OF THE BOTTOM OF FOOTING

I MOMENT OF INERTIA OF THE GROUP OF PILES WITH RESPECT TO GEOMETRICAL CENTER

x DISTANCE FROM THE GEOMETRICAL CENTER OF THE GROUP OF PILES TO THE CENTER OF THE PILE TO BE CALCULATED

3-1. ARRANGEMENT OF PILES



3-2 REACTION FORCE ACTING ON PILES DUE TO TRANSVERSAL LOAD

	N (t)	M (t·m)	$\frac{N}{n}$ (t)	$\frac{M}{I}x$ (t)	Pmax (t)	Pmin (t)
No 1	1378.38	1754.94	30.63	2.60	46.23	15.03
No 2	1638.67	2581.47	36.41	3.82	59.33	13.49
No 3	1353.97	2581.47	30.09	3.82	53.01	7.17
No 4	1638.67	2884.48	36.41	4.27	62.03	10.79
No 5	1353.97	2884.48	30.09	4.27	55.71	4.47
No 6	1378.38	2893.11	30.63	4.29	56.37	4.87
No 7	1932.08	——	42.94	——	42.94	42.94
No 8	2452.66	573.76	54.50	0.85	59.60	49.40
No 9	2167.96	573.76	48.18	0.85	53.28	43.08
No 10	2452.66	776.96	54.50	1.15	61.40	47.60
No 11	2167.96	776.96	48.18	1.15	55.08	41.28
No 12	1932.08	2091.67	42.94	3.10	61.54	24.34

$$I = (1.50^2 + 3.00^2 + 4.50^2 + 6.00^2) \times 2 \times 5 = 675.00\ m^2$$

$$x = 6.00\ m$$

3-3. REACTION FORCE ACTING ON PILES DUE TO LONGITUDINAL LOAD.

	N (t)	M (t·m)	$\frac{N}{n}$ (t)	$\frac{M}{I}$ ($\frac{t}{m}$)	$x_{(m)}$	P_{max} (t)	P_{min} (t)
No1	1932.08	40.87	42.94	0.29	x_1	43.30	42.58
					x_2	43.67	42.21
					x_3		
No2	2452.66	396.73	54.50	2.82	x_1	58.03	50.97
					x_2	61.55	47.45
					x_3		
No3	2167.96	396.73	48.18	2.82	x_1	51.71	44.65
					x_2	55.23	41.13
					x_3		
No4	2452.66	748.64	54.50	5.32	x_1	61.15	47.85
					x_2	67.80	41.20
					x_3		
No5	2167.96	748.64	48.18	5.32	x_1	54.83	41.53
					x_2	61.48	34.88
					x_3		
No6	1932.08	2258.24	42.94	16.06	x_1	63.02	22.86
					x_2	83.09	2.79
					x_3		

$$I = (1.25^2 + 2.50^2) \times 2 \times 9 = 140.63 \, m^2$$

$$x_1 = 1.25 \, m$$

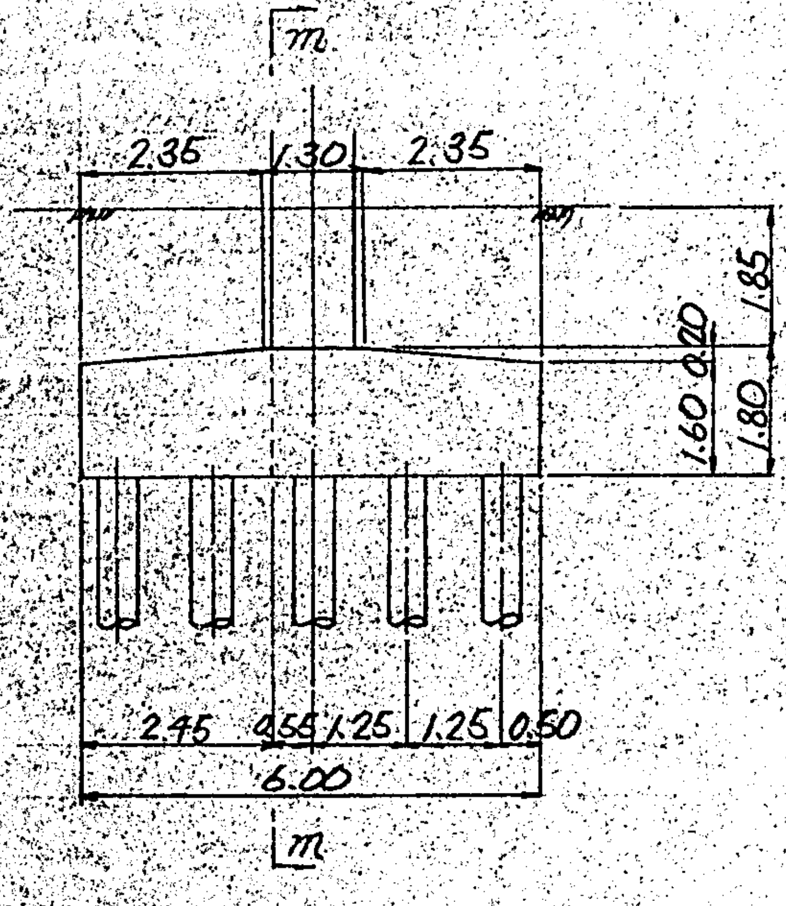
$$x_2 = 2.50 \, ''$$

5 DESIGN OF FOOTING

1. DESIGN OF FOOTING AGAINST LONGITUDINAL LOADING

1-1. EXAMINATION OF SAFETY AGAINST BENDING MOMENT

a) BENDING MOMENT DUE TO OWN WEIGHT OF FOOTING AND WEIGHT OF EARTH COVER.



WHERE: m SECTION WHERE MOMENT IS CALCULATED

Mm BENDING MOMENT AT SECTION m

BENDING MOMENT AT SECTION m

i) THE CASE NO BUOYANCY IS CONSIDERED

$$M_m = (2.5^{t/m^3} \times 1.80 + 1.8^{t/m^3} \times 1.85) \times \frac{1}{2} \times 2.45^2$$

$$-(2.5-1.8) \times 1/2 \times 2.35 \times 0.20 \times 1.667 = 23.23^{tm}$$

ii) THE CASE BUOYANCY IS CONSIDERED

$$M_m = 23.23 - \frac{1}{2} \times 2.45^2 \times 3.65 \times 1.0^{t/m^3} = 12.28^{tm}$$

b) STRESS DUE TO REACTION FORCE ON PILES

BENDING MOMENT AT SECTION m

NO1 $M_m = (43.30 \times 0.80 + 43.67 \times 2.05) \times \frac{9}{13.00} = 85.96^{tm}$

NO2 $M_m = (58.03 \times$ 〃 $+ 61.55 \times$ 〃 $) \times$ 〃 $= 119.49$ 〃

NO3 $M_m = (51.71 \times$ 〃 $+ 55.23 \times$ 〃 $) \times$ 〃 $= 107.02$ 〃

NO4 $M_m = (61.15 \times$ 〃 $+ 67.80 \times$ 〃 $) \times$ 〃 $= 130.09$ 〃

NO5 $M_m = (54.83 \times$ 〃 $+ 61.48 \times$ 〃 $) \times$ 〃 $= 117.62$ 〃

NO6 $M_m = (63.02 \times$ 〃 $+ 83.09 \times$ 〃 $) \times$ 〃 $= 152.83$ 〃

c). SUMMARY OF BENDING MOMENT ON FOOTING

No1 : $M_m = (85.96 - 23.23) \times \frac{1.8}{1.4} = 80.65^{tm}$

No2 : $M_m = (119.49 - 23.23) \times \frac{1}{1.0} = 96.26$ "

No3 : $M_m = (107.02 - 12.28) \times \frac{1}{1.0} = 94.74$ "

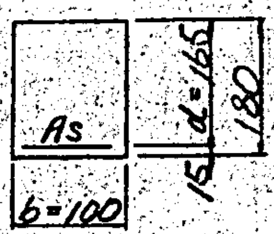
No4 : $M_m = (130.09 - 23.23) \times \frac{1}{1.15} = 92.92$ "

No5 : $M_m = (117.62 - 12.28) \times \frac{1}{1.15} = 91.60$ "

No6 : $M_m = (152.83 - 23.23) \times \frac{1}{1.5} = 86.40$ "

d). EXAMINATION OF SAFETY

$$M_m = 96.26^{tm}$$



$A_s = D29 - 6.67 = 42.85^{cm^2}$

$$p = \frac{A_s}{b \cdot d} = \frac{42.85}{100 \times 165} = 0.00260$$

$$\frac{1}{L_c} = 8.94 \qquad \frac{1}{L_s} = 418$$

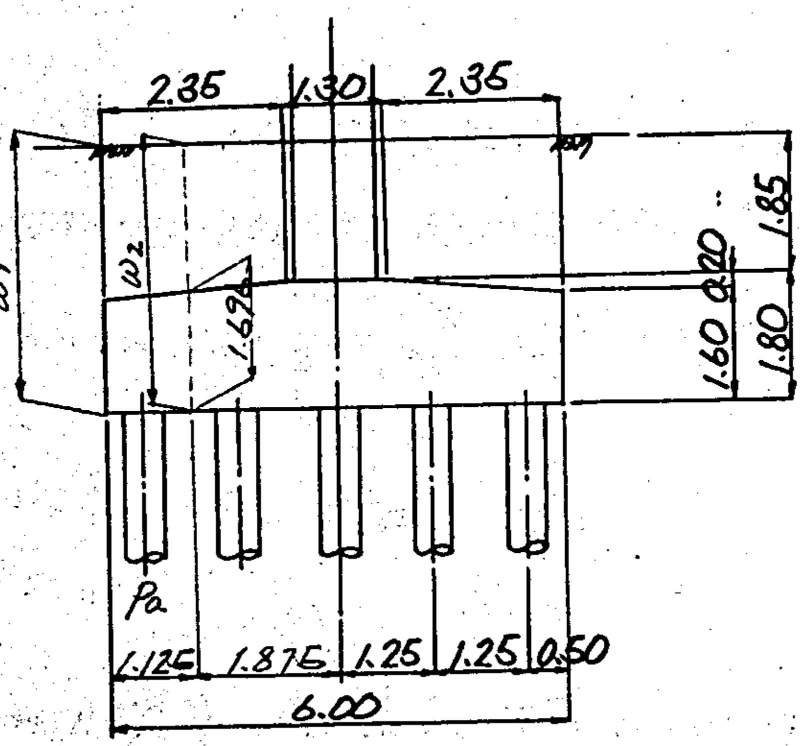
$$\sigma_c = \frac{M}{b \cdot d^2} \times \frac{1}{L_c} = \frac{96.26 \times 10^5}{100 \times 165^2} \times 8.94 = 31.6^{kg/cm^2} < 80^{kg/cm^2}$$

$$\sigma_s = \frac{M}{b \cdot d^2} \times \frac{1}{L_s} = \text{—— '' ——} \times 418 = 1478\text{ ''} < 1800\text{ ''}$$

1-2. EXAMINATION OF SAFETY AGAINST SHEARING FORCE.

EXAMINATION ON THE COMBINATION No.6

a-). SHEARING FORCE DUE TO OWN WEIGHT OF FOOTING AND WEIGHT OF EARTH COVER.



WHERE: s SECTION WHERE SHEARING FORCE IS CALCULATED

S_s SHEARING FORCE AT SECTION s

- SHEARING FORCE AT SECTION S

$$\omega_1 = 2.5^{t/m^3} \times 1.60 + 1.8^{t/m^3} \times 2.05 = 7.69^{t/m}$$

$$\omega_2 = (2.5'' \times 1.696 + 1.8'' \times 1.954) \times \frac{1.325}{2 \times (1.696 - 0.15)} = 3.32''$$

$$S_S = \tfrac{1}{2} \times (7.69 + 3.32) \times 1.125 = 6.19^t$$

b). STRESS DUE TO REACTION FORCE ON PILES

SHEARING FORCE AT SECTION S

$$P_a = 83.09 \times \frac{1.95}{2 \times (1.696 - 0.15)} = 52.40^t$$

$$S_S = 52.40 \times \frac{9}{13.00} = 36.28^t$$

c). SUMMARY OF SHEARING FORCES ON FOOTING

$$S_S = 36.28 - 6.19 = 30.09^t$$

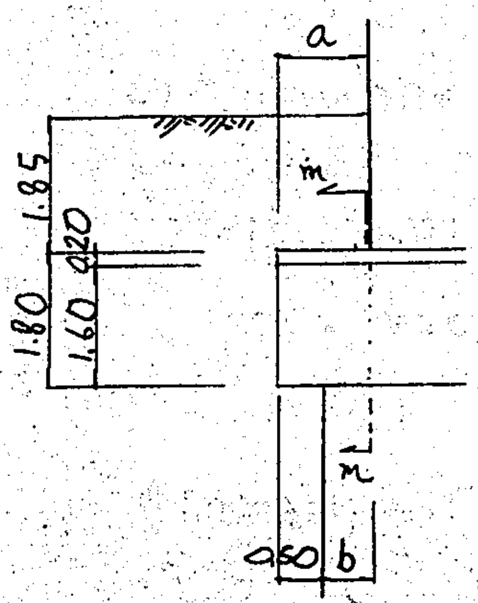
d). EXAMINATION OF SAFETY,

$$\tau = \frac{30.09 \times 10^3}{100 \times 154.6} = 1.95^{kg/cm^2} < 3.7^{kg/cm^2}$$

2. DESIGN OF FOOTING AGAINST TRANSVERSAL LOADING

2-1 EXAMINATION OF SAFETY AGAINST BENDING MOMENT

a) BENDING MOMENT DUE TO OWN WEIGHT OF FOOTING AND WEIGHT OF EARTH COVER



$$a = 1.55 - \frac{1}{2} \times \sqrt{\frac{\pi \cdot 1.10^2}{4}} = 1.063^{m}$$

$$b = 1.063 - (0.50 - 0.10) = 0.663^{m}$$

BENDING MOMENT AT SECTION m

$$w = 2.5 \times \left\{ \frac{1}{2} \times (1.30 + 6.00) \times 0.20 + 1.60 \times 6.00 \right\}^{25.53}$$

$$+ 1.8 \times \left(\frac{1}{2} \times 0.20 \times 2.35 \times 2 + 1.85 \times 6.00 \right)^{20.83}$$

$$= 46.66^{t/m}$$

$$\therefore M_m = 46.66 \times 1.063^2 \times \frac{1}{2} = 26.36^{tm}$$

b) STRESS DUE TO REACTION FORCE ON PILES

BENDING MOMENT AT SECTION m

CASE No. 8

$M_n = 59.60 \times 5 \times 0.663 = 197.24^{tm}$

c) SUMMARY OF BENDING MOMENT ON FOOTING

$\Sigma M_m = 197.24 - 26.36$

$= 170.88^{tm}$

d) EXAMINATION OF SAFETY

$Be = 110 + 162.6 \times 2 = 435.2^{cm}$

$h = 180^{cm} \quad d = 162.6^{cm}$

$As = 29 - D19 = 83.09^{cm^2}$

$p = 83.09 / 435.2 \times 162.6 = 0.00117$

$\therefore \sigma_c = \dfrac{170.88 \times 10^5}{435.2 \times 162.6^2} \times 12.4 = 18.4^{kg/cm^2} < 80^{kg/cm^2}$

$\sigma_s = \quad \text{"} \quad \times 907 = 1347\text{"} < 1800\text{"}$

6 DESIGN OF SUBSTRUCTURE.

EXAMINATION IS MADE ONLY THE CASE OF LONGITUDINAL LOADING.

1. COMBINATION OF LOADS

NO.6 DEAD LOAD + EARTHQUAKE LOAD

2. BENDING MOMENT AND AXIAL FORCE ACTING AT THE BOTTOM OF WALL.

THE FOLLOWING FIGURES ARE REFERRED TO THE CALCULATION OF THE REACTION FORCES TRANSMITTED FROM THE SUPERSTRUCTURE.

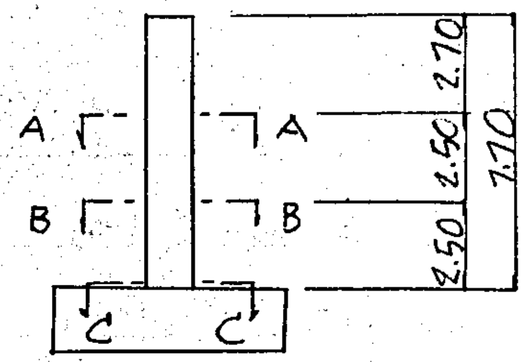
$$M = 40.87 + 45.36 \times 0.1 \times 7.35 + 13.96 \times 0.1 \times 6.862 + 198.32 \times 0.1 \times 3.35 + 60.92 \times 2 \times 9.67 + 27.69 \times 2 \times 9.67 = 1863.74^{t \cdot m}$$

$$N = 45.36 + 13.96 + 198.32 + (254.16 + 299.54) \times 2 = 1365.04^{t}$$

3. EXAMINATION OF SAFETY

M (tm)	1863.94	
N (t)	1365.04	
S (t)		
b (cm)	990	
h (cm)	110	
d (cm)		
d' (cm)	8.5	
As (cm^2)	D32-67 =532.11	(ctc150)
p	0.00488	
As' (cm^2)	=As	
p'	=p	
e=M/N (cm)	136.5	
e=M/N+u (cm)		
e=M/N−u (cm)		
e/h	1.241	
d/e		
d'/h		
d'/d	0.077	
Ne/bd² (kg/cm²)	12.534	
k	0.351	
c	0.114	
j		
1/Lc		
1/Ls		
β=σs/σc		
σc (kg/cm²)	109.7	
σs (kg/cm²)	2670	
τ (kg/cm²)		
σsa (kg/cm²)	2700	
σca (kg/cm²)	120	
τa (kg/cm²)		

4. DEDUCTION OF REINFORCING BARS



4-1 BENDING MOMENT AND AXIAL FORCE ACTING AT THE SECTION A AND B

$$M_A = 40.87 + (45.36 \times 2.35 + 13.96 \times 1.862 + 2.5 \times 11.840 \times 1.70^2 \times 1/2) \times 0.1 + (60.92 + 27.69) \times 4.67 \times 2 = 886.02^{tm}$$

$$N_A = 45.36 + 13.96 + 2.5 \times 11.840 \times 1.70 + (254.16 + 299.54) \times 2 = 1217.04^{t}$$

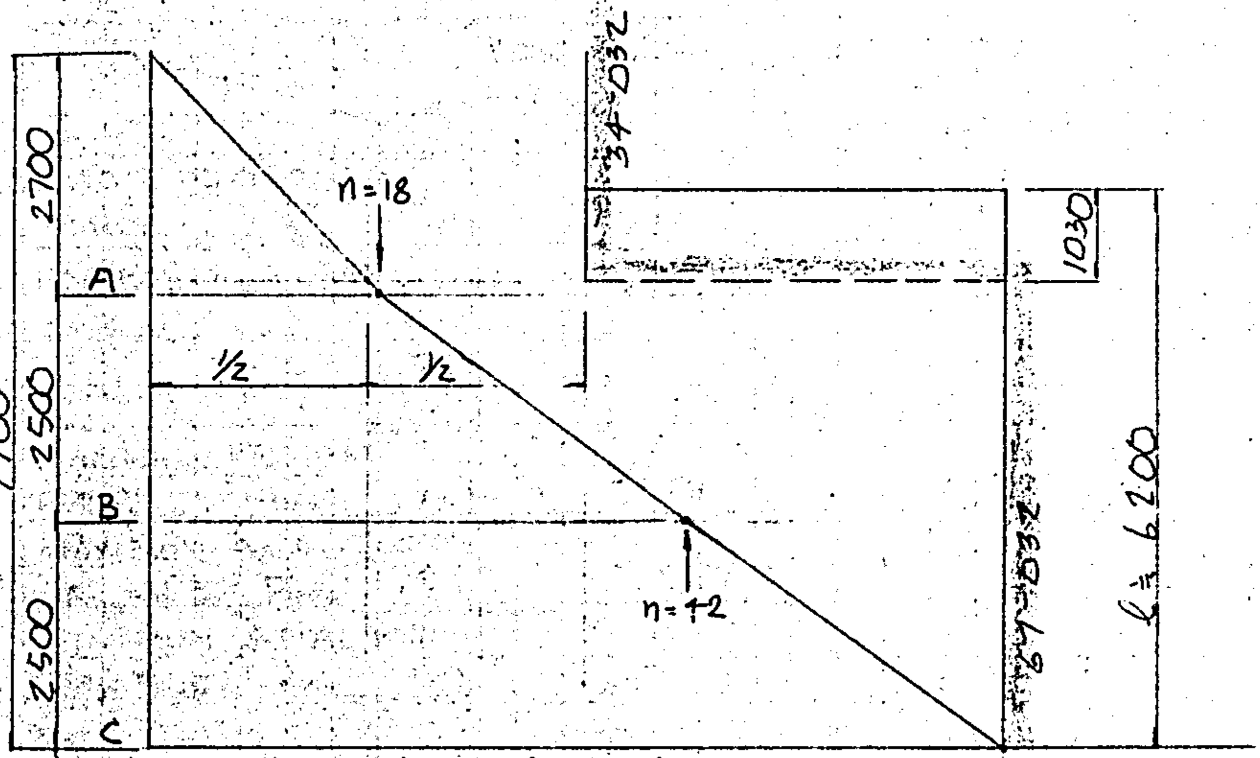
$$M_B = 40.87 + (45.36 \times 4.85 + 13.96 \times 4.362 + 2.5 \times 11.840 \times 4.20^2 \times 1/2) \times 0.1 + (60.92 + 27.69) \times 7.17 \times 2 = 1365.73^{tm}$$

$$N_B = 1217.04 + 2.5 \times 11.840 \times 2.50 = 1291.04^{t}$$

4-2. THE LEAST REINFORCING BARS REQUIRED AT THE SECTION A AND B

SECTION	A	B	C
M (tm)	886.02	1365.73	1863.94
N (t)	1217.04	1291.04	1365.04
b (cm)	990	〃	〃
h (〃)	110	〃	〃
d' (〃)	8.5	〃	〃
As	D32-18	D32-42	D32-67
σ_c (kg/cm²)	88.3	99.9	109.7
σ_s (〃)	2698	2678	2670

4-3. MOMENT DIAGRAM



7 DESIGN OF PILE

1. REACTION FORCES ACTING ON PILES

EXAMINATION IS MADE ONLY TO THE EARTHQUAKE LOADING.

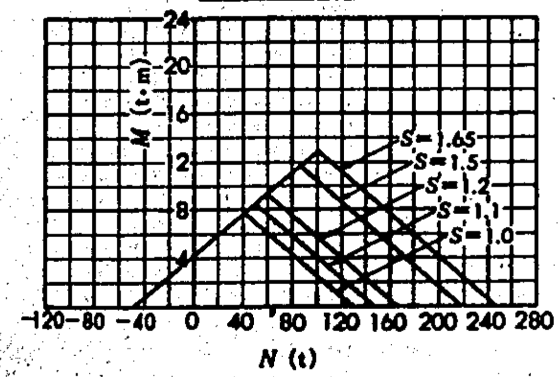
	LONGITUDINAL DIRECTION ①	TRANSVERSAL DIRECTION	
		② SINGLE TRACK	③ DOUBLE TRACK
WHOLE HORIZONTAL FORCE, ΣH (t)	236.56	142.47	225.60
HORIZONTAL FORCE PER PILE, H (t)	5.26	3.17	5.01
VALUE OF β (m^{-1})	0.214	〃	〃
MAXIMUM MOMENT PER PILE, M_{max} (tm)	7.91	4.77	7.54
MAXIMUM AXIAL FORCE PER PILE. P_{max} (t)	83.09	56.37	61.54
MINIMUM AXIAL FORCE PER PILE. P_{min} (t)	2.79	4.89	24.34

WHERE, $H = \Sigma H / n$, n .... NUMBER OF PILE, $n = 45$

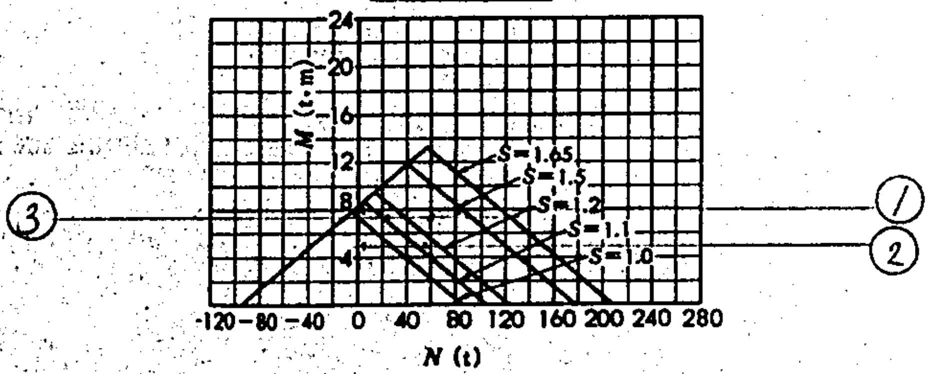
$$M_{max} = \frac{0.322 \cdot H}{\beta}$$

2. EXAMINATION OF SAFETY

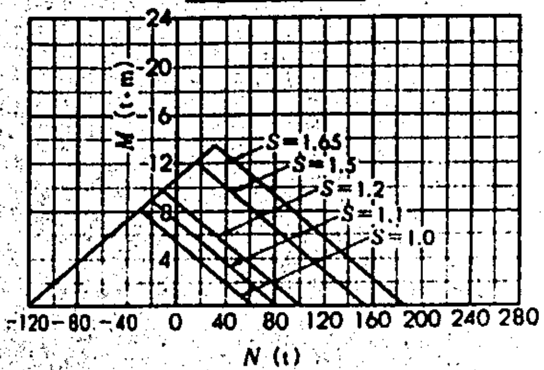
(13) D500-A



(14) D500-B

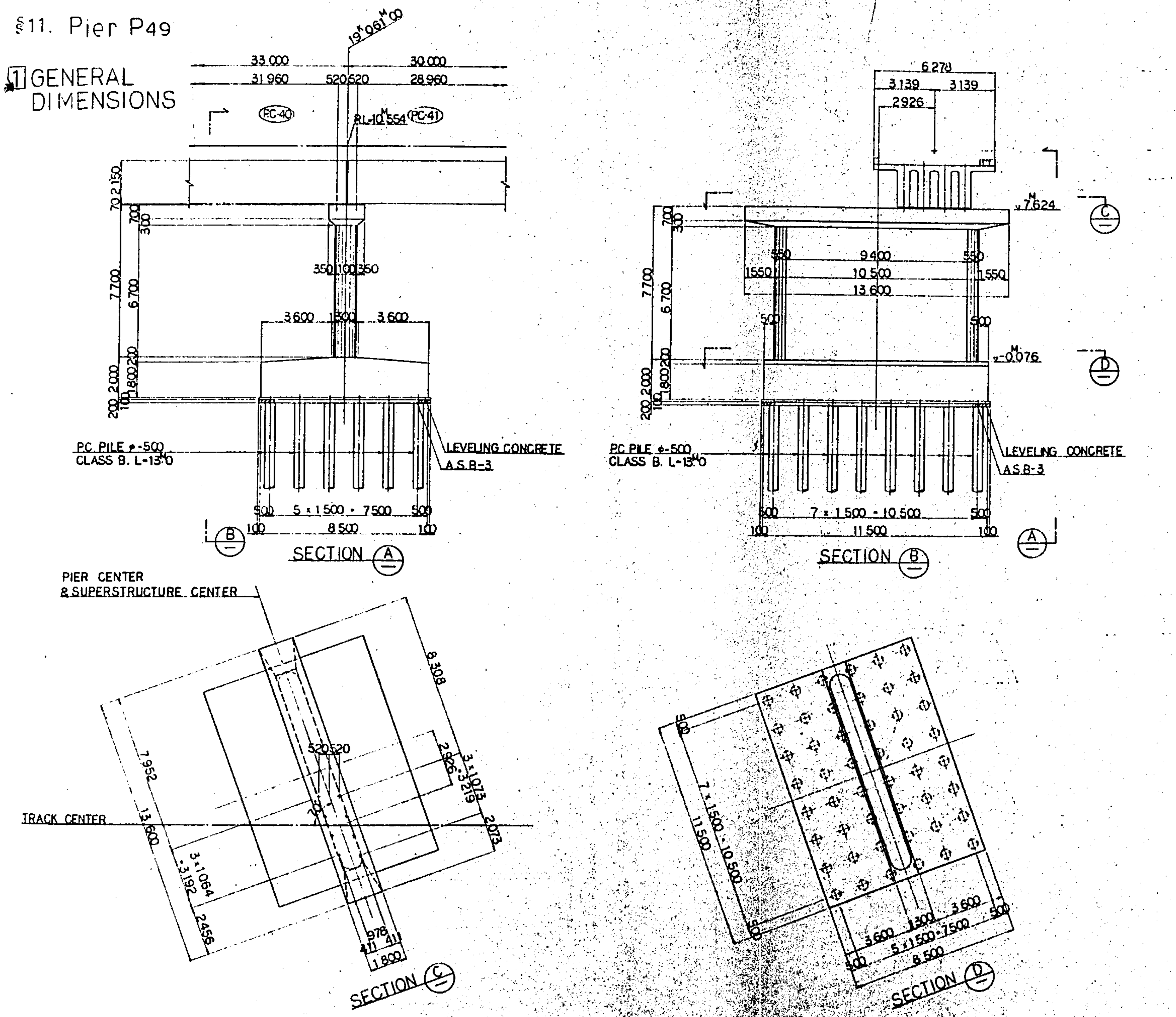


(15) D500-C

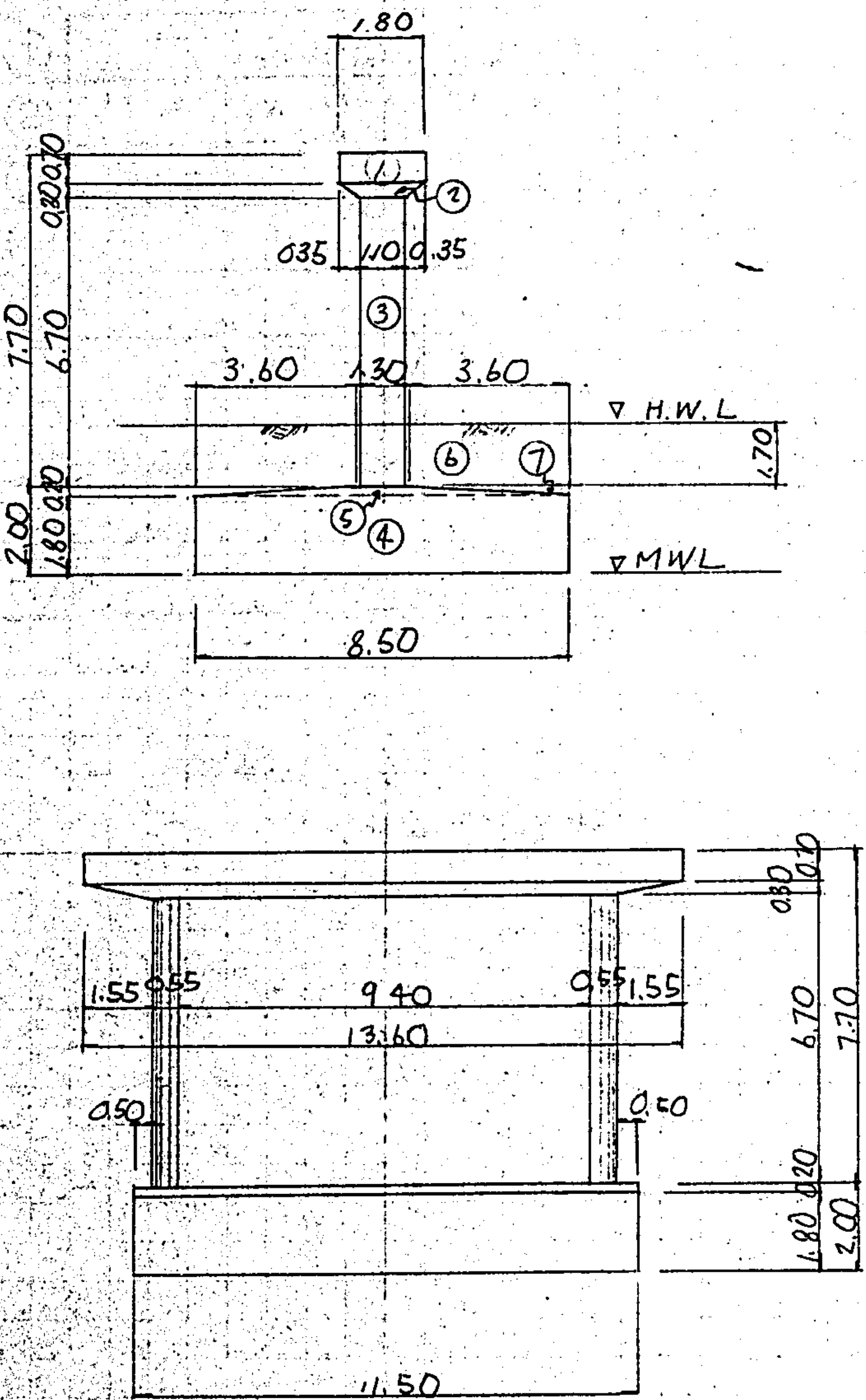


§11. Pier P49

1 GENERAL DIMENSIONS



[2] OWN WEIGHT OF SUBSTRUCTURE AND WEIGHT OF EARTH COVER



1. OWN WEIGHT OF SUBSTRUCTURE AND WEIGHT OF EARTH COVER.

SUBSTRUCTURE

①	$2.5^{t/m^3} \times 1.80 \times 0.70 \times 13.60$	42.84^{t}
②	$2.5'' \times 0.30/6 \times \{13.60 \times 1.80 + 10.50 \times 1.10 + (13.60+10.50)(1.80+1.10)\}$	13.24 "
③	$2.6'' \times (1/4 \times \pi \times 1.10^2 + 9.40 \times 1.10) \overset{\sim 11.290}{} \times 6.70$	189.11 "
④	$2.5'' \times 1/2 \times (1.30 + 8.50) \times 0.20 \times 11.50$	28.18 "
⑤	$2.5'' \times 1.80 \times 8.50 \times 11.50$	439.88 "
	SUB-TOTAL	713.25^{t}

EARTH COVER

⑥	$1.8^{t/m^3} \times (8.50 \times 11.50 - 11.290) \times 1.70$	264.57^{t}
⑦	$1.8'' \times 1/2 \times 3.60 \times 0.20 \times 11.50 \times 2$	14.90 "
	SUB-TOTAL	279.47^{t}

TOTAL

$713.25 + 279.47 = 992.72^{t}$

2. BUOYANCY

$1.0^{t/m^3} \times 8.50 \times 11.50 \times 3.70 = 361.68^{t}$

3. HORIZONTAL FORCES DUE TO EARTHQUAKE LOAD

	N (t)	y (m)	N×y (t·m)
①	42.84	9.35	400.55
②	13.24	8.862	117.33
③	189.11	5.35	1011.74
④	28.18	1.876	52.87
⑤	439.88	0.90	395.89
Σ	713.25		1978.38

NOTE N: AXIAL FORCE

y: DISTANCE FROM THE BOTTOM OF FOOTING TO GRAVITY CENTER

4. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

$$y_e = \frac{N \cdot y}{N} = \frac{1978.38}{713.25} = 2.774^{m}$$

$$P_E = 713.25 \times 0.1 = 71.33^{t}$$

$$M_0 = 71.33 \times 2.774 = 197.87^{tm}$$

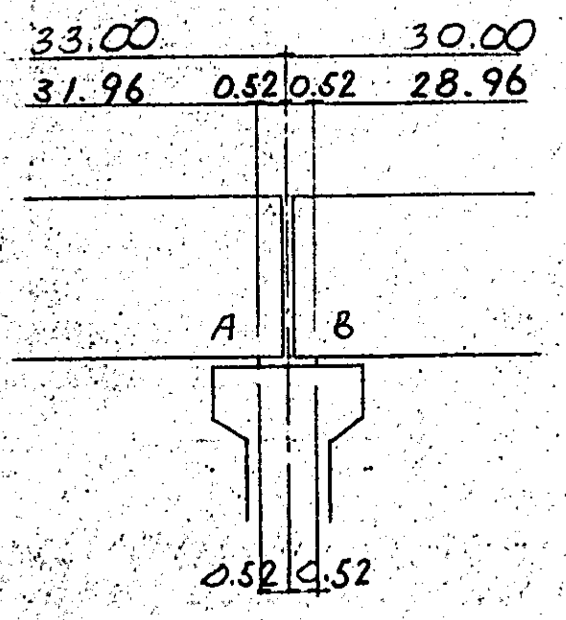
NOTE y_e : DISTANCE FROM THE BOTTOM OF FOOTING TO THE CENTER OF SUBSTRUCTURE.

P_E : HORIZONTAL FORCE DUE TO EARTHQUAKE LOAD

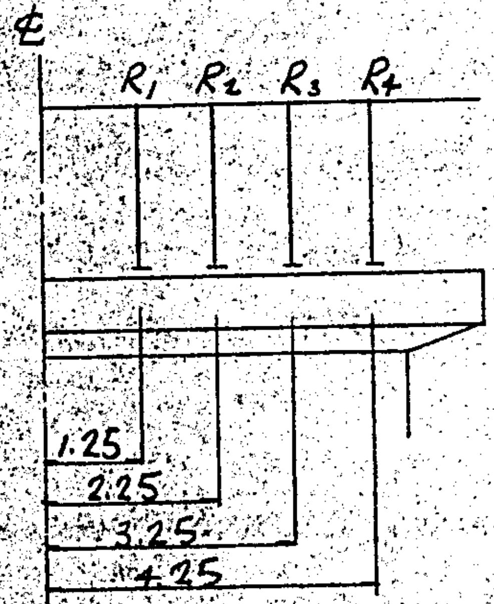
M_0 : OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

3 REACTION FORCES TRANSMITTED FROM SUPERSTRUCTURE

1. REACTION FORCES DUE TO DEAD WEIGHT OF SUPERSTRUCTURE



1-1. REACTION FORCES ACTING AT BEARINGS - A



R_1 = 76.04 t

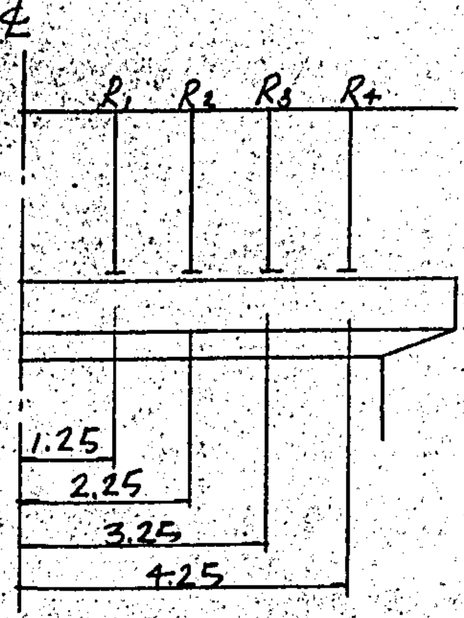
R_2 = 74.72 "

R_3 = 73.29 "

R_4 = 75.49 "

TOTAL = 299.54 t

1-2. REACTION FORCES ACTING AT BEARINGS - B



$R_1 = 70.00^t$

$R_2 = $ "

$R_3 = $ "

$R_4 = $ "

TOTAL = 280.00^t

1-3. SECTIONAL MOMENT AT THE CENTER OF PIER SHAFT DUE TO DEAD WEIGHT OF SUPERSTRUCTURE

SINGLE - TRACK LOADING FOR CALCULATION OF TRANSVERSAL STABILITY. DOUBLE-TRACK LOADING FOR CALCULATION OF LONGITUDINAL STABILITY

TRANSVERSAL DIRECTION

$$M_1 = (76.04 \times 1.25 + 74.72 \times 2.25 + 73.29 \times 3.25 + 75.49 \times 4.25 + 70.00 \times 4 \times 2.75) \times \frac{1}{\cos 20^\circ}$$

$$= 1694.38^{tm}$$

LONGITUDINAL DIRECTION

$$M_L = (-299.54 + 280.00) \times 2 \times 0.52 \times \cos 20^\circ = -19.10^{tm}$$

1-4. HORIZONTAL FORCES DUE TO EARTHQUAKE ACTING ON DEAD WEIGHT OF SUPERSTRUCTURE

a) LONGITUDINAL DIRECTION

31.96^{m} - SPAN SIDE

$P_{E_1} = 299.54 \times 0.1 \times 2 - \frac{1}{2} \times 0.1 \times 299.54 = 44.93^{t}$

28.96^{m} - SPAN SIDE

$P_{E_2} = 280.00 \times 0.10 = 28.00^{t}$

$\Sigma P_E = 44.93 + 28.00 = 72.93^{t}$

OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

COMPONENT OF ΣP_E VERTICAL TO THE WALL

$H_L = 72.93 \times \sin 70° = 68.53^{t}$

COMPONENT OF ΣP_E PARALLEL TO THE WALL

$H_T = 72.93 \times \cos 70° = 24.94^{t}$

$M_L = 68.53 \times 11.67 = 799.75^{tm}$

$M_T = 24.94 \times 11.67 = 291.05$ "

b) TRANSVERSAL DIRECTION

31.96 - SPAN SIDE

$P_{E_1} = 299.54 \times 0.1 = 29.95^t$

28.96 - SPAN SIDE

$P_{E_2} = 280.00 \times 0.1 = 28.00^t$

$\Sigma P_E = 29.95 + 28.00 = 57.95^t$

OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

COMPONENT OF ΣP_E VERTICAL TO THE WALL

$H_L = 57.95 \times \cos 70° = 19.82^t$

COMPONENT OF ΣP_E PARALLEL TO THE WALL

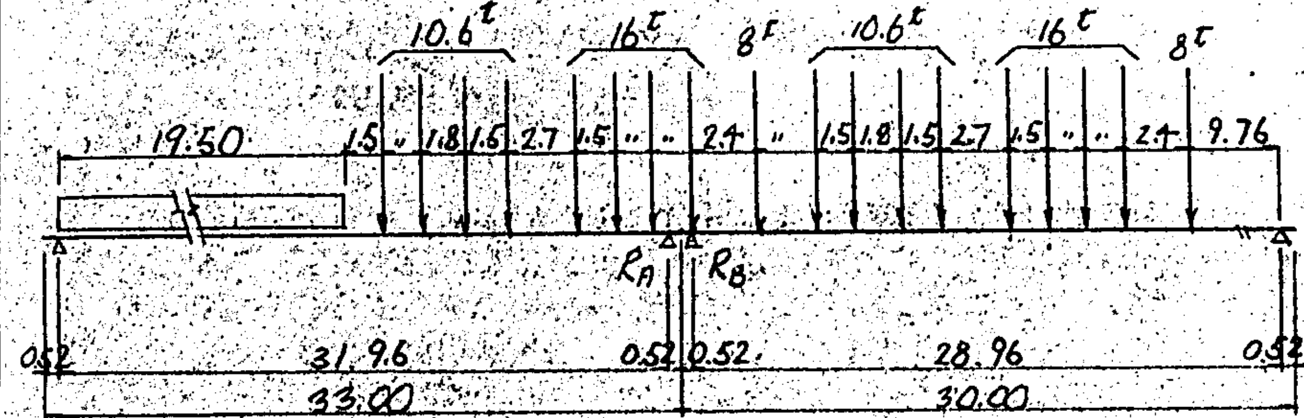
$H_T = 57.95 \times \sin 70° = 54.46^t$

$M_L = 19.82 \times 11.67 = 231.30^{tm}$

$M_T = 54.46 \times 11.67 = 635.55$ "

2. REACTION FORCES DUE TO LIVE LOAD PLUS IMPACT

EQUIVALENT TO KS-16 LOADING. CALCULATION IS CARRIED OUT UNDER THE LOADING CONDITION OF PRODUCING MAXIMUM REACTION FORCE ON PIER



$$R_A = \frac{1}{31.96} \times (19.50^2 \times 5.3 \times 1/2 + 10.6 \times 4 \times 23.40 + 16 \times 3 \times 30.00) = 107.63^t$$

$$R_B = \frac{1}{28.96} \times (16 \times 28.96 + 8 \times 26.56 + 10.6 \times 4 \times 21.76 + 16 \times 4 \times 14.41 + 8 \times 9.76) = 89.74''$$

TOTAL = 197.37^t

IMPACT COEFFICIENT

31.96 - SPAN SIDE --- i = 0.336

28.96 - SPAN SIDE --- i = 0.343

LIVE LOAD PLUS IMPACT

$R(A+L) = 107.63 \times 1.336 = 143.79^{t}$

$R(B+L) = 89.74 \times 1.343 = 120.52''$

264.31^{t}

2-1. SECTIONAL MOMENT ACTING AT THE CENTER OF PIER SHAFT

SINGLE-TRACK LOADING FOR CALCULATION OF TRANSVERSAL STABILITY. DOUBLE-TRACK LOADING FOR CALCULATION OF LONGITUDINAL STABILITY.

TRANSVERSAL DIRECTION

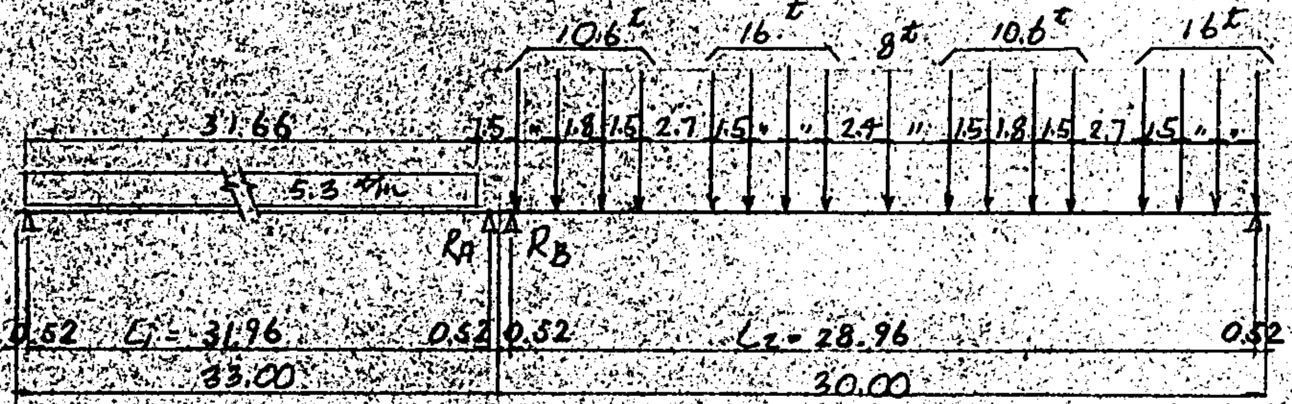
$$M_1 = 264.31 \times 2.75 \times \frac{1}{\cos 20^\circ} = 773.50^{tm}$$

LONGITUDINAL DIRECTION

$$M_2 = (-143.79 + 120.52) \times 2 \times 0.52 \times \cos 20^\circ = -22.74^{tm}$$

3. BRAKE LOAD AND TRACTION LOAD

UNDER THE LOADING CONDITION AS SHOWN BELOW.



3-1. BRAKE LOAD

15% OF KS LOADING

L1 - SPAN SIDE

$P_{B-1} = 5.3 \times 31.66 \times 0.15 \times 1/2 = 12.58^t$

L2 - SPAN SIDE

$P_{B-2} = (10.6 \times 8 + 16 \times 8 + 8) \times 0.15 \times 1/2 = 16.56^t$

$\Sigma P_B = 12.58 + 16.56 = 29.14^t$

3-2. TRACTION LOAD

25% OF MOVING WHEEL AXLE LOAD
OF KS LOADING

L1 - SPAN SIDE

$P_{T-1} = 0$

L2 - SPAN SIDE

$P_{T-2} = 16 \times 8 \times 0.25 \times 1/2 = 16.00^t$

$\therefore \Sigma P_T = 0 + 16.00 = 16.00^t < \Sigma P_B = 29.14^t$

3-3. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING

COMPONENT OF ΣP_B VERTICAL TO THE WALL

$H_L = 29.14 \times \sin 70° = 27.38^t$

COMPONENT OF ΣP_B PARALLEL TO THE WALL

$H_T = 29.14 \times \cos 70° = 9.97^t$

$M_L = 27.38 \times 14.43 = 395.09^{tm}$

$M_T = 9.97 \times 14.43 = 143.87$ "

4. CENTRIFUGAL LOAD

ASSUMED THAT THE LOAD IS EQUIVALENT TO THE LIVE (TRAIN) LOAD MULTIPLIED BY α AND IS ACTING TRANSVERSALLY ON 1.8 m ABOVE THE TRACK LEVEL.

REFERENCE IS MADE TO THE LOADING CALCULATION OF LIVE (TRAIN) LOAD PLUS IMPACT.

$R = 500$ ---- $\alpha = 0.12$

$P_c = 197.37 \times 0.12 = 23.68^t$

4-1. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.

COMPONENT OF P_c VERTICAL TO THE WALL

$H_L = 23.68 \times \cos 70° = 8.10^t$

COMPONENT OF P_c PARALLEL TO THE WALL.

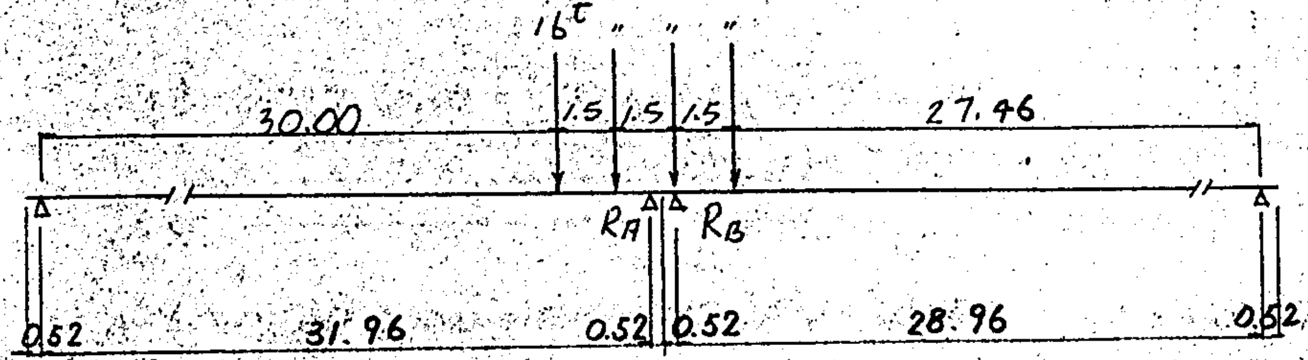
$H_T = 23.68 \times \sin 70° = 22.25^t$

$M_L = 8.10 \times 14.43 = 116.88^{tm}$

$M_T = 22.25 \times 14.43 = 321.07$ "

5. TRAIN LATERAL LOAD

TRANSVERSAL FORCE DUE TO LIVE (TRAIN) LOAD IS ASSUMED TO BE EQUIVALENT TO THE SERIES OF CONCENTRATED LOADS CONSISTED OF 15% OF MOVING WHEEL AXLE LOAD ACTING TRANSVERSALLY AT THE TRACK LEVEL.
CALCULATION IS MADE UNDER THE SINGLE-TRACK LOADING



$$R_A + R_B = \frac{16}{31.96} \times (30.00 + 30.75) + \frac{16}{28.96} \times (27.46 + 28.96)$$

$$= 61.58^{t}$$

$$P_Q = 61.58 \times 0.15 = 9.24^{t}$$

5-1. OVERTURNING MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.

COMPONENT OF P_Q VERTICAL TO THE WALL

$$H_L = 9.24 \times \cos 70° = 3.16^{t}$$

COMPONENT OF P_Q PARALLEL TO THE WALL

$$H_T = 9.24 \times \sin 70° = 8.68^{t}$$

$$M_L = 3.16 \times 12.63 = 39.91^{tm}$$

$$M_T = 8.68 \times 12.63 = 109.63$$

4 CALCULATION ON STABILITY

1. COMBINATION OF LOADS

1-1. TRANSVERSAL DIRECTION

No1. DEAD LOAD (M.W.L)

No2. DEAD LOAD + (TRAIN + IMPACT) LOAD (M.W.L)

No3. ——— " ——— (H.W.L)

No4. DEAD LOAD + (TRAIN + IMPACT) LOAD
+ TRAIN LATERAL LOAD
+ BRAKE LOAD OR TRACTION LOAD (M.W.L)

No5. ——— " ——— (H.W.L)

No6. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

No7. DEAD LOAD (M.W.L)

No8. DEAD LOAD + (TRAIN + IMPACT) LOAD
+ CENTRIFUGAL LOAD (M.W.L)

No.9. ——— " ——— (H.W.L)

No10. DEAD LOAD + (TRAIN + IMPACT) LOAD
+ CENTRIFUGAL LOAD
+ BRAKE LOAD OR TRACTION LOAD (M.W.L)

No11 ——— " ——— (H.W.L)

No.12 DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

THE ABOVE LOADING COMBINATIONS ARE APPLIED NO. 1 THRU NO. 6 FOR SINGLE-TRACK LOADING AND NO. 7 THRU NO. 12 FOR DOUBLE-TRACK LOADING.

1-2. LONGITUDINAL DIRECTION.

No.1. DEAD LOAD (M.W.L)

No.2. DEAD LOAD + (TRAIN + IMPACT) LOAD
+ CENTRIFUGAL LOAD (M.W.L)

No.3. —————— " —————— (H.W.L)

No.4. DEAD LOAD + (TRAIN + IMPACT) LOAD
+ CENTRIFUGAL LOAD
+ BRAKE LOAD or TRACTION LOAD (M.W.L)

No.5. —————— " —————— (H.W.L)

No.6. DEAD LOAD + EARTHQUAKE LOAD (M.W.L)

ALL OF THE ABOVE LOADING COMBINATIONS ARE APPLIED FOR DOUBLE-TRACK LOADING.

2. TABLE OF FORCE AND MOMENT ACTING AT THE MID-POINT OF THE BOTTOM OF FOOTING.

2-1. TRANSVERSAL DIRECTION

SINGLE-TRACK LOADING

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No1	992.72 + 299.64 + 280.00 = 1572.26	1694.38	—
No2	1572.26 + 264.31 = 1836.57	1694.38 + 773.50 = 2467.88	—
No3	1836.57 − 361.68 = 1474.89	2467.88	—
No4	1836.57	2467.88 + 109.63 + 143.87 = 2721.36	8.68 + 9.97 = 18.65
No5	1474.89	2721.36	18.65
No6	1572.26	197.87 + 1694.38 + 291.05 + 635.55 = 2818.85	71.33 + 24.94 + 54.46 = 150.73

DOUBLE-TRACK LOADING

	AXIAL FORCE	MOMENT	HORIZONTAL FORCE
No7	992.72 + (299.64 + 280.00) × 2 = 2152.00	——	——
No8	2152.00 + 264.31 × 2 = 2680.62	321.07 × 2 = 642.14	22.25 × 2 = 44.50
No9	2680.62 − 361.68 = 2318.94	642.14	44.50
No10	2680.62	642.14 + 143.87 = 786.01	44.50 + 9.97 = 54.47
No11	2318.94	786.01	54.47
No12	2152.00	197.87 + 291.05 × 2 + 635.55 × 2 = 2051.07	71.33 + 24.94 × 2 + 54.46 × 2 = 230.13