AR-2. Structural Calculation Sheets for Main Powerhouse Substructure

Contents

1/8

1. General (一般事項)

1-1. Design Loads and code (設計荷重及び規準)

Dead and live load, equipment load ,crane load, column loads are refered to calculation sheet of superstructure structural analysis.

Coad ; AIJ

Standards for Calculation for Reinforced Concrete

Standards for Structural Design of Building Foundations

1-2. Allowable stresses of materials (材料の許容応力度)

Allowable stresses of materials are refered to the next page.
Grade of materials to be used for the substructure structural analysis are shown below.

Concrete	Fc= 210Kg/cm^2 (3,000 psi)
Re-bar	SD-30 or equivalent (ASTM A 615 Grade 40)
Steel pipe pile	ϕ-609.6×9.0 STK-41

1-3. Column axial force & Loading diagram (柱／その他荷重表)

See the attached sheets page- .

1-4. Assumptions (仮定条件)

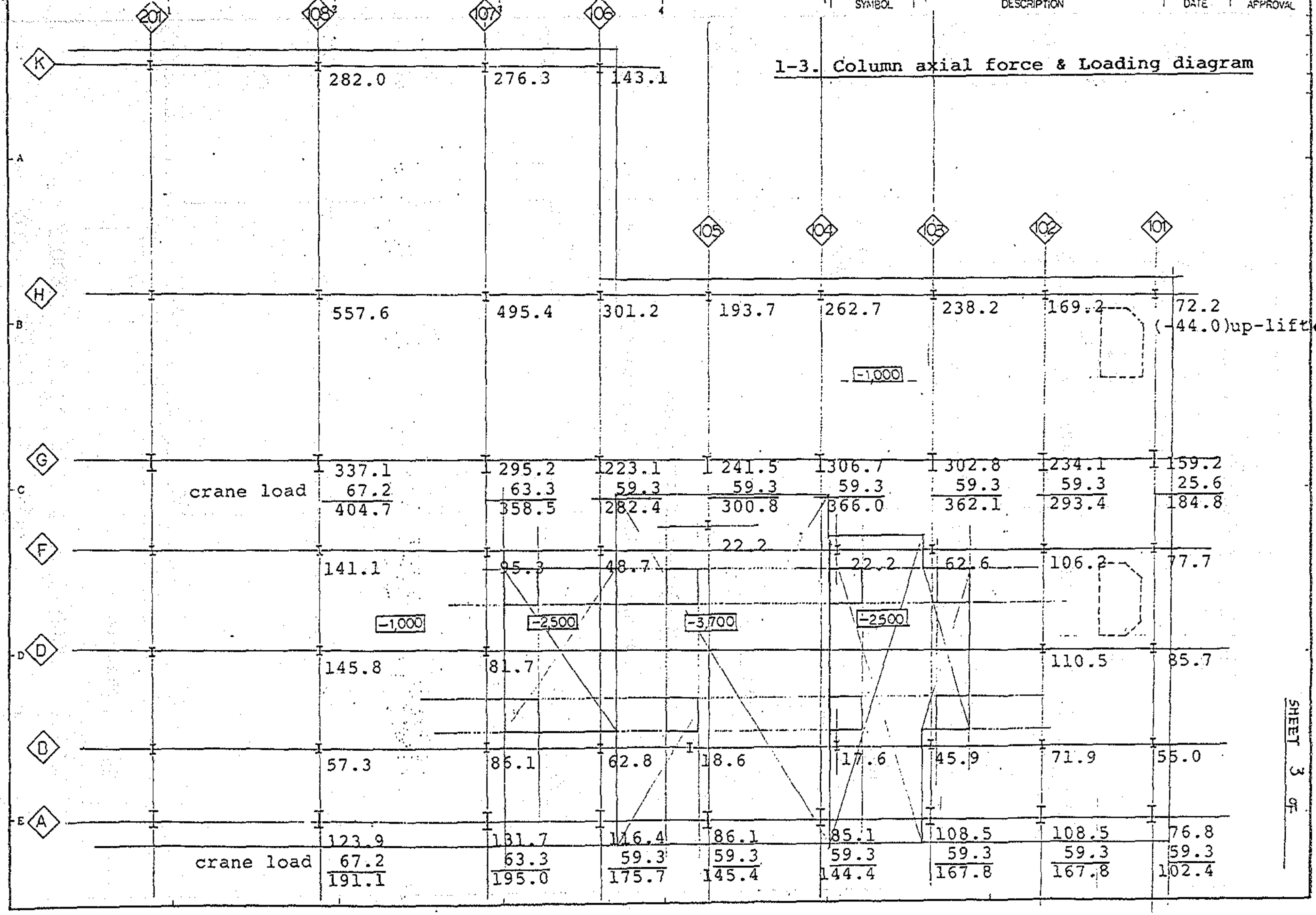
a) Column axial force of boiler structure and T/G pedestal are assumed as a 200MW of power plant.

b) Analysis of mat foundation

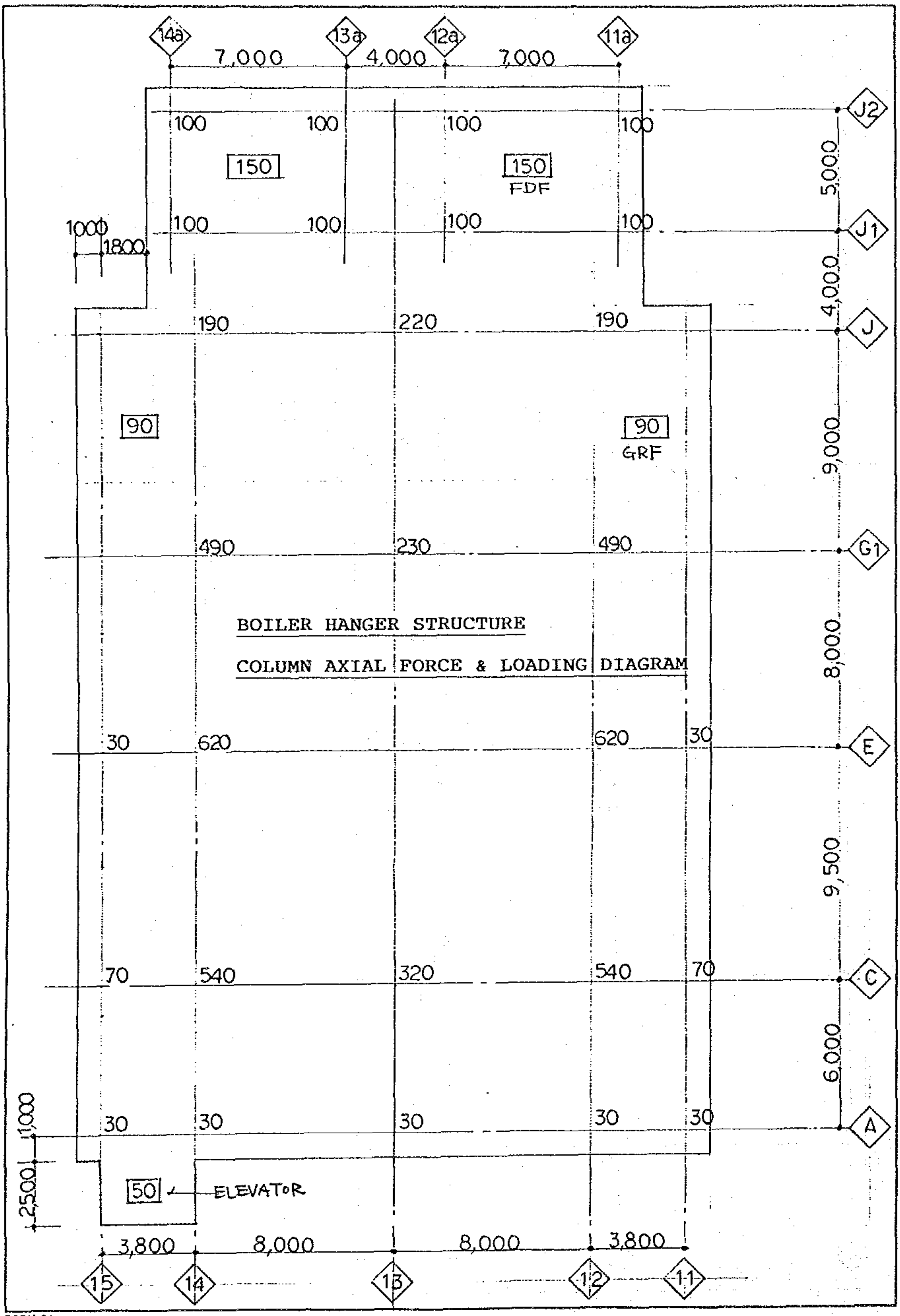
Maximum un-uniformed sinking is 1/15,000 of longitudinal length of mat foundation(l=111.6m). Therefore, the stress of the mat is calculated in consideration of 7.44mm sinking.

SYMBOL	DESCRIPTION	DATE	APPROVAL

1-3. Column axial force & Loading diagram



SHEET 3 of


BOILER HANGER STRUCTURE
COLUMN AXIAL FORCE & LOADING DIAGRAM
14a
13a
12a
11a
7,000
4,000
7,000
J2
J1
J
G1
E
C
A
5,000
4,000
9,000
8,000
9,500
6,000
100
150
150
FDF
1000
1800
190
220
190
90
90
GRF
490
230
490
30
620
620
30
70
540
320
540
70
30
30
30
30
30
1,000
2,500
50
ELEVATOR
3,800
8,000
8,000
3,800
15
14
13
12
11

294

2. Culculation of allowable bearing capacity of pile (杭の許容耐力)

2-1. Allowable axial force of pile material (STK 41)

(杭材料の許容耐力)

Allowable compression strength of material : $_{L}fc$ = 1.372 T/cm²

Gross sectional area of pile : $_{G}Ap$ = 131.6 cm²

Decreasing ratio due to the welded joint : 5 % decrease

Ra = 1.372 T/cm² × 131.6 cm² × 0.95 = 172 ton/pile

2-2. Allowable bearing capacity of pile due to soil condition

(地盤による杭の許容耐力)

φ609.6 ×9.0 Effective thickness is 9.0 - 2.0 = 7.0 mm

GL -26.0 m L=23.5 m

The allowable bearing capacity of steel pipe pile by soil is culculated according to the following formula.

$$Ra = \frac{1}{3} \times \{\eta \times 30 \cdot N \cdot Ap + \Sigma \frac{N}{5} \times \Psi \times Ls\}$$

where, η : Coefficient of open bottom end of steel pipe pile
0.66

N : N-value of bearing stratum / N-value of sandy stratum
N = 50 N = 22.4

Ap : Area of pile 0.292 m²

Ψ : Circumference of pile 1.914 m

Ls : Pile length in the sandy stratum 16 m

Ra = 142.1 ton/pile

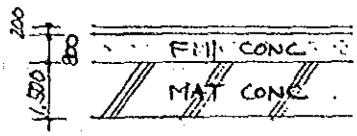
Therefore, the allowable bearing capacity of steel pipe pile is determined <u>140 ton/pile</u> .

3 CALCULATION FOR NUMBERS OF PILE (杭本数の算定)

3.1 LOADS (荷重)

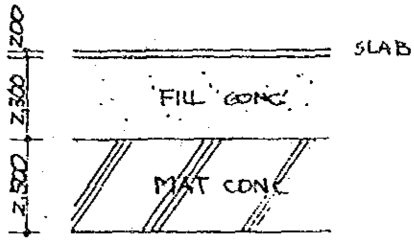
(1) T/G Room & T/G PEDESTAL

(a) DEAD LOAD



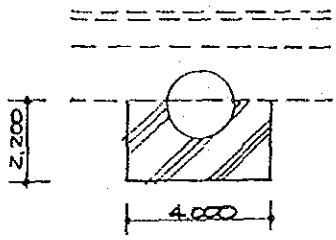
T/G ROOM

	t(m)		T/m³		T/m²
SLAB	0.2	×	2.4	=	0.48
FILL CONC'	0.8	×	1.8	=	1.44
MAT	1.5	×	2.4	=	3.60
					5.52 T/m²



FOR T/G PEDESTAL MAT

SLAB	0.2	×	2.4	=	0.48
FILL CONC'	2.3	×	1.8	=	4.14
MAT	2.5	×	2.4	=	6.0
					10.62



FOR C.W. PIPE

CONC'. 2.2 × 4.0 × 2.4 = 21.12 T/m

WALL.

PRECAST CONCRETE PANEL
t=120mm h=5.5m

0.12 × 5.5 × 2.4 = 1.58 T/m
0.15 × 1.0 × 2.4 = 0.36
1.94 T/m

CONCRETE WALL
COLUMN LINE A
t=300mm h=3.7m

0.3 × 3.7 × 2.4 = 2.66 T/m
1.58
4.24 T/m

(b) LIVE LOAD.

EQUIPMENTS LOAD FOR ALL AREA	0.35 T/m²
BOILER FEED PUMP (BFP)	30 TON × 3 UNITS
MAIN OIL TANK	60 TON
COOLING WATER HEAT EXCHANGER	58 TON × 2 UNITS
CONDENSATE PUMP	20 TON × 2 〃

FORM 04

(C) T/G PEDESTAL

TURBINE	HP+LP = 165 + 215 =	380 TON
GENERATOR		320 TON
PEDESTAL	$800 m^3 \times 2.4$	1,920 TON
		2,620 TON

AREA OF FOUNDATION

$31.5 \times 13.0 = 409.5 m^2 \Rightarrow 6.40\ TON/m^2$

BOTTOM OF CONDENSOR (870 TON)

AREA OF CONDENSOR .

$8.0 \times 13.0 = 104.0 m^2 \Rightarrow 8.37\ TON/m^2$

(D) UNIT LOAD FOR FOUNDATION

FOR T/G ROOM .

	5.52
	0.35
	5.87 TON/m^2

FOR T/G PEDESTAL

CONDENSOR	8.37	—
T/G	6.40	6.40
MAT	6.00	10.62
	20.77 T/m^2	17.02 T/m^2

FOR C.W. PIT .

	3.60
PIPING	1.00
	4.60 T/m^2

(E) OVER-TURNING MOMENT OF T/G PEDESTAL (ASSUMED) & C/mass

TURBINE	380	×	0.1	=	38	14.7 m
GENERATOR	320	×	0.1	=	32	14.7 m
PEDESTAL	1,920	×	0.1	=	192	12.7 m

$M = (38 + 32) \times 14.7 + 192 \times 12.7 + (38+32+192) \times 2.5$

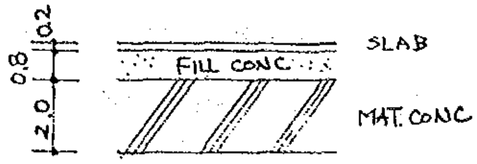
$+ 31.5 \times 13.0 \times 2.5 \times 2.4 \times 0.05 \times 2.5 \times 1/2$

$= 508.4 + 2,438.4 + 655.0 + 153.6 = 3,755.4\ Tm$

79

(2) Boiler MAT .

(a) DEAD LOAD .



	t(m)		T/m³		T/m²
SLAB	0.2	×	2.4	=	0.48
FILL CONC'	0.8	×	1.8	=	1.44
MAT	1.5	×	2.4	=	3.60
					5.52 T/m²

(b) LIVE LOAD

MISC. EQUIPMENT FOR ALL AREA ---------- 0.35 T/m²

FDF 50 TON × 2 UNITS = 100 TON

GRF 20 × 2 = 40 TON

ELEVATOR . 50 TON

(c) UNIT LOAD FOR FOUNDATION

DEAD	5.52
LIVE	0.35
	5.87

→ 5.87 T/m²

(d) ASSUMING OF THE AXIAL FORCE OF MAIN COLUMNS OF BOILER STRUCTURE AT SEISMIC TERM .

WEIGHT OF BOILER	3.200 TON
〃 OF STRUCTURE	770 TON
	3.970 TON
SEISMIC COEFFICIENT	K = 0.13
NUMBER OF MAIN BRACE	6
HEIGHT OF CENTER OF MASS	h = 27 m
STANCE OF BRACE	8 m

$$N = 3.970 \times 0.13 \times 27 \times \frac{1}{6} \times \frac{1}{8} = \pm 290 \text{ TON}.$$

(e) WEIGHT OF EQUIPMENT FOUNDATION (ABOVE FL±0)

FDF . 8 m × 2.5 m × 2 m × 2.4 = 96 TON/UNIT .

GRF 6 m × 2.5 × 2 × 2.4 = 72 TON/UNIT .

Calculation of number of pile (杭本数の算定) M.P.H -1

Column No.	Col. load ton	Area m^2	Mat ton	Fill conc. ton	Wall ton	Equip. ton	Total ton	Numbers of pile	Ton/pile
A - 101	102.4	12.1	71.0		7.15m 13.9	—	187.3	2.0	93.7
102	167.8	18.7	109.8		13.2	—	290.8	3.0	96.9
103	167.8	11.9 + 18.7	264.7 (179.6 / 85.1)	(4.3×1.5×5.5×2.4	13.2	—	445.7	4.0	111.4
104	144.4	11.9 + 18.7	200.2 (140.8 / 59.4)	(3.0×1.5×5.5×2.4	28.8	—	373.4	3.5	106.7
105	145.4	11.9 + 18.7	140.8		28.8	—	315.0	4.0	78.8
106	175.7	11.9 + 18.7	268.7 (179.6 / 89.1)	(2.5×2.7×5.5×2.4	13.2	—	457.6	4.5	101.7
107	195.0	23.1	135.6		16.3	—	346.9	4.25	81.6
108	191.1	27.5	161.4		19.4	—	371.9	4.5	82.6
	1289.6	156.2 + 47.6 = 203.8				(subtotal)	(2788.6)	(29.75)	(93.7)
B - 101	55.0	23.1	135.6		10.2	60×1/6 10.0	210.8	2.5	84.3
102	71.9	34.3	201.3		—	10.0	283.2	2.5	113.3
103	T/G ← 45.9	A-103 ← 11.9					—		
104	T/G ← 17.6	A-104 ← 11.9					—	} T/G PEDESTAL	
105	T/G ← 18.6	A-105 ← 11.9					—		
106	T/G ← 62.8	A-106 ← 11.9					—		
107	T/G ← 86.1	30.45	178.7		—	58×1/3 19.3	198.0	1.75	113.1
108	57.3	52.5	308.7		—	19.3	385.3	4.0	96.3
	415.2	140.35					(1077.3)	(10.75)	(100.2)

FORM 04

Calculation of number of pile (杭本数の算定) MPH - 2

Column No.	Col.load ton	Area m^2	Mat ton	Fill conc. ton	Wall ton	Equip. ton	Total ton	Numbers of pile	Ton/pile
D - 101	85.7	+13.6 26.4	+16.3 155.0	—	11.6	10	+16.3 262.3	2.5	111.4
- 102	110.5	38.4	225.4	—	—	10	345.9	3.5	98.8
107	T/G ← 81.7	27.6	158.5	—	—	19.3	177.8	2.0	88.9
108	145.8	60.0	352.2	—	—	19.3	516.5	5.0	103.3
	423.7					(sub total)	(1.302.5)	(13.0)	(100.2)
F - 101	77.7	+13.6 25.3	+16.3 148.5	—	11.2	10	+16.3 247.4	2.5	105.5
102	106.2	37.7	221.3	—	—	10	337.5	3.5	96.4
103	T/G ← 62.6	17.0	161.5 (99.8, 61.7)	1.0×2.5×3.9×2.4, 2.2×2.5×2.9×2.4	—	20	181.5	1.5	121.0
104	T/G ← 22.2	17.0	135.8 (99.8, 36.0)	1.0×2.9×2.25×2.4, 1.5×2.9×1.95×2.4	—	20	155.8	1.5	103.9
105	T/G ← 22.2	17.0	99.8	—	—	—	99.8	1.5	66.5
106	T/G ← 48.7	17.0	158.1 (99.8, 58.3)	2.7×2.25×4.0×2.4	—	—	158.1	1.25	126.5
107	T/G ← 95.3	34.65	203.4	—	—	19.3	222.7	2.25	99.0
108	141.1	57.5	337.5	—	—	19.3	497.9	5.0	99.6
	576.0						(1.900.7)	(19.0)	(100.0)
G - 101	184.8	34.1	200.2	—	15.0	—	400.0	4.5	88.9
102	293.4	52.7	309.4	—	—	—	602.8	6.5	92.7
103	362.1	52.7	334.9 (309.4, 25.5)	1.25×3.4×2.5×2.4	—	—	697.0	7.5	92.9
104	366.0	52.7	472.3 (309.4, 162.9)	5.2×3.8×2.5×2.4, 21.1×½×4.2	—	—	838.3	8.0	104.8

FORM 04

300

108

SHEET 11 OF

Calculation of number of pile (杭本数の算定) MPH-3

Column No.	Col. load ton	Area m^2	Mat ton	Fill conc. ton	Wall ton	Equip. ton	Total ton	Numbers of pile	Ton/pile
G-105	300.8	52.7	508.8 (309.4 / 199.4)	6.8×3.8×2.5×2.4 / 21.12×½×4.2	—	—	809.6	8.0	101.2
106	282.4	52.7	440.6 (309.4 / 131.2)	5.2×3.8×2.5×2.4 / 2.8×0.75×2.5×2.4	—	—	723.0	8.25	87.6
107	358.5	65.1	382.1	—	—	—	740.6	8.25	89.8
108	404.3	77.5	454.9	—	—	—	859.2	8.5	101.1
	2,552.3					(Subtotal)	(5,670.5)	(59.5)	(95.3)
H-101	72.2	26.4	+ 31.7 155.0	—	20.2	—	+ 31.7 247.4	3.0	93.0
102	169.2	40.8	239.5	—	13.2	—	421.9	5.0	84.4
103	238.2	40.8	239.5	—	13.2	30	520.9	5.0	104.2
104	262.7	40.8	302.9 (239.5 / 63.4)	21.12×½×6	13.2	15	593.8	5.0	118.8
105	193.7	40.8	302.9		13.2	15	524.8	5.0	106.0
106	301.2	67.2	399.5	—	8.4 16.3	15	727.0	8.25	88.1
107	495.4	100.8	591.7	—	—	15	1,102.1	10.0	110.0
108	557.6	120.0	704.4	—	—	—	1,262.0	11.0	114.7
	2,290.2						(5399.9)	(52.25)	(103.3)
K-106	143.1	35.2	206.6	—	12.4 24.1	—	373.8	4.75	78.7
107	276.3	67.2	394.5	—	9.4 16.3	—	687.1	6.0	114.5
108	282.0	80.0	469.6	—	19.4	—	771.0	7.0	110.1
						(subtotal)	(1831.9)	(17.75)	(103.2)

FORM 04

Calculation of number of pile (杭本数の算定)　MPH - 4.　T/G PEDESTAL

Column No.	Col. load ton	Area m^2	Mat ton	Fill conc. ton	Wall ton	Equip. ton	Total ton	Numbers of pile	Ton/pile
T/G PEDESTAL	563.7	409.5							
		├ 104.0 × 20.77 = 2160.1					2160.1		
		└ 305.5 × 17.02 = 5199.6		1.5×1.5×13 = / 1.5×1.5×6.8×2 =	} 100.4 m³ × 2.4 = 241.0		5440.6		
				1.5×1.5×13 = / 1.5×1.5×2.5×2 = }			563.7		
							8164.4	84	97.2
							(19.94 TON/m²)		
T/G ROOM									
TOTAL	7,684.7	1771.7					19,971.4	202	98.9
							(11.27 TON/m²)		

FORM 04

302

Calculation of number of pile (杭本数の算定) BOILER AREA -1

Column No.	Col.load ton	Area m^2	Mat ton	Fill conc. ton	Wall ton	Equip. ton	Total ton	Numbers of pile	Ton/pile
A - 11	30.0	11.6	68.1				98.1	1.5	65.4
12	30.0	23.6	138.5				168.5	2.25	74.9
13	30.0	32.0	187.8				217.8	3.0	72.6
14	30.0	23.6	138.5				168.5	2.25	74.9
15	30.0	11.6	68.1				98.1	1.5	65.4
C - 11	70.0	22.48	132.0				202.0	2.0	101.0
12	540.0	45.73	268.4				808.4	7.0	115.5
13	320.0	62.0	363.9				683.9	6.0	113.9
14	540.0	45.73	268.4				808.4	7.0	115.5
15	70.0	22.48	132.0				202.0	2.0	113.9
E - 11	30.0	25.38	149.0				179.0	2.0	89.5
12	620.0	51.63	303.1				923.1	8.0	115.4
13	—	70.0	410.9				410.9	4.0	102.5
14	620.0	51.63	303.1				923.1	8.0	115.4
15	30.0	25.38	149.0				179.0	2.0	89.5

FORM 04

903

Calculation of number of pile (杭本数の算定) BOILER AREA - 2

Column No.	Col.load ton	Area m²	Mat ton	Fill conc. ton	Wall ton	Equip. ton	Total ton	Numbers of pile	Ton/pile
G1 - 11	—	24.65	144.7			GRF 22.5	167.2	2.0	83.6
12	490	50.15	294.4			22.5	806.9	7.0	115.2
13	230	68.0	399.2				629.2	6.0	104.9
14	490	50.15	294.4			22.5	806.9	7.0	115.2
15	—	24.65	144.7			22.5	167.2	2.0	83.6
J - 11	—	15.95	93.6			22.5	116.1	1.5	77.4
12	190	38.35	225.1			22.5	437.6	4.25	103.0
13	220	52.0	305.2				525.2	5.0	105.0
14	190	38.35	225.1			22.5	437.6	4.25	103.0
15	—	15.95	93.6			22.5	116.1	1.5	77.4
J1 - 11a	100	20.25	118.9			FDF 37.5	256.4	2.25	114.0
12a	100	24.75	145.3			37.5	282.8	2.25	125.7
13a	100	20.25	145.3			37.5	282.8	2.25	125.7
14a	100	24.75	118.9			37.5	256.4	2.25	114.0

FORM 04

Calculation of number of pile (杭本数の算定) BOILER AREA -3

Column No.	Col.load ton	Area m^2	Mat ton	Fill conc. ton	Wall ton	Equip. ton	Total ton	Numbers of pile	Ton/pile
J2-11a	100	15.75	92.5			37.5	230.0	2.25	102.2
12a	100	19.25	113.0			37.5	250.5	2.25	113.3
13a	100	19.25	113.0			37.5	250.5	2.25	113.3
14a	100	15.75	92.5			37.5	230.0	2.25	102.2
ELEVATOR	50	9.5	55.8			—	105.8	1.0	105.8
TOTAL	5650	1072.54					12,426.0	118.	105.3
							(11.59 TON/m^2)		

FORM 04

506

FORM 04

Calculation of number of pile (杭本数の算定)

Column No.	Col.load ton	Area m^2	Mat ton	Fill conc. ton	Wall ton	Equip. ton	Total ton	Numbers of pile	Ton/pile
Transformer Yard Foundation									
Main Trans	—	10.3×10.3=106.1	3.1×2.4=7.44 789.4	—	0.25×6×8.5×2.4×$\frac{1}{2}$ 15.3	240.0	1044.7	12	87.1
Aux. Trans	—	6.1×6.0= 36.6	272.3	—	0.25×6×7.0×2.4×$\frac{1}{2}$ 15.3+12.6	42.0	342.2	4	85.6
St. Trans	—	36.6	272.3	—	12.6	52.0	336.9	4	84.2
Unit-1	M.Tr.+Aux Tr +St Tr.	179.3	1334	—	55.8	334.0	1.723.8	20	86.2
Unit-2	M.Tr+Aux Tr.	142.7	1061.7	—	55.8	282.0	1.399.5	16	87.5
TOTAL								36	

3-3. TABULATION OF LOAD & NUMBERS OF PILE (荷重／杭本数総括表)

Location	Loads			Numbers of Pile	tons/ pile	tons/ m^2
	Super-structure	Sub-structure	Total Weight			
T/G ROOM	7,684.7	12,286.7	19,971.4	202	98.9	11.27
T/G PEDESTAL	4,053.7	4,110.7	8,164.4	84	97.2	19.94
Trans Unit-1	389.8	1,334.0	1,723.8	20	86.2	9.61
Trans Unit-2	337.8	1,061.7	1,399.5	16	87.5	9.81
Boier Area	5,650.0	6,776.0	12,426.0	118	105.3	11.59
Total			84,246.9	844	99.8	

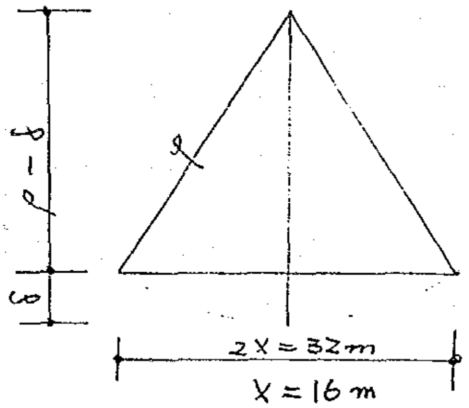
FORM 04

4. CALCULATION OF BENDING MOMENT OF MAT FOUNDATION DUE TO THE STTLEMENT.

Longitudinal length of mat : $l = 111.6m$

Max. sinking value of mat : $l \times \frac{1}{15{,}000} = 7.44 mm = \delta$

Bending moment : $M = \frac{EI}{\rho}$



$$\rho \fallingdotseq \frac{\delta^2 + X^2}{2\delta}$$

$$= \frac{0.00744^2 \times 16^2}{2 \times 0.00744}$$

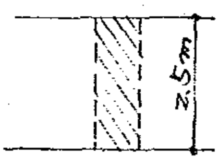
$$= 17.204$$

$$E = 2.1 \times 10^5 \times \left(\frac{\gamma}{2.3}\right)^{1.5} \times \sqrt{\frac{Fc}{200}}$$

γ : 2.3 Fc = 210

$$= 2.152 \times 10^5 \ kg/cm^2$$

T/G mat Foundation



$$A = 1.0 \times 2.5 = 2.5 m^2$$

$$I = \frac{1}{12} \times 1.0 \times 2.5^3 = 1.302 m^4$$

$$M = \frac{2.152 \times 10^6 \times 1.302}{17{,}204} = 162.8 \ Tm/m$$

$$at = \frac{162.8 \times 10^5}{1{,}867 \times 240 \times 7/8} = 41.5 \ cm^2$$

#7 @ 150 Double, (51.6 cm²)

T/G Room. ≒. BOILER MAT FOUNDATION

$$A = 1.0 \times 1.5 = 1.5 m^2$$

$$I = \frac{1}{12} \times 1.0 \times 1.5^3 = 0.281 m^4$$

$$M = \frac{2.152 \times 10^6 \times 0.281}{17{,}204} = 35.1 \ Tm/m$$

→ See next page.

$$at = \frac{(35.1 + 15.6) \times 10^5}{1{,}867 \times 140 \times 7/8} = 22.2 \ cm^2$$

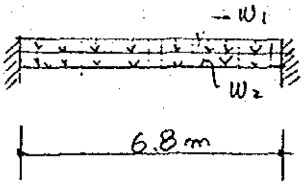
#7 @ 150 single (25.8 cm²)

Max moment of mat (Slab).

$w = 5.87\ t/m^2$ $\quad l_x = 6.0$ $\quad l_y = 10.0$ $\quad \lambda = \frac{l_y}{l_x} = 1.67$.

$M_{max} = 0.074 \times 5.87 \times 6.0^2 = \underline{15.6\ Tm/m}$.

Moment at the part of Cooling Water Pipe



$w_1 = 5.87 + 4.41 = 10.28\ T/m$
(BFP)

$w_2 = 5.28\ t/m$ (C.W Pipe covering Concrete).

$w = 10.28 + 5.28 = 15.6\ T/m$

$C = \frac{1}{24} \times 15.6 \times 6.8^2 = 30.1\ tm/m$ (upper)

$M_0 = \frac{1}{8} \times 15.6 \times 6.8^2 = 90.2\ tm/m$

$M_c = 90.2 - 30.1 = 60.1\ tm/m$. (bottom)

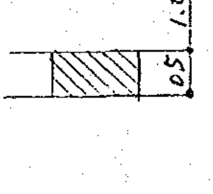
$_u M_{max} = 35.1 + 30.1 = 65.1\ tm$

$a_t = \frac{65.1 \times 10^5}{1.867 \times 140 \times 7/8} = 28.5\ cm^2$ $\quad$ #17 @150 + @300 (2段目)
(38.7 cm²)

$_B M_{max} = 35.1 + 60.1 = 95.2\ tm$

$a_t = \frac{95.2 \times 10^5}{1.867 \times 350 \times 7/8} = 16.65\ cm^2$ $\quad$ #7 @ 150
(25.8 cm²).

Sump Pit Area.



$A = 1.0 \times 1.0 = 1.0\ m^2$

$I = 2 \times 0.5 \times 1.0^2 = 1.0\ m^4$

$M = \frac{2.152 \times 10^6 \times 1.0}{17{,}204} = 125\ Tm/m$

$a_t = \frac{125 \times 10^5}{1.867 \times 190 \times 7/8} = 40.2\ cm^2$

#7 @ 150 Double.
(51.6 cm²)

309

Upper Slab $\quad l_x = 4.2 \quad l_y = 2.6 \quad \lambda = 1.62$

$w = 0.5 \times 2.4 + 0.8 \times 1.8 + 0.2 \times 2.4 + 0.35 = 3.47\ t/m^2$

$M_{max} = 0.073 \times 3.47 \times 4.2^2 = 4.5\ Tm/m$

$$At = \frac{450}{1.867 \times 45 \times 7/8} = 6.12\ cm^2$$

$40.2 + 6.12 = 46.32 \ll 51.6\ cm^2$

$\therefore$ #7 @ 150 Double .... OK

AR-3. Structural Calculation Sheet for Stack

3/1

CONTENTS

ﾒ/ﾁ

I. GAS CONDITIONS AND FLUE DESIGN

1. DESIGN CONCEPT FOR DECISION OF FLUE INSIDE DIAMETER
[内筒直径決定の考え方]

The effective inside diameter of flue shall be decided so as to conform to the following requirements:

a. Exhaust gas velocity at the top of stack shall be more than 30 m per second under the operation condition of ECR from the view point of environmental pollution protection.

b. The required forced draft at the breeching opening of flue shall be less than 50 mmAq under the operation condition of MCR from the view point of the boiler efficiency.

2. DESIGN CONDITION [設計条件]

2.1 Climate condition [気象条件]

Ambient temperature	25 ℃
Specific gravity of air at 0℃ and 1013 mili-bar	1,293

2.2 Exhaust gas condition [排出ガス条件]

Operation	ECR	MCR
Temperature ℃	145	145
Gas volume Nm^3 /sec	157	165
Qg=Nm^3 /sec(at gas temp.)	240.4	252.6
Specific gravity of gas (Kg/Nm^3)	1.293	1.293
at gas temp.($\gamma g=kg/m^3$)	0.845	0.845

3. DECISION OF FLUE DIAMETER [内筒直径の決定]

3.1 Decision of a nozzle diameter at the flue top [内筒頂部直径の決定]

Required cross sectional area of a nozzle to keep the exhaust gas velocity of 30 m/sec under condition of ECR is;

$$\text{Req } A = \frac{Qg}{30} = \frac{240.4}{30} = 8.0 \text{ m}^2$$

Therefore, diameter is

$$d = \sqrt{\frac{8.0 \times 4}{\pi}} = 3.19 \text{ m}\phi$$

Decided cross sectional area of top nozzle having diameter of 3.15 m is 7.79 m^2 .

3.2 Decision of effective diameter of flue [内筒有効直径の決定]

1) Natural draft force (theoretically calculated) under condition of MCR. [自然通気力の計算]

Specific gravity of air (γa) at 25 ℃ of ambient temperature is

$$\gamma a = 1.293 \times \frac{273}{273 + 25} = 1.185$$

Height of breeching opening center is 10.0 m above ground and specific gravity of gas at temperature of 145℃ is 0.845.

Therefore, natural draft force (Z) can be calculated as follows:

$$Z = (140.0 - 10.0) \times (1.185 - 0.845) \times 0.95 = 42.0 \text{ mmAq}$$

Where, 0.95 is reduction factor due to gas temperature drop between opening and top nozzle.

2) Calculation of pressure loss (Δh) [圧力損失の計算]

a) Exhaust loss at top nozzle(Δh_1) [頂部の排出損失]

$$\Delta h_1 = \lambda_1 \frac{\gamma g}{2g} V_{g1}^2 \qquad V_{g1} = \frac{252.6}{7.79} = 32.43 \text{ m/sec}$$

$$= 1.2 \times \frac{0.845}{2 \times 9.8} \times 32.43^2$$

$$= 54.4 \text{ mmAq}$$

b) Friction loss in flue(Δh_2) (内筒の摩擦損失)

$$\Delta h_2 = \lambda_2 \frac{\gamma g}{2g} V_{g2}^2 \times \frac{H}{D}$$

Here, assuming that the flue diameter is 3.5 m, cross sectional area of flue is 9.621m^2 .

Therefore, gas velocity in flue becomes 26.26 m/sec.

$$\Delta h_2 = 0.02 \times 0.0431 \times 26.26^2 \times 130/3.5 = 22.1 \text{ mmAq}$$

c) Connection loss at breeching opening [内筒への入口損失]

Dimension of breeching opening is 2m×7m and area is 14.0m^2 .

Gas velocity(V_{g3}) at breeching opening is 18.04 m/sec.

3/5

Therefore, connection loss can be calculated as follows;

$$\Delta h_3 = \lambda_3 \frac{\gamma g}{2g} V_{g3}^2$$

$$= 1.05 \times 0.0431 \times 18.04^2 = 14.7 \text{ mmAq}$$

d) Total pressure loss [合計損失]

$$\Delta h = \Delta h_1 + \Delta h_2 + \Delta h_3$$

$$= 54.4 + 22.1 + 14.7 = 91.2 \text{ mmAq}$$

e) Required forced draft[必要強制通気力] can be obtained by subtracting natural draft force (Z) from total pressure loss

$$\Delta h - Z = 91.2 - 42.0 = 49.2 \text{ mmAq} < 50 \text{ mmAq}$$

Consequently, the diameter of stack is decided as follows:

Top nozzle (effective) [有効頂部直径] ϕ 3.15 m

Flue(effective) [有効内筒直径] ϕ 3.5 m

The dimension of reinforced concrete windshield is decided based upon the inner flue diameter. Refer to the Secton II.

II. STRUCTURAL CALCULATION

1. GENERAL
[一般事項]

1-1 DESIGN BASIS [設計基本事項]

The reinforced concrete chimney (Height : 137 m) for the West Wharf Thermal Power Plant Project Units No.1 and No.2 is designed to resist stresses resulting from the weight of the chimney, and the effect of temperature, wind and earthquake.

The dynamic analysis is used for the seismic load as well as the static analysis. The maximum stresses are applied for the decision of the section of the windshield and the foundation.

The stresses are calculated in accordance with the Architectural Institute of Japan. The section is decided so that the stresses do not exeed the allowable stresses. Also, the economical section is considered.

Table of Reinforcing Bars (ASTM Standard)

SIZE	NOMINAL DIAMETER (mm)	NOMINAL AREA (mm2)
# 3	9.52	71
# 4	12.70	129
# 5	15.88	200
# 6	19.05	284
# 7	22.22	387
# 8	25.40	510
# 9	28.65	645
#10	32.26	819
#11	35.81	1006
#14	43.00	1452
#18	57.33	2581

318

1-2 ALLOWABLE STRESS
[許容応力度]

(1) ALLOWABLE UNIT STRESS OF CONCRETE (kg/cm2)

		PERMANENT CONDITIONS				TEMPORARY CONDITIONS		
		COMPRESSION	SHEAR	BOND		COMPRESSION	SHEAR	BOND
				A	B			
NORMAL CONCRETE Fc=270	BAR 1	90	7.7	9.0	13.5	PERMANENT CONDITIONS x 2.0	PERMANENT CONDITIONS x 1.5	
	BAR 2			16.2	24.3			

NOTE : BAR 1 --- PLAIN BAR
BAR 2 --- DEFORMED BAR
A --- TOP BAR OF FLECTIONAL MEMBER
B --- OTHER BARS

(2) ALLOWABLE UNIT STRESS OF REINFORCED BARS (kg/cm2)

	PERMANENT CONDITIONS		TEMPORARY CONDITIONS	
	TENSION COMPRESSION	FOR SHEAR	TENSION COMPRESSION	FOR SHEAR
DEFORMED BAR ASTM A615 GRADE 40	1,870	1,870	2,800	2,800

(3) ALLOWABLE UNIT STRESS OF STRUCTURAL STEEL (kg/cm2)

	PERMANENT CONDITIONS		TEMPORARY CONDITIONS	
	COMPRESSION TENSION BENDING	SHEAR	COMPRESSION TENSION BENDING	SHEAR
STRUCTURAL STEEL SS41 AND SM41A THICKNESS ≦ 40mm	1,600	920	2,400	1,380
STRUCTURAL STEEL SS41 AND SM41A THICKNESS > 40mm	1,460	840	2,200	1,270

(4) ALLOWABLE UNIT STRESS OF WELDING JOINT (kg/cm2)

		PERMANENT CONDITIONS		TEMPORARY CONDITIONS	
		BUTT WELD	FILLET WELD AND SHEAR	BUTT WELD	FILLET WELD AND SHEAR
SS41 AND SM41A THICKNESS≦ 40mm	A	1,440	830	2,160	1,245
	B	1,200	700	1,800	1,050
SS41 AND SM41A THICKNESS> 40mm	A	1,320	760	1,980	1,140
	B	1,100	635	1,650	950

NOTE : A --- FLAT OR HORIZONTAL POSITION
B --- OVERHEAD OR VERTICAL POSITION

(3) BEARING CAPACITY OF STEEL PIPE PILE (t/pile)

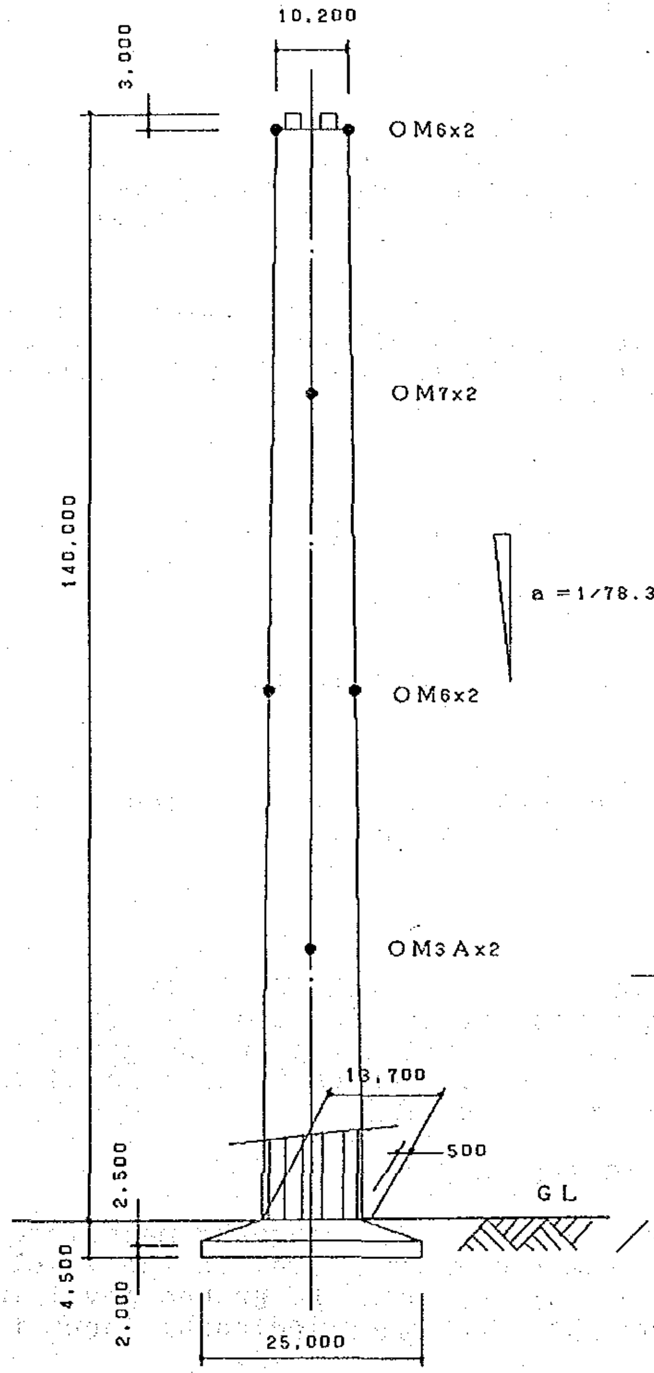
	PERMANENT CONDITIONS	TEMPORARY CONDITIONS
STEEL PIPE PILE ϕ 609.6x9 STK41	120	240

318

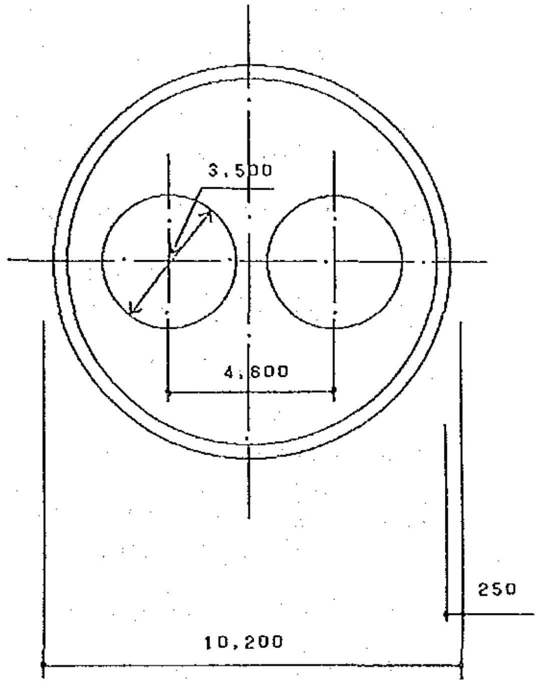
2. STRUCTURAL DATA
2-1 STRUCTURAL DATA
［構造概要］

DESIGN CONDITIONS ［設計条件］				
FUEL		OIL		
EXHAUST GAS VOLUME (Nm3/sec)		157 (ECR) 165 (MCR)		
EXHAUST GAS TEMPERATURE (℃)		145		
TYPE		INNER FLUE TYPE		
DIMENSION ［各部寸法］				
TOTAL HEIGHT (m)	Ho	140		
HEIGHT OF WINDSHIELD (m)	Hw	137		
TOP OUTER DIAMETER (m)	Dt	10.2		
BOTTOM OUTER DIAMETER (m)	Db	13.7		
TOP WALL THICKNESS (m)	Tt	0.25		
BOTTOM WALL THICKNESS (m)	Tb	0.5		
SLOPE (2xHw/(Db-Dt))	S	78.29		
EFFECTIVE DIAMETER OF INNER FLUE (m)		3.5		
INSIDE DIAMETER OF INNER FLUE (m)		3.6		
FOUNDATION ［基礎形式］				
TYPE		OCTAGONAL RC FOUNDATION		
WIDTH (m)		25		
SUPPORTING SYSTEM		STEEL PIPE PILE φ 609.6x9		
LINING AND INSULATION ［ライニング及び保温材］				
LINING MATERIAL (THICKNESS:50mm)		GUNITE TYPE CASTABLE LINING		
INSULATION MATERIAL (THICKNESS:50mm)		GLASS FIBER		
MATERIAL QUANTITY ［材料数量］				
REINFORCED CONCRETE (m3) &	WINDSHIELD	1,900 m3		
REINFORCED STEEL BAR (t)	FOUNDATION	1,850 m3		
STEEL (t)		280 t		
NUMBER OF PILE		124 piles		
QUALITY OF STRUCTURAL MEMBER ［構造材料仕様］				
REINFORCED CONCRETE		Fc = 270 kg/cm2		
REINFORCED STEEL BAR		GRADE 40 (ASTM A615)		
INNER FLUE		SM41A		
DEAD WEIGHT (t) ［重量］				
WINDSHIELD	ρ = 2.4 t/m3	4,560 t		
INNER FLUE	ρ = 7.86 t/m3	2 t/m	t/m	TOTAL(t)
LINING	ρ = 2.0 t/m3	2.3 t/m	4.5	630
INSULATION	ρ = 0.15 t/m3	0.2 t/m		
FOUNDATION	ρ = 2.4 t/m3	4,430 t		
SOIL ABOVE FOUNDATION	ρ = 1.8 t/m3	880 t		
WIND CONDITIONS ［風荷重条件］				
MAXIMUM WIND VELOCITY (m/s)		50 AT 10 METER HEIGHT		
WIND PRESSURE (kg/m2)	h< 16 m	$45\sqrt{h}$		
	h≧ 16 m	$90\sqrt[4]{h}$		
CONDITIONS OF DYNAMIC ANALYSIS ［動的解析条件］				
INPUT SEISMIC WAVE		EL CENTRO (NS) AND TAFT (EW)		
INPUT ACCELERATION (GAL)		150		
DAMPING RATIO		2 %		
RESULTS OF DYNAMIC ANALYSIS ［動的解析結果］				
NATURAL PERIOD (sec)	1st mode	2.199		
	2nd mode	0.465		
	3rd mode	0.252		
MAXIMUM RESPONSE ACCELERATION (GAL)		888 (TAFT)		
MAXIMUM RESPONSE DISPLACEMENT (cm)		22.1 (EL CENTRO)		
MAXIMUM BENDING MOMENT (tm)		40,344.3 (EL CENTRO)		
MAXIMUM SHEAR FORCE (t)		1,021.2 (EL CENTRO)		
MAXIMUM SHEAR COEFFICIENT	TOP Ct	0.85		
	BOTTOM Cb	0.244		

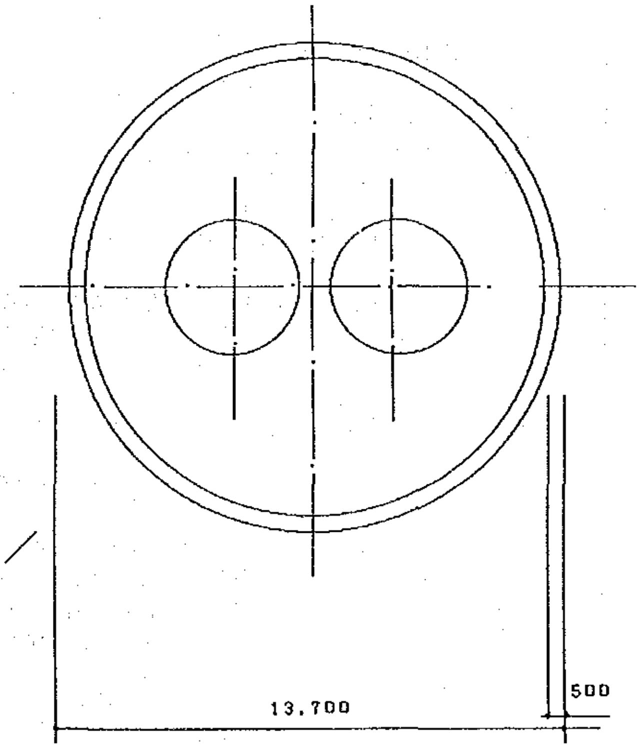
2-2 STRUCTURAL DRAWING [構造図]



ELEVATION



PLAN GL+137m



PLAN GL±0

3. DESIGN LOAD (1)
[設計荷重]

3-1 DEAD LOAD [固定荷重]

Dead load consists of concrete windshield, inner flue, lining, insulation and other accessories.

Unit weight of each material is as follows.

Reinforced concrete:	2.4 t/m3
Steel inner flue:	1.0 t/m (average thickness : 11mm)
Lining:	1.12 t/m (thickness : 50mm)
Insulation:	0.09 t/m (thickness : 50mm)
Soil:	1.8 t/m3

The weight of steel inner flue with lining and insulation is 2.21 t/m (=1+1.12+0.09). Total weight of two inner flues is 4.42 t/m (=2x2.21). Then the weight of inner flue for structural calculation is considered to be 4.5 t/m.

3-2 LIVE LOAD [積載荷重]

Live load is considered to be 100 kg/m2 for only the decision of stage members.

3-3 SEISMIC LOAD [地震荷重]

Seismic load is calculated from the dead load.

(1) Superstructure

The design shear force and bending moment are calculated at each level from the following equations.

Qi = Ci*W
Mi = 0.4*H*Ci*W

where, Qi : Shear force at the level of "i" (t)
Mi : Bending moment at the level of "i" (tm)
Ci : Coefficient indicating the stress distribution by height direction which is calculated from the following equation

Ci = 0.15*Z*(1-hi/H)

Z : Zone coefficient for earthquake magnitude (=1.0)
hi : Height from the ground level to the level of "i"
H : Height of chimeny from the ground level (m)
W : Total weight of chimney including inner flues

322

3. DESIGN LOAD (2)
[設計荷重]

(2) Foundation

Seismic force of foundation is calculated from the following equation.

$$P = K*Wf$$
$$K = 0.05*Z*(1-h/40)$$

where, P : Seismic force of foundation (t)
K : Seismic coefficient
Wf : Weight of foundation (t)
Z : Zone coefficient for earthquake magnitude (=1.0)
h : Depth from the ground level (m)

3-4 WIND LOAD [風荷重]

Two kinds of wind loads are considered for the design wind load. One is static wind load and the other is resonant wind load. Static wind load is calculated from the maximum wind velocity. Resonant wind load is calculated from the wind velocity by which the chimney is resonated at the first mode. The static wind load by that wind velocity is combined with the resonant wind load by vector.

(1) Static wind load [静的風荷重]

The horizontal static wind load is calculated from the following equation.

$$Pi = C*qi*Di$$

where, Pi : Horizontal static wind load at the level of "i" (t/m)
C : Coefficient of wind pressure (=0.7 ; cylinder shape)
qi : Wind pressure at the level of "i" (kg/m2)
$qi = 90 \sqrt[4]{hi}$
hi : Height from the ground level to the level of "i" (m)
Di : Outer diameter of chimney at the level of "i" (m)

3. DESIGN LOAD (3)
[設計荷重]

(2) Resonant wind load [揚力]

The resonant wind load due to Karman vortex is calculated from the following equation.

Pri = Cr*qr*Di

where, Pri: Resonant wind load at the level of "i" (t/m) (t/m)
Cr : Coefficient of wind pressure at resonance which is decided by the value of (Vr*D). Where, Vr is resonant wind velocity (m/s) and D is outer diameter (m) of chimney at the height of (2/3)H.
qr : Wind pressure at resonance (kg/m2)
Di : Outer diameter of chimney at the level of "i" (m)

(Detail explanation)

Vr:Resonant wind velocity (m/s)
Vr = D/(Sr*T)
where, D :Outer diameter of chimney at the height of (2/3)H (m)
Sr:Strouhal number
Sr=0.18 in case of Vr*D< 100
Sr=0.25 in case of Vr*D≧ 100
T :Natural period of chimney at the first mode (sec)

qr:Wind pressure at resonance (kg/m2)
qr = 1.5*qro*h/H
where, qro:Basic wind pressure at resonance (kg/m2)
qro=Vr*Vr/16
h :Height from the ground level (m)
H :Height of chimney from the ground level (m)

Cr:Coefficient of wind pressure at resonance decided from the following table

	$\rho\sqrt{\eta} < 1$	$1 \leq \rho\sqrt{\eta}$
Vr*D<3	$(2.3+3.0*(1-\rho\sqrt{\eta})^2)/\sqrt{\eta}$	$2.3/\sqrt{\eta}$
3≦ Vr*D<6	Linear interpolation	Linear interpolation
6≦ Vr*D<100	$(0.7+1.9*(1-\rho\sqrt{\eta})^2)/\sqrt{\eta}$	$0.7/\sqrt{\eta}$

NOTE : η --- Damping ratio of chimney (2%)
ρ --- Relative density of chimney calculated as below (kg·sec2/m4)
ρ =W/(9.8*H*D*Db)
where, W :Weight of chimney (kg)
Db:Outer diameter of chimney bottom (m)

4. DESIGN OF SUPERSTRUCTURE (1)
[上部の設計]

4-1 STATIC ANALYSIS [静的解析]

4-1.1 STRESS ANALYSIS OF SEISMIC LOAD [地震時の応力解析]

Shear force and bending moment are calculated and the results are indicated in the following table.

Height hi (m)	Outer Diameter Di (m)	Thickness Ti (m)	Inner Diameter di (m)	Weight Wi (t)	Shear Force Qi (t)	Bending Moment Mi (tm)
137	10.20	0.25	9.70	0.0	0.0	0.0
130	10.38	0.26	9.85	135.8	39.7	2177.1
120	10.63	0.28	10.07	345.6	96.5	5287.3
110	10.89	0.30	10.29	574.7	153.2	8397.5
100	11.15	0.32	10.51	823.8	210.0	11507.6
90	11.40	0.34	10.73	1093.4	266.7	14617.8
80	11.66	0.35	10.95	1384.2	323.5	17728.0
70	11.91	0.37	11.17	1697.0	380.3	20838.1
60	12.17	0.39	11.39	2032.2	437.0	23948.3
50	12.42	0.41	11.61	2390.7	493.8	27058.5
40	12.68	0.43	11.82	2773.0	550.5	30168.6
30	12.93	0.45	12.04	3179.8	607.3	33278.8
20	13.19	0.46	12.26	3611.7	664.0	36389.0
10	13.44	0.48	12.48	4069.4	720.8	39499.1
0	13.70	0.50	12.70	4553.6	777.5	42609.3

4-1.2 STRESS ANALYSIS OF STATIC WIND LOAD [静的風圧力による応力解析]

Shear force and bending moment are calculated and the results are indicated in the following table.

Height hi (m)	Shear Force Qi (t)	Bending Moment Mi (tm)
137.0		
127.9	19.0	173.7
118.7	38.1	521.9
109.6	57.3	1045.0
100.5	76.4	1743.2
91.3	95.6	2616.1
82.2	114.6	3663.0
73.1	133.5	4882.5
63.9	152.2	6272.6
54.8	170.6	7830.6
45.7	188.5	9552.7
36.5	206.0	11433.7
27.4	222.6	13466.7
18.3	238.2	15642.1
9.1	252.1	17945.0
0.0	262.9	19145.8

4. DESIGN OF SUPERSTRUCTURE (2)
[上部の設計]

4-2 DYNAMIC SEISMIC ANALYSIS [動的地震応答解析]

4-2.1 Analysis conditions

a. The reinforced concrete windshield (H=137m) is divided into 15 parts in the same height with the mass concentrated in the center of each part. The mass of foundation is considered to be one mass.

b. Only flectional stiffness is considered for the analysis model of windshield. The stiffness of inner flues is not considered for the analysis.

c. The stiffness of sway and rocking is considered for the analysis model of foundation. The stiffness of steel pipe pile and soil is also considered for those stiffnesses. The stiffness is calculated as follows.

- Spring constant of sway stiffness : Ks (t/m)

  $Ks = n \times Kh*B/\beta = 3.428E05$ t/m

  where, n : Number of pile (n=101 piles)
  Kh: Coefficient of ground reaction decided ground conditions (Kh=2.31kg/cm3)
  B : Pile diameter (B=60.96 cm)
  β : $= \sqrt[4]{Kh*B/(4*E*I)} = 0.004148$ cm-1
  E = 2100 t/cm2 (Young modulus of steel pile)
  I = 76600 cm4 (Section inertia moment of steel pipe pile ϕ 609.6x9)

- Spring constant of rocking stiffness : Kr (tm/rad)

  $Kr = \alpha *E*Io/L = 1.218E08$ tm/rad

  where, α : Coefficient considered ground effectiveness
  Io: Inertia moment of a group of steel pipe piles
  $Io = 0.5*A*\Sigma (n*r*r)$
  A :Section area of one steel pile (0.01698 m2)
  Σ :Sumation of all sizes of r
  n :Number of piles with the same size of r
  r :Radius of pile locations from the center of foundation (m)
  L : Pile length (25 m)

(Detail explanation)
$Kh = 0.8*Eo*B^{-3/4} = 0.8*(7*9)*60.96^{-3/4} = 2.31$ kg/cm3
where, Eo:Coefficient of soil deformation; =7*N (N:N-value)
$\alpha = \lambda *(\lambda *\tanh\lambda +\gamma)/(\gamma *\tanh\lambda +\lambda) = 1.744$
where, γ =At*kv*L/(A*E) (At:Closed section area of pile bottom, kv:Coefficient of vertical ground reaction, L:pile length)
$\lambda = L*\sqrt{cs*U/(A*E)}$ (cs:Friction coefficient between pile and soil, U:Circumference of steel pipe pile)

4. DESIGN OF SUPERSTRUCTURE (3)
[上部の設計]

d. Damping ratio : h1 = h2 = h3 = 0.02

e. Maximum input acceleration : 150 gal

f. Input earthquake wave

EL CENTRO (1940 NS COMPONENT)

Number of data :	2,688
Time difference between data :	0.02 sec
Analysis period :	53.76 sec

TAFT (1952 EW COMPONENT)

Number of data :	2,720
Time difference between data :	0.02 sec
Analysis period :	54.40 sec

4. DESIGN OF SUPERSTRUCTURE (4)
[上部の設計]

4.2-2 Analysis model

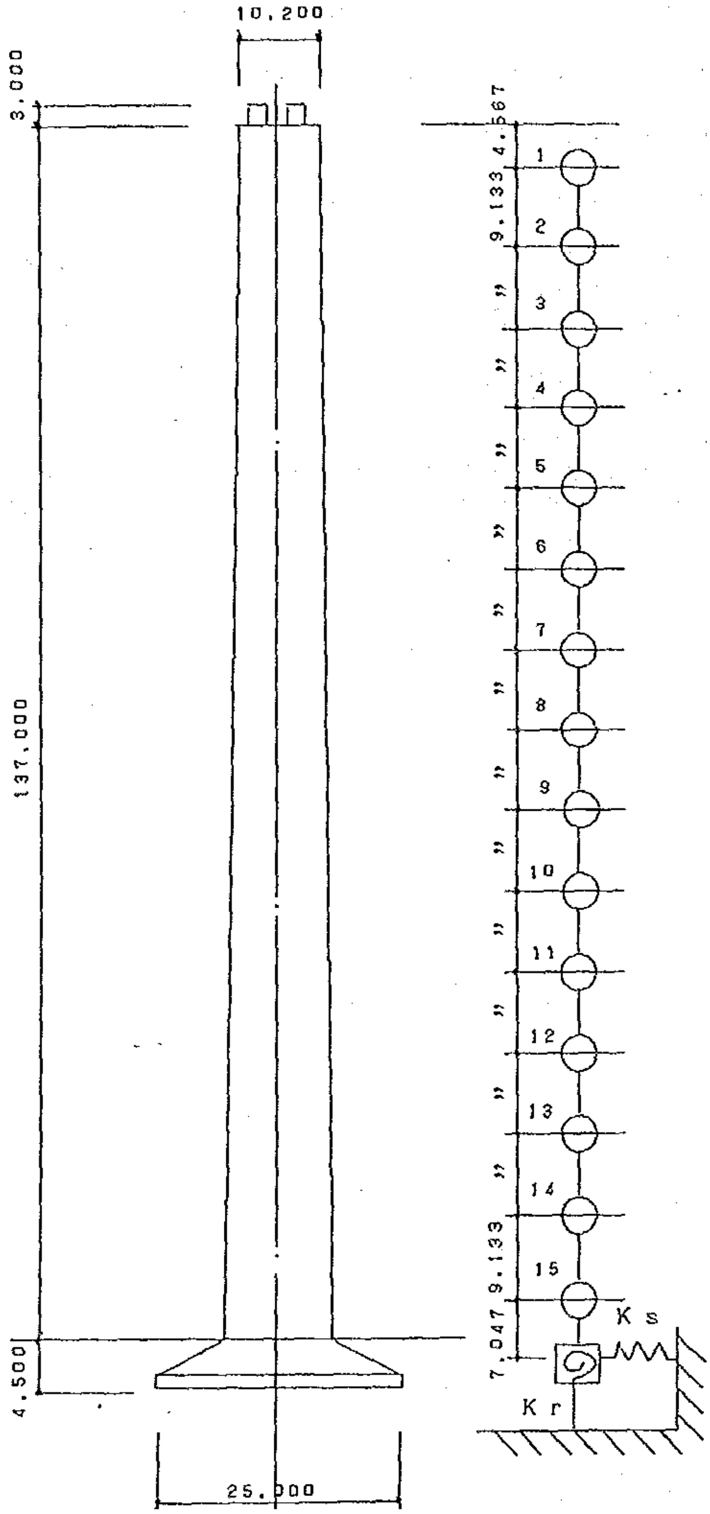


Table 4-2.1 DATA FOR VIBRATION MODEL

タイトル : W E S T W H A R F   RC-STACK

＊＊＊＊＊ 振 動 モ デ ル ＊＊＊＊＊

Mass point 質点		Height 高さ (m)	Weight 重量 (t)	Mass 質量 (t.sec2/m)	Length of division 区間長 (m)	I Section inertia moment (m4)
1	O	132.433	233.556	23.832		
	|				9.133	0.110119E+03
2	O	123.300	235.703	24.051		
	|				9.133	0.124650E+03
3	O	114.167	251.847	25.699		
	|				9.133	0.140425E+03
4	O	105.033	268.489	27.397		
	|				9.133	0.157512E+03
5	O	95.900	285.629	29.146		
	|				9.133	0.175976E+03
6	O	86.767	303.265	30.945		
	|				9.133	0.195887E+03
7	O	77.634	321.399	32.796		
	|				9.133	0.217313E+03
8	O	68.500	340.031	34.697		
	|				9.133	0.240327E+03
9	O	59.367	359.159	36.649		
	|				9.133	0.265002E+03
10	O	50.234	378.785	38.652		
	|				9.133	0.291414E+03
11	O	41.100	398.909	40.705		
	|				9.133	0.319637E+03
12	O	31.967	419.529	42.809		
	|				9.133	0.349752E+03
13	O	22.834	440.647	44.964		
	|				9.133	0.381836E+03
14	O	13.700	462.263	47.170		
	|				9.133	0.415973E+03
15	O	4.567	484.402	49.429		
	|				4.567	0.442972E+03
	- - -	-2.480		Young modulus ヤング係数 :	0.24400E+07 (t/m2)	

		Weight of foundation 基礎体重量	Mass of foundation 質量	Spring constant of sway stiffness スウェイバネ
16	(SWAY)	0.442100E+04 (t)	0.451122E+03	0.342800E+06 (t/m)
		Rotatory inertia moment 回転慣性モーメント	Mass 質量	Spring constant of rocking stiffness 回転バネ
17	(ROCKING)	0.147000E+06 (tm2)	0.150000E+05	0.121800E+09 (tm/rad)

4. DESIGN OF SUPERSTRUCTURE (5)
[上部の設計]

4-2.3 Results of Dynamic Seismic Analysis

(1) Eigen value

Natural Period, modal particpation factor and mode shape of each mass at each mode are shown in the tables 4-2.2 and 4-2.3.

(2) Maximum response

Maximum response values are shown in the tables 4-2.4 and 4-2.5. Response displacement, acceleration, shear force and bending moment are indicated. Table 4-2.4 shows the results of EL CENTRO seismic wave and table 4-2.5 shows the results of TAFT seismic wave.

4-3 DYNAMIC ANALYSIS FOR RESONANT WIND LOAD

4-3.1 Calculation of initial data

Each data necessary to stress analysis is calculated and shown in the table 4-3.1.

4-3.2 Results of stress analysis

Shear force and bending moment by resonant wind load and by static wind load at resonant wind velocity are indicated in the table 4-3.2.
Shear force and bending moment by combined loads of the resonant wind load and the static wind load are shown in the table 4-3.3.

4-4 RESULTS OF ALL STRESS ANALYSIS

The results of all stress analysis are shown in the figures 4-4.1 to 4-4.6. The contents of the figures are as follows.

Figure 4-4.1 Vibration Mode Diagram 1 (U)
Figure 4-4.2 Vibration Mode Diagram 2 (β *U)
Figure 4-4.3 Maximum Displacement Response
Figure 4-4.4 Maximum Acceleration Response
Figure 4-4.5 Shear Force
Figure 4-4.6 Bending Moment

/EC

Table 4-2.2 EIGEN VALUE (1)

タイトル : W E S T W H A R F RC-STACK

RESULTS OF EIGEN VALUE

＊＊＊＊＊ 固 有 値 解 析 結 果 ＊＊＊＊＊

Mode 次数	1	2	3	4	5	6	7	8	9	10
Natural period 固有周期 (sec) (秒)	2.19868	0.46502	0.25232	0.15911	0.08876	0.05857	0.04209	0.03037	0.02239	0.01706
Participation factor 刺激係数	1.66070	1.31266	0.94518	-0.33283	0.04630	-0.00626	0.00216	-0.00233	-0.00136	0.00081
1	1.00000	-1.00000	1.00000	1.00000	1.00000	0.96095	-0.84115	-0.73222	0.61327	0.46804
2	0.90168	-0.66086	0.50182	0.31778	-0.01775	-0.34428	0.59672	0.83581	-1.00000	-1.00000
3	0.80395	-0.33431	0.04542	-0.26227	-0.72408	-1.00000	1.00000	0.80967	-0.39323	0.12543
4	0.70759	-0.03543	-0.32419	-0.64459	-0.91080	-0.75220	0.26541	-0.38937	0.91813	0.93638
5	0.61360	0.22079	-0.57031	-0.77505	-0.59144	0.06243	-0.70237	-1.00000	0.56680	-0.30552
6	0.52302	0.42240	-0.67449	-0.66112	0.00595	0.78261	-0.92464	-0.27368	-0.70961	-0.81707
7	0.43691	0.56215	-0.63972	-0.36686	0.56267	0.90671	-0.25721	0.74497	-0.72230	0.38977
8	0.35630	0.63816	-0.48834	0.00857	0.82198	0.40367	0.59858	0.76245	0.43625	0.72679
9	0.28214	0.65387	-0.25655	0.35943	0.69290	-0.33320	0.84731	-0.15240	0.82226	-0.40364
10	0.21531	0.61740	0.01288	0.59976	0.26679	-0.80098	0.32021	-0.82126	-0.10166	-0.67260
11	0.15656	0.54060	0.27818	0.68153	-0.24656	-0.72516	-0.45712	-0.47590	-0.80833	0.36830
12	0.10655	0.43793	0.50513	0.60137	-0.62331	-0.20586	-0.80391	0.40680	-0.24488	0.64594
13	0.06582	0.32527	0.67194	0.39623	-0.72101	0.38619	-0.48444	0.79965	0.66678	-0.30816
14	0.03480	0.21883	0.77199	0.13079	-0.52813	0.65971	0.12917	0.35887	0.61922	-0.69289
15	0.01384	0.13431	0.81451	-0.11920	-0.15530	0.42360	0.38165	-0.20219	-0.06896	-0.02519
16	0.00436	0.09180	0.82307	-0.26037	0.14699	-0.06174	0.03647	-0.06695	-0.06764	0.05827
17	0.00116	0.00530	-0.00081	0.01811	-0.04177	0.07579	0.06633	-0.04253	-0.02850	0.01933

Table 4-2.3 EIGEN VALUE (2)

タイトル : WEST WHARF RC-STACK

RESULTS OF EIGEN VALUE

＊＊＊＊＊ 固 有 値 解 析 結 果 ＊＊＊＊＊

Mode 次数	11	12	13	14	15	16	17
Natural period 固有周期 (sec) (秒)	0.01344	0.01091	0.00912	0.00786	0.00698	0.00625	0.00407
Participation factor 刺激係数	-0.00046	-0.00026	-0.00018	0.00011	-0.00007	0.00006	-0.00020
1	0.38013	-0.31214	0.20235	0.12856	0.05791	0.00952	0.00000
2	-1.00000	0.96443	-0.70696	-0.49200	-0.23674	-0.04118	-0.00001
3	0.60353	-1.00000	1.00000	0.84857	0.46591	0.09013	0.00003
4	0.55133	0.15464	-0.75888	-1.00000	-0.69093	-0.15751	-0.00008
5	-0.90344	0.77306	0.11149	0.88154	0.88493	0.25094	0.00021
6	0.01252	-0.89970	0.56449	-0.49418	-1.00000	-0.37447	-0.00051
7	0.83711	0.11163	-0.82921	-0.05035	0.98308	0.52613	0.00123
8	-0.42673	0.74582	0.49382	0.54429	-0.79694	-0.69439	-0.00293
9	-0.59018	-0.73221	0.19349	-0.76328	0.44594	0.85516	0.00683
10	0.64626	-0.11693	-0.68855	0.58818	0.00483	-0.97176	-0.01563
11	0.31025	0.77908	0.57893	-0.10176	-0.43179	1.00000	0.03510
12	-0.71317	-0.44957	0.03517	-0.41985	0.68735	-0.90009	-0.07732
13	-0.06534	-0.42454	-0.58181	0.64971	-0.66112	0.65292	0.16781
14	0.73157	0.73207	0.56306	-0.45006	0.36445	-0.29250	-0.34149
15	0.09627	0.16097	0.18039	-0.20020	0.21983	-0.25085	1.00000
16	-0.05361	-0.05118	-0.04052	0.03549	-0.03300	0.03274	-0.08550
17	-0.01509	-0.01275	-0.00918	0.00748	-0.00659	0.00622	-0.01376

338

Table 4-2.4 RESULTS OF DYNAMIC SEISMIC ANALYSIS (1)

タイトル : WEST WHARF RC-STACK

＊＊＊＊＊ 地 震 応 答 解 析 結 果 ＊＊＊＊＊

Earthquake wave 地震波タイトル : EL CENTRO (NS) MAY 18,1940 (THE BUILDING CENTER)
Maximum input accel. 入力最大加速度 : 150.000 GAL
Time step 計算刻み : 0.020 秒 (sec)

Mass 質点	Height 高さ (m)	Displace 変位 (cm)	Time 時刻 (sec)	Acceleration 加速度 (gal)	Time 時刻 (sec)	Shear force せん断力 (ton)	Time 時刻 (sec)	Moment 転倒モーメント (t・m)	Time 時刻 (sec)
1	132.433	-22.083	6.54	-834.845	5.34	198.962	5.34	0.000	0.00
2	123.300	-19.268	6.54	-541.139	5.34	329.113	5.34	1817.180	5.34
3	114.167	-16.500	6.54	301.377	6.52	397.546	5.34	4823.068	5.34
4	105.033	-13.942	6.58	-178.989	5.74	406.448	5.36	8453.972	5.34
5	95.900	-12.021	6.66	324.467	2.58	-386.317	6.52	12159.805	5.34
6	86.767	10.841	5.58	450.883	2.58	-335.402	6.52	15459.062	5.34
7	77.634	9.614	5.58	494.154	2.58	271.932	5.74	18024.980	5.36
8	68.500	8.320	5.58	461.870	2.58	-304.936	5.66	-20025.824	6.52
9	59.367	6.987	5.58	-453.189	5.14	411.538	5.56	-21388.773	6.52
10	50.234	5.654	5.58	-425.201	5.14	529.037	5.56	-21726.832	6.52
11	41.100	4.368	5.58	-371.636	5.14	634.449	5.14	-21076.679	6.52
12	31.967	3.177	5.58	-381.953	2.82	764.071	5.14	-19578.534	6.52
13	22.834	2.132	5.58	-382.599	2.82	867.191	5.14	-21556.013	6.66
14	13.700	1.286	5.60	-363.784	2.82	945.124	5.12	28298.950	5.56
15	4.567	0.854	2.82	-347.564	2.56	1021.183	5.12	36123.886	5.58
	0.000							40344.260	5.58
FS	-2.480	0.701	2.82	-369.947	2.56	2409.173	2.82		
FR	-2.480	0.035	5.58	4.855	4.92			42635.958	5.58

Table 4-2.5 RESULTS OF DYNAMIC SEISMIC ANALYSIS (2)

タイトル : WEST WHARF RC-STACK

＊＊＊＊＊ 地 震 応 答 解 析 結 果 ＊＊＊＊＊

Earthquake wave 地震波タイトル : TAFT (EW) JUL 21,1952 (THE BUILDING CENTER)
Maximum input accel. 入力最大加速度 : 150.000 GAL
Time step 計算刻み : 0.020 秒 (sec)

Mass 質点	Height 高さ (m)	Displacement 変位 (cm)	Time 時刻 (sec)	Acceleration 加速度 (gal)	Time 時刻 (sec)	Shear force せん断力 (ton)	Time 時刻 (sec)	Moment 転倒モーメント (t・m)	Time 時刻 (sec)
1	132.433	15.015	38.80	887.662	8.08	-211.549	8.08	0.000	0.00
2	123.300	13.516	38.80	-542.211	7.44	-341.031	8.08	-1932.145	8.08
3	114.167	12.037	38.82	271.630	6.78	397.317	7.44	-5046.879	8.08
4	105.033	10.593	38.82	-177.325	12.78	-399.668	6.74	-8653.757	8.08
5	95.900	9.205	38.84	-305.768	12.78	-355.077	6.76	-12142.724	6.74
6	86.767	7.876	38.86	-446.325	8.08	-279.627	6.78	-15304.616	6.74
7	77.634	6.888	5.88	-518.730	8.08	-209.918	4.98	-17580.204	6.74
8	68.500	5.926	5.86	-522.678	8.08	284.714	12.78	-18791.075	6.76
9	59.367	4.934	5.86	-494.219	8.10	379.419	5.88	-18899.444	6.76
10	50.234	3.934	5.86	-447.334	8.12	524.170	8.08	-17706.725	6.76
11	41.100	2.966	5.86	-394.249	7.66	642.107	8.10	-15365.222	6.78
12	31.967	-2.230	6.98	-344.150	7.66	743.859	8.10	13655.960	38.76
13	22.834	-1.567	6.98	-327.847	11.88	807.939	7.66	16913.853	5.88
14	13.700	1.048	12.40	-345.833	11.88	900.769	7.66	21732.631	5.88
15	4.567	0.760	12.40	-346.752	11.88	964.499	7.66	26630.885	5.86
	0.000							28945.282	5.86
FS	-2.480	0.617	12.40	-342.593	11.88	2126.261	11.88		
FR	-2.480	0.025	7.66	5.056	7.90			30238.216	7.66

Table 4-3.1 INITIAL DATA FOR CALCULATION

タイトル ： W E S T W H A R F RC-STACK

＊＊＊＊＊ 風 圧 力 解 析 ＊＊＊＊＊

NO.	Height 高さ (m)	Objected area 見付面積(m2)	Level レベル (m)	Diameter 外径 (m)	Thickness 厚さ (m)	Weight 重量 (t)
			137.000	10.200	0.250	0.000
1	132.433	94.225				
			127.867	10.433	0.267	178.956
2	123.300	96.356				
			118.733	10.667	0.283	373.559
3	114.167	98.487				
			109.600	10.900	0.300	584.306
4	105.033	100.618				
			100.467	11.133	0.317	811.696
5	95.900	102.750				
			91.334	11.367	0.333	1056.224
6	86.767	104.881				
			82.200	11.600	0.350	1318.390
7	77.634	107.012				
			73.067	11.833	0.367	1598.689
8	68.500	109.143				
			63.934	12.067	0.383	1897.620
9	59.367	111.274				
			54.800	12.300	0.400	2215.679
10	50.234	113.405				
			45.667	12.533	0.417	2553.364
11	41.100	115.536				
			36.534	12.767	0.433	2911.173
12	31.967	117.667				
			27.400	13.000	0.450	3289.602
13	22.834	119.798				
			18.267	13.233	0.467	3689.150
14	13.700	121.929				
			9.134	13.467	0.483	4110.313
15	4.567	124.067				
			0.000	13.700	0.500	4553.613

Dm	hl	Pl	Vm	Vr	Sr	Vr*D	T1
11.400	0.02	1.00	49.23	20.74	0.25	236.43	2.1987

＃＃＃＃＃ Cr = 14.120 ＃＃＃＃＃

[RHOs*ROOT(ETA) (1.0 , 100.0 (= Vr*D (Sr = 0.25)]

Table 4-3.2 RESULTS OF STRESS ANALYSIS BY WIND (1)

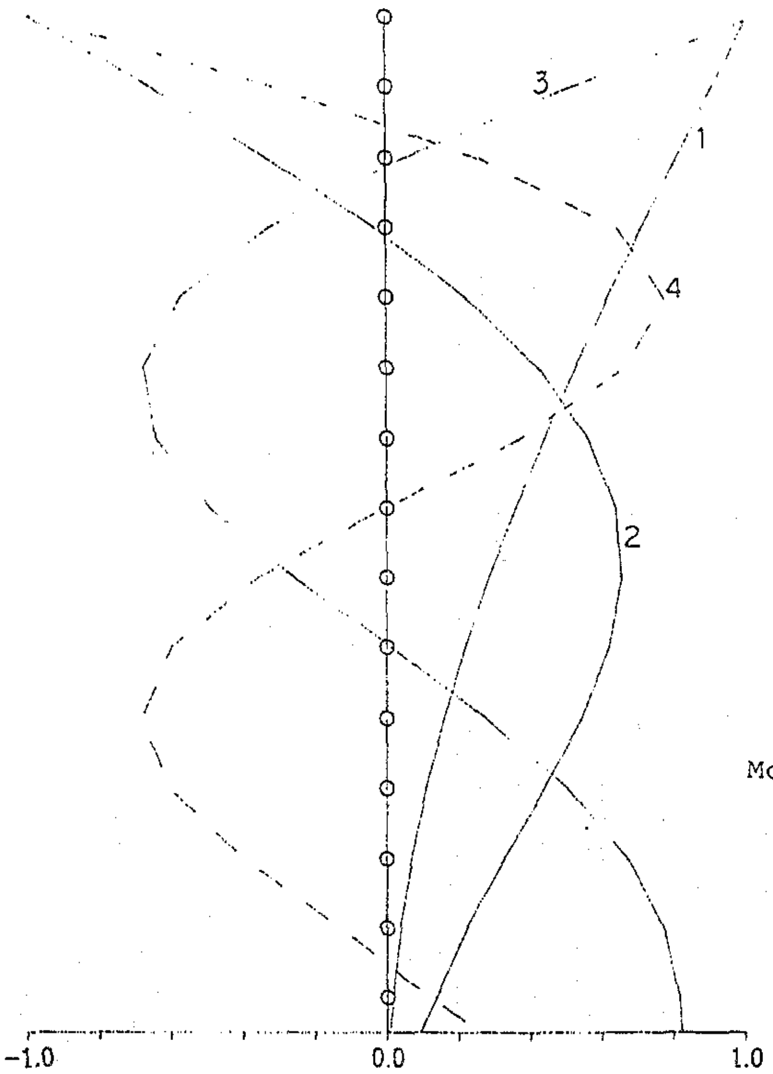
(1) 揚力,および共振風速に対する抗力 < V r = 20.74 m/sec >

NO.	高さ(m) Height	by Resonant wind load 揚力 せん断力(t) Shear force	by Resonant wind load 揚力 モーメント(t*m) Moment	by static wind load 抗力 せん断力(t) Shear force	by static wind load 抗力 モーメント(t*m) Moment
1	132.433		0.000		0.000
		51.865		1.773	
2	123.300		473.694		16.195
		101.244		3.586	
3	114.167		1398.389		48.951
		147.978		5.440	
4	105.033		2749.913		98.635
		191.903		7.333	
5	95.900		4502.616		165.612
		232.857		9.267	
6	86.767		6629.373		250.250
		270.680		11.241	
7	77.634		9101.577		352.914
		305.210		13.254	
8	68.500		11889.148		473.970
		336.283		15.308	
9	59.367		14960.524		613.786
		363.740		17.402	
10	50.234		18282.669		772.726
		387.417		19.536	
11	41.100		21821.065		951.158
		407.154		21.711	
12	31.967		25539.721		1149.448
		422.787		23.925	
13	22.834		29401.164		1367.962
		434.157		26.179	
14	13.700		33366.447		1607.067
		441.100		28.474	
15	4.567		37395.143		1867.127
		443.455		30.809	
16	0.000		39420.468		2007.835

Table 4-3.3 RESULTS OF STRESS ANALYSIS BY WIND (2)
(2) 揚力,および共振風速に対する抗力の合成応力 < SQRT(揚力**2 + 抗力**2) * 1.00 >

NO.	高さ (m) Height	せん断力 (t) Shear force	モーメント(t*m) Moment
1	132.433		0.000
		51.895	
2	123.300		473.971
		101.308	
3	114.167		1399.245
		148.078	
4	105.033		2751.681
		192.043	
5	95.900		4505.661
		233.042	
6	86.767		6634.094
		270.914	
7	77.634		9108.417
		305.497	
8	68.500		11898.592
		336.632	
9	59.367		14973.110
		364.156	
10	50.234		18298.991
		387.909	
11	41.100		21841.785
		407.732	
12	31.967		25565.574
		423.464	
13	22.834		29432.971
		434.945	
14	13.700		33405.127
		442.018	
15	4.567		37441.727
		444.524	
16	0.000		39471.568

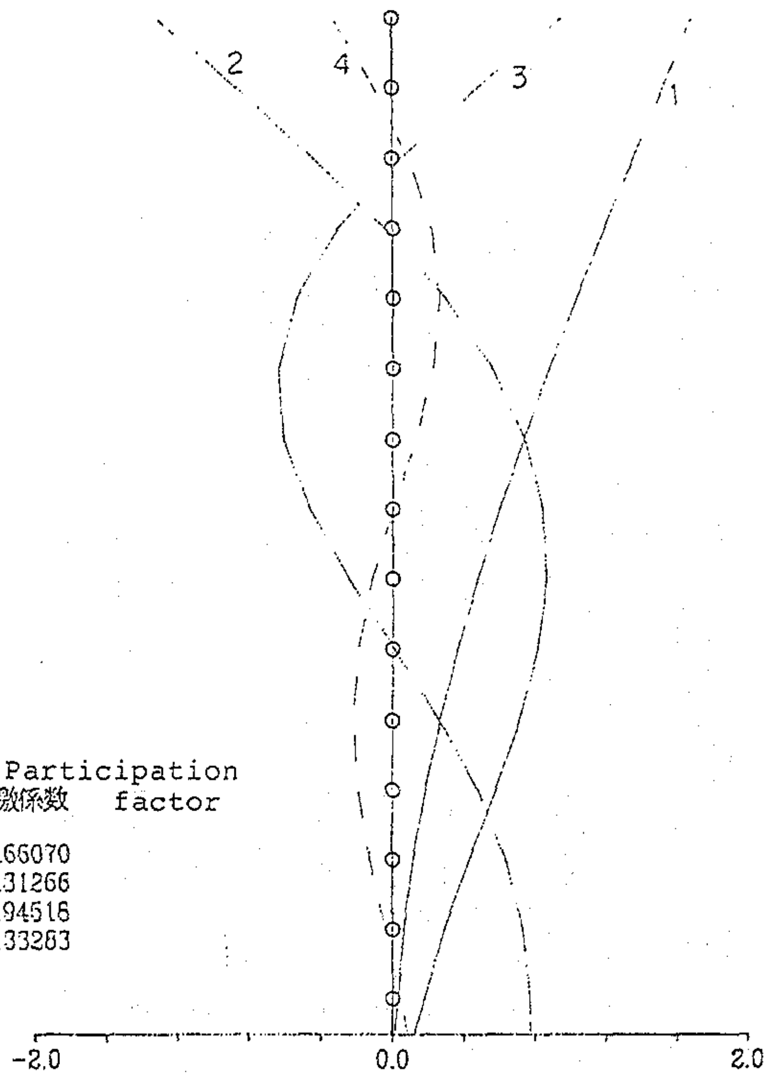
タイトル : WEST WHARF RC-STACK



振動モード図

Figure 4-4.1 VIBRATION MODE DIAGRAM 1 (U)

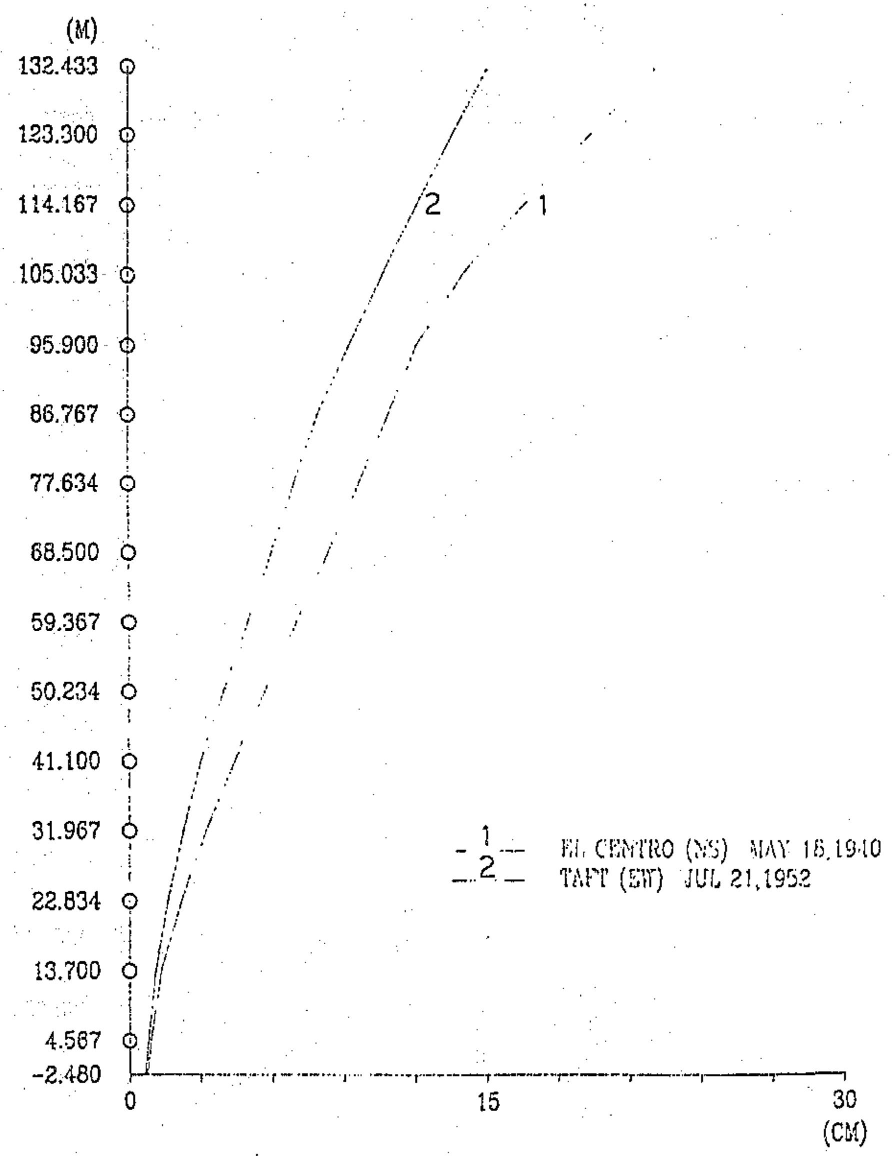
Mode 次数	Period 周期	Participation factor 刺激係数
1	2.19868	1.66070
2	0.46502	1.31266
3	0.25232	0.94516
4	0.15911	-0.33283



振動モード図 (BETA＊U)

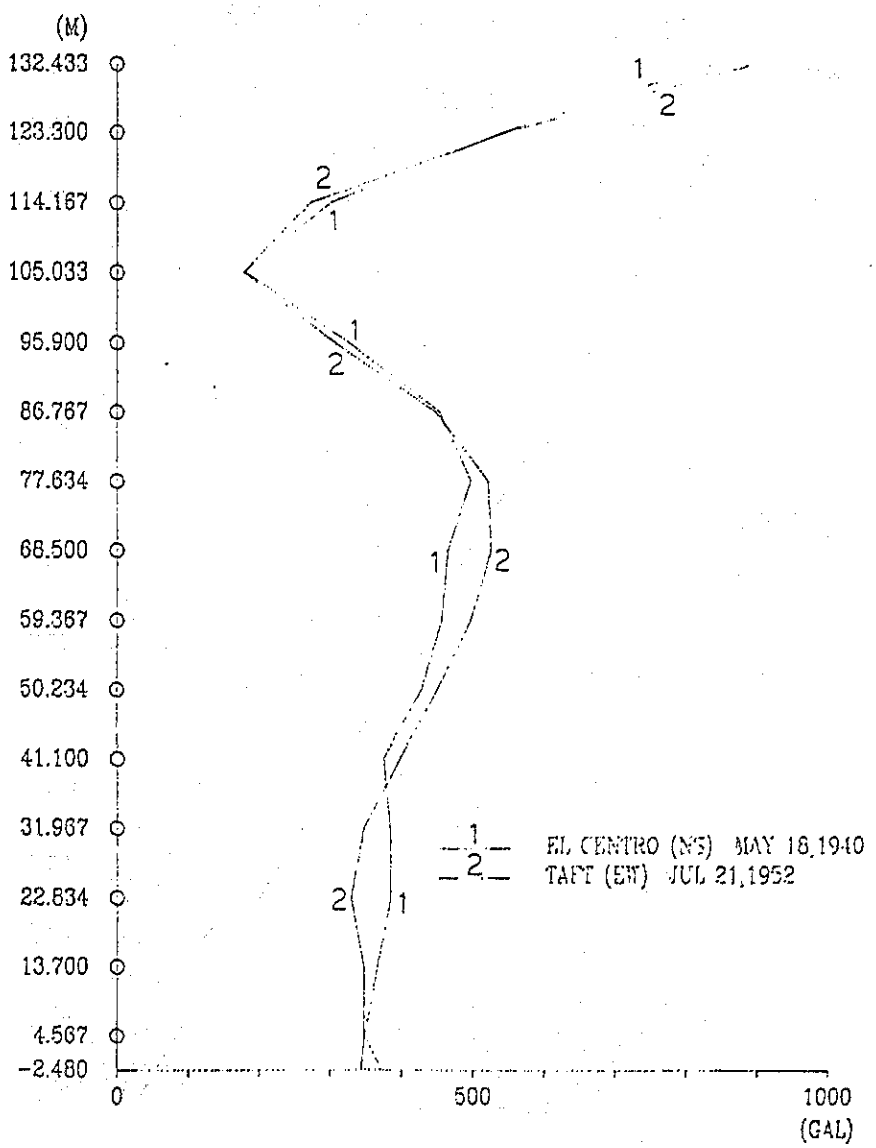
Figure 4-4.2 VIBRATION MODE DIAGRAM 2

タイトル : WEST WHARF RC-STACK



応答最大変位図

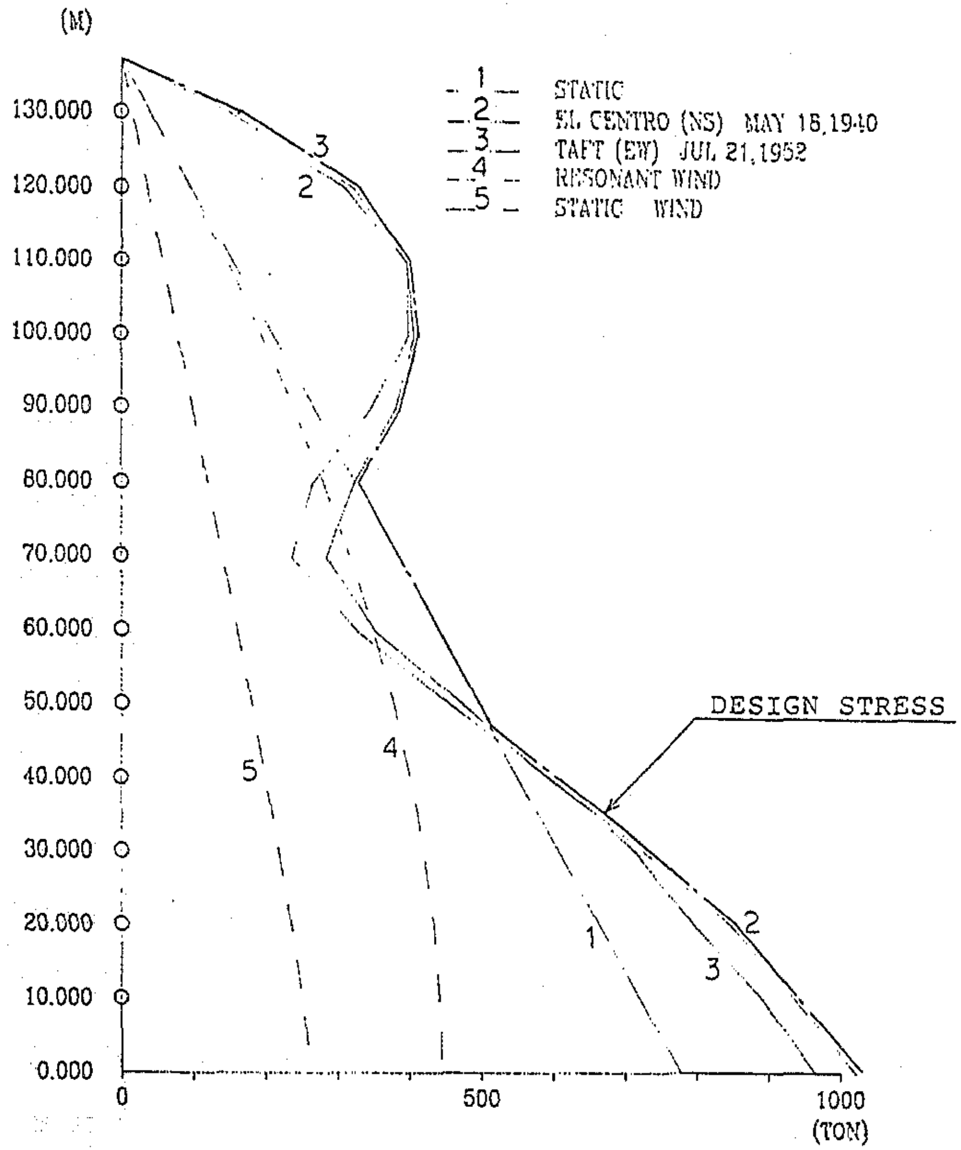
Figure 4-4.3 MAXIMUM DISPLACEMENT RESPONSE



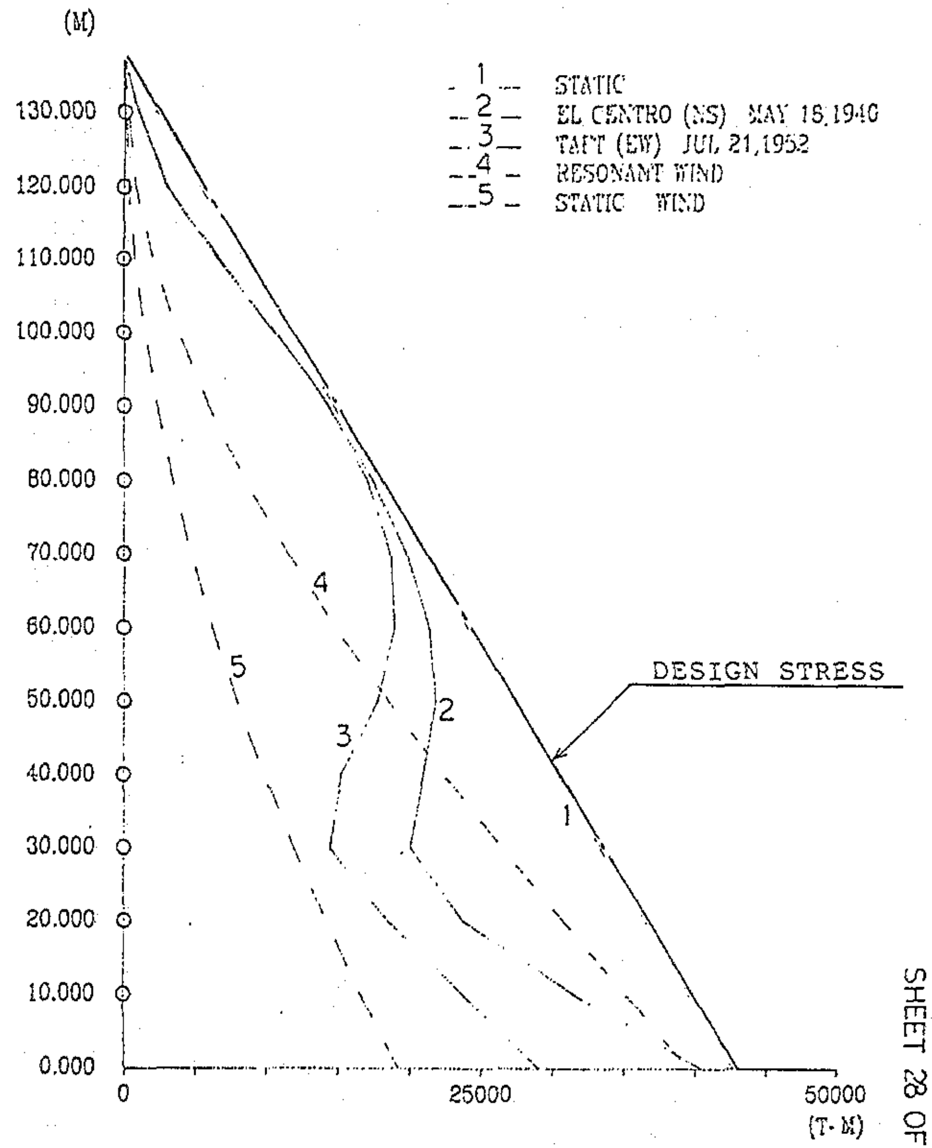
応答最大加速度図

Figure 4-4.4 MAXIMUM ACCELERATION RESPONSE

タイトル : WEST WHARF RC−STACK



せん断力図
Figure 4-4.5 SHEAR FORCE



転倒モーメント図
Figure 4-4.6 BENDING MOMENT

340

4-5 DECISION OF SECTION (1) [断面算定]	Concrete : fc = 180 kg/cm2 Reinforcing bar : ft = 2800 kg/cm2

4-5.1 DECISION OF MAIN REINFORCING BAR [主筋の算定]

Main reinforcing bar is decided from the maximum bending moment and the weight at each level of section. The results of the calculation are shown in the following table.

hi	SECTION DATA				STRESS		CALCULATION				RE-BAR RATIO			AREA	RE-BAR ARRANGEMENT		
	Di	Ti	r	A	W	M	W/A	fc/W/A	ft/W/A	e/r	p1	p2	p3	sA	SIZE-n	@	D/S
m	m	m	m	m2	t	tm	kg/cm2				%	%	%	cm2			
137	10.20	0.25	4.98	7.81	0.0	0.0	0.00	-	-	-	-	-	-	-	-	-	-
130	10.38	0.26	5.06	8.35	135.8	2177.1	1.63	110.7	1722	3.17	0.50	0.50	0.50	418	#5-210	295	D
120	10.63	0.28	5.18	9.14	345.6	5287.3	3.78	47.6	741	2.96	0.50	0.50	0.50	457	#5-230	275	D
110	10.89	0.30	5.30	9.96	574.7	8397.5	5.77	31.2	485	2.76	0.50	0.59	0.50	587	#5-294	225	D
100	11.15	0.32	5.41	10.80	823.8	11507.6	7.63	23.6	367	2.58	0.50	0.72	0.50	778	#6-274	245	D
90	11.40	0.34	5.53	11.67	1093.4	14617.8	9.37	19.2	299	2.42	0.50	0.83	0.50	969	#6-342	200	D
80	11.66	0.35	5.65	12.57	1384.2	17728.0	11.01	16.3	254	2.27	0.50	0.91	0.50	1144	#7-296	240	D
70	11.91	0.37	5.77	13.50	1697.0	20838.1	12.57	14.3	223	2.13	0.50	0.94	0.50	1269	#7-328	220	D
60	12.17	0.39	5.89	14.45	2032.2	23948.3	14.07	12.8	199	2.00	0.50	0.95	0.50	1373	#8-270	270	D
50	12.42	0.41	6.01	15.43	2390.7	27058.5	15.50	11.6	181	1.88	0.50	0.95	0.50	1466	#8-288	260	D
40	12.68	0.43	6.13	16.43	2773.0	30168.6	16.87	10.7	166	1.78	0.50	0.93	0.50	1528	#8-300	255	D
30	12.93	0.45	6.24	17.47	3179.8	33278.8	18.20	9.9	154	1.68	0.50	0.90	0.50	1572	#8-310	250	D
20	13.19	0.46	6.36	18.53	3611.7	36389.0	19.49	9.2	144	1.58	0.50	0.86	0.50	1594	#8-314	250	D
10	13.44	0.48	6.48	19.62	4069.4	39499.1	20.74	8.7	135	1.50	0.50	0.82	0.50	1609	#8-325 #8-316	250 255	D D
0	13.70	0.50	6.60	20.73	4553.6	42609.3	21.96	8.2	127	1.42	0.50	0.76	0.50	1576	#8-331 #8-310	250 265	D D

4-5 DESIGN OF SECTION (2)
[断面算定]

4-5.2 DECISION OF SHEAR REINFORCEMENT

Shear reinforcement is decided from the maximum shear force at each level of section. The results of calculation are shown in the following table.

hi	Ti	A	Q	τ	ps	As	RE-BAR ARRANGEMENT		
m	m	m2	t	kg/cm2	%	cm2	SIZE-n	@	D/T
137	0.25	7.81	0.0	0.00	0.00	-	-	-	-
130	0.26	8.35	332.2	3.98	0.28	7.5	#4-06	200	D
120	0.28	9.14	387.8	4.24	0.30	8.5	#4-07	200	D
110	0.30	9.96	428.8	4.31	0.31	9.2	#4-08	200	D
100	0.32	10.80	411.4	3.81	0.27	8.6	#4-07	200	D
90	0.34	11.67	353.4	3.03	0.22	7.3	#4-06	200	D
80	0.35	12.57	323.5	2.57	0.18	6.5	#4-06	200	D
70	0.37	13.50	380.3	2.82	0.20	7.5	#4-06	200	D
60	0.39	14.45	437.0	3.02	0.22	8.4	#4-07	200	D
50	0.41	15.43	493.8	3.20	0.23	9.3	#4-08	200	D
40	0.43	16.43	618.8	3.77	0.27	11.5	#4-09	200	D
30	0.45	17.47	782.0	4.48	0.32	14.2	#5-08	200	D
20	0.46	18.53	891.4	4.81	0.34	15.9	#5-08	200	D
10	0.48	19.62	975.9	4.97	0.36	17.1	#5-09	200	D
0	0.50	20.73	1059.2	5.11	0.36	18.2	#5-10	200	D

NOTE: τ --- Shear stress ; Q/A
ps --- ratio of shear reinforcement
= 2*τ /ft*100
(ft : Allowable tension stress of shear reinforcement in permanent conditions ; 2,800 kg/cm2)
As --- Required area of shear reinforcement; =ps*T*100
(T: Thickness of wall)
D/T --- D; Double, T; Triple

342

4-5 DECISION OF SECTION (3) [断面算定]

Concrete : fc = 180 kg/cm2
Reinforcing bar : ft = 2800 kg/cm2

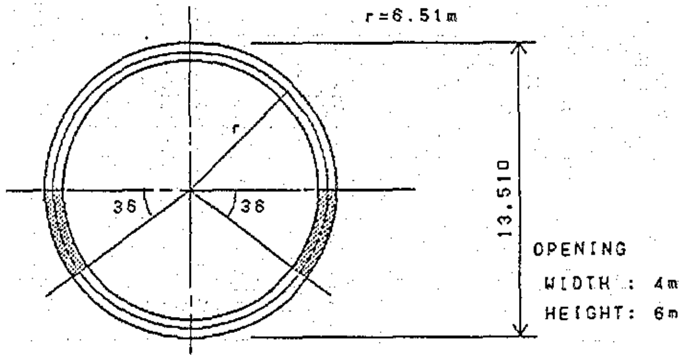
4-5.3 DESIGN OF OPENING [開口部の設計]

The openings are loacated at GL+7.5m (for branch connection of flue duct) and GL+0 (for temporary opening of erection).

(1) Main reinforcing bar at the opening GL+7.5m

There are two openings at this level. The section is shown in the figure on the right side.

The calculation is executed in the four cases according to the direction of the seismic load as follows.



hi	SECTION DATA				STRESS		CALCULATION				RE-BAR RATIO			AREA	RE-BAR ARRANGEMENT	
	Di	Ti	r	A	W	M	W/A	fc/W/A	ft/W/A	e/r	p1	p2	p3	sA	SIZE-n @	D/S
m	m	m	m	m2	t	tm	kg/cm2				%	%	%	cm2		
137	10.20	0.25	4.98	7.81	0.0	0.0	0.00	-	-	-	-	-	-	-	-	-
130	10.38	0.26	5.06	8.35	135.8	2177.1	1.63	110.7	1722	3.17	0.50	0.50	0.50	418	#5-210295	D
120	10.63	0.28	5.18	9.14	345.6	5287.3	3.78	47.6	741	2.96	0.50	0.50	0.50	457	#5-230275	D
110	10.89	0.30	5.30	9.96	574.7	8397.5	5.77	31.2	485	2.76	0.50	0.59	0.50	587	#5-294225	D
100	11.15	0.32	5.41	10.80	823.8	11507.6	7.63	23.6	367	2.58	0.50	0.72	0.50	778	#6-274245	D
90	11.40	0.34	5.53	11.67	1093.4	14617.8	9.37	19.2	299	2.42	0.50	0.83	0.50	969	#6-342200	D
80	11.66	0.35	5.65	12.57	1384.2	17728.0	11.01	16.3	254	2.27	0.50	0.91	0.50	1144	#7-296240	D
70	11.91	0.37	5.77	13.50	1697.0	20838.1	12.57	14.3	223	2.13	0.50	0.94	0.50	1269	#7-328220	D
60	12.17	0.39	5.89	14.45	2032.2	23948.3	14.07	12.8	199	2.00	0.50	0.95	0.50	1373	#8-270270	D
50	12.42	0.41	6.01	15.43	2390.7	27058.5	15.50	11.6	181	1.88	0.50	0.95	0.50	1466	#8-288260	D
40	12.68	0.43	6.13	16.43	2773.0	30168.6	16.87	10.7	166	1.78	0.50	0.93	0.50	1528	#8-300255	D
30	12.93	0.45	6.24	17.47	3179.8	33278.8	18.20	9.9	154	1.68	0.50	0.90	0.50	1572	#8-310250	D
20	13.19	0.46	6.36	18.53	3611.7	36389.0	19.49	9.2	144	1.58	0.50	0.86	0.50	1594	#8-314250	D
10	13.44	0.48	6.48	19.62	4069.4	39499.1	20.74	8.7	135	1.50	0.50	0.82	0.50	1609	#8-325250	D
0	13.70	0.50	6.60	20.73	4553.6	42609.3	21.96	8.2	127	1.42	0.50	0.76	0.50	1576	#8-331250	D
7.5	13.51	0.49	6.51	19.90	4188.0	40276.7	21.05	8.6	133	1.48	0.50	0.81	0.50	1612	#8-318255	D
7.5	13.51	0.49	6.51	15.92	4131.6	40276.7	25.96	6.9	108	1.50	0.50	0.82	0.50	1305	#8-256255	D
											0.50	1.63	0.50	2594	#8-510128	D
											0.50	0.98	0.50	1560	#8-306210	D
											0.50	1.45	0.50	2308	#8-454144	D

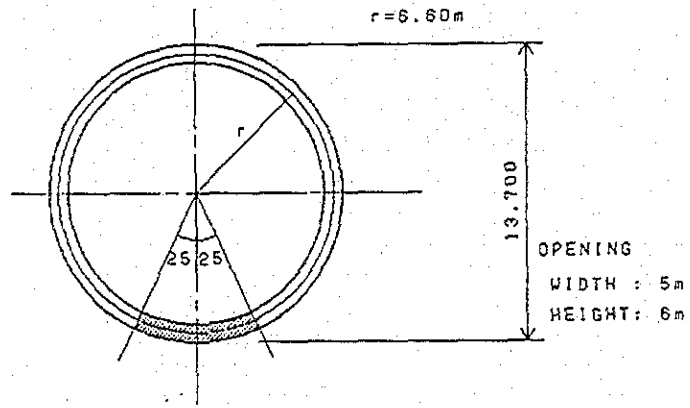
4-5 DECISION OF SECTION (4)
[断面算定]

Concrete : fc = 180 kg/cm2
Reinforcing bar : ft = 2800 kg/cm2

(2) Main reinforcing bar at the opening GL+0m

There is one opening at this level.
The section is shown in the figure on the right side.

The calculation is executed in the two cases according to the direction of the seismic load as follows.



hi	SECTION DATA				STRESS		CALCULATION				RE-BAR RATIO			AREA	RE-BAR ARRANGEMENT	
	Di	Ti	r	A	W	M	W/A	fc / W/A	ft / W/A	e/r	p1	p2	p3	sA	SIZE-n @	D/S
m	m	m	m	m2	t	tm	kg/cm2				%	%	%	cm2		
137	10.20	0.25	4.98	7.81	0.0	0.0	0.00	-	-	-	-	-	-	-	- -	-
130	10.38	0.26	5.06	8.35	135.8	2177.1	1.63	110.7	1722	3.17	0.50	0.50	0.50	418	#5-210295	D
120	10.63	0.28	5.18	9.14	345.6	5287.3	3.78	47.6	741	2.96	0.50	0.50	0.50	457	#5-230275	D
110	10.89	0.30	5.30	9.96	574.7	8397.5	5.77	31.2	485	2.76	0.50	0.59	0.50	587	#5-294225	D
100	11.15	0.32	5.41	10.80	823.8	11507.6	7.63	23.6	367	2.58	0.50	0.72	0.50	778	#6-274245	D
90	11.40	0.34	5.53	11.67	1093.4	14617.8	9.37	19.2	299	2.42	0.50	0.83	0.50	969	#6-342200	D
80	11.66	0.35	5.65	12.57	1384.2	17728.0	11.01	16.3	254	2.27	0.50	0.91	0.50	1144	#7-296240	D
70	11.91	0.37	5.77	13.50	1697.0	20838.1	12.57	14.3	223	2.13	0.50	0.94	0.50	1269	#7-328220	D
60	12.17	0.39	5.89	14.45	2032.2	23948.3	14.07	12.8	199	2.00	0.50	0.95	0.50	1373	#8-270270	D
50	12.42	0.41	6.01	15.43	2390.7	27058.5	15.50	11.6	181	1.88	0.50	0.95	0.50	1466	#8-288260	D
40	12.68	0.43	6.13	16.43	2773.0	30168.6	16.87	10.7	166	1.78	0.50	0.93	0.50	1528	#8-300255	D
30	12.93	0.45	6.24	17.47	3179.8	33278.8	18.20	9.9	154	1.68	0.50	0.90	0.50	1572	#8-310250	D
20	13.19	0.46	6.36	18.53	3611.7	36389.0	19.49	9.2	144	1.58	0.50	0.86	0.50	1594	#8-314250	D
10	13.44	0.48	6.48	19.62	4069.4	39499.1	20.74	8.7	135	1.50	0.50	0.82	0.50	1609	#8-325250	D
0	13.70	0.50	6.60	20.73	4553.6	42609.3	21.96	8.2	127	1.42	0.50	0.76	0.50	1576	#8-331250	D
0	13.70	0.50	6.60	17.83	4461.3	42609.3	25.02	7.2	112	1.45	0.50	1.24	0.50	2211	#8-434168	D
											0.50	1.30	0.50	2318	#8-456160	D

344

4-5 DESIGN OF SECTION (5)
[断面算定]

(3) DECISION OF ADDITIONAL REINFORCEMENT AROUND OPENING

Additional reinforcement around opening at each direction is calculated from tension force which is calculated by the following equations based on the shear force.

a. Vertical direction

Tv=(h*t/2)*τ (ton)

b. Horizontal direction

Th=(L*t/2)*τ (ton)

c. Diagonal direction

Td=d*t*τ (ton)

where, h : Height of opening (m)
L : Width of opening (m)
d : (h+L)/2 2 (m)
t : Thickness of wall (m)
τ : Shear stress =Q/A (t/m2)
Q : Shear force (ton)
A : Section area (m2)

The area of additional vertical and horizontal reinforcing bars with decrease of the area of the original bars can be counted for the diagonal tension. But the area is multiplied by 1/ 2.

The calculation is shown in the following table.

- Opening at the level of GL+7.5m

ft= 2.8 t/cm2

h= 6.0	L= 4.0	t= 0.49	Q= 996.7		A= 19.9
	Calculation a, b, c	Req. area at (cm2)	Arrangement Size	n	(at-ao)*1/ 2 (cm2)
Tv	(ht/2)*(Q/A): 74	26.3	#8	6	av'= 14.42
Th	(Lt/2)*(Q/A): 49	17.5	#8	4	ah'= 11.59
Td	d*t*(Q/A) : 177				-
	(av'+ah')*ft: 73	37.2	#8	8	-

- Opening at the level of GL+0m

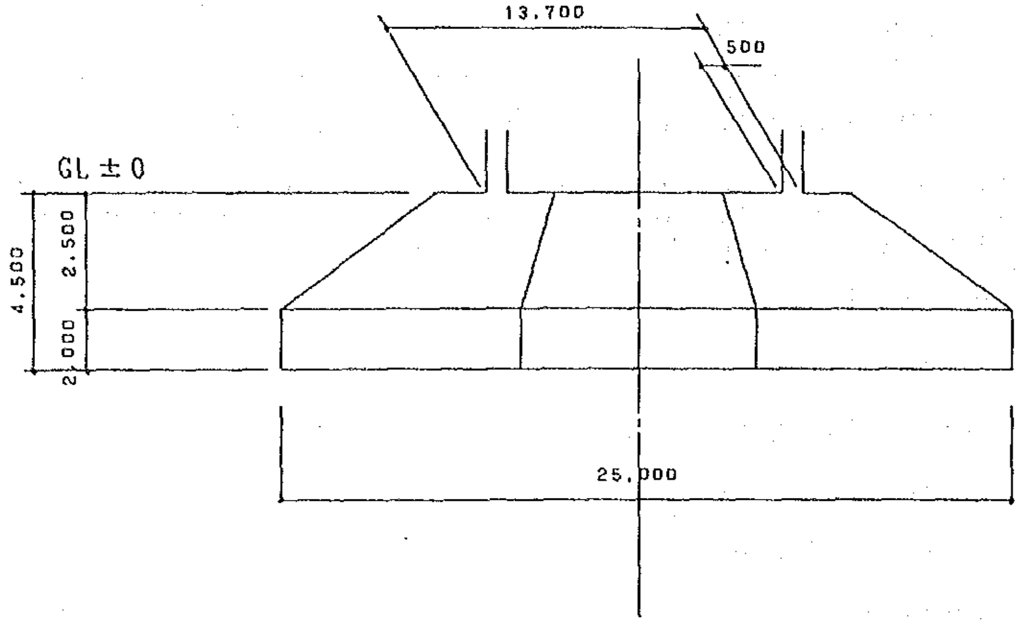
ft= 2.8 t/cm2

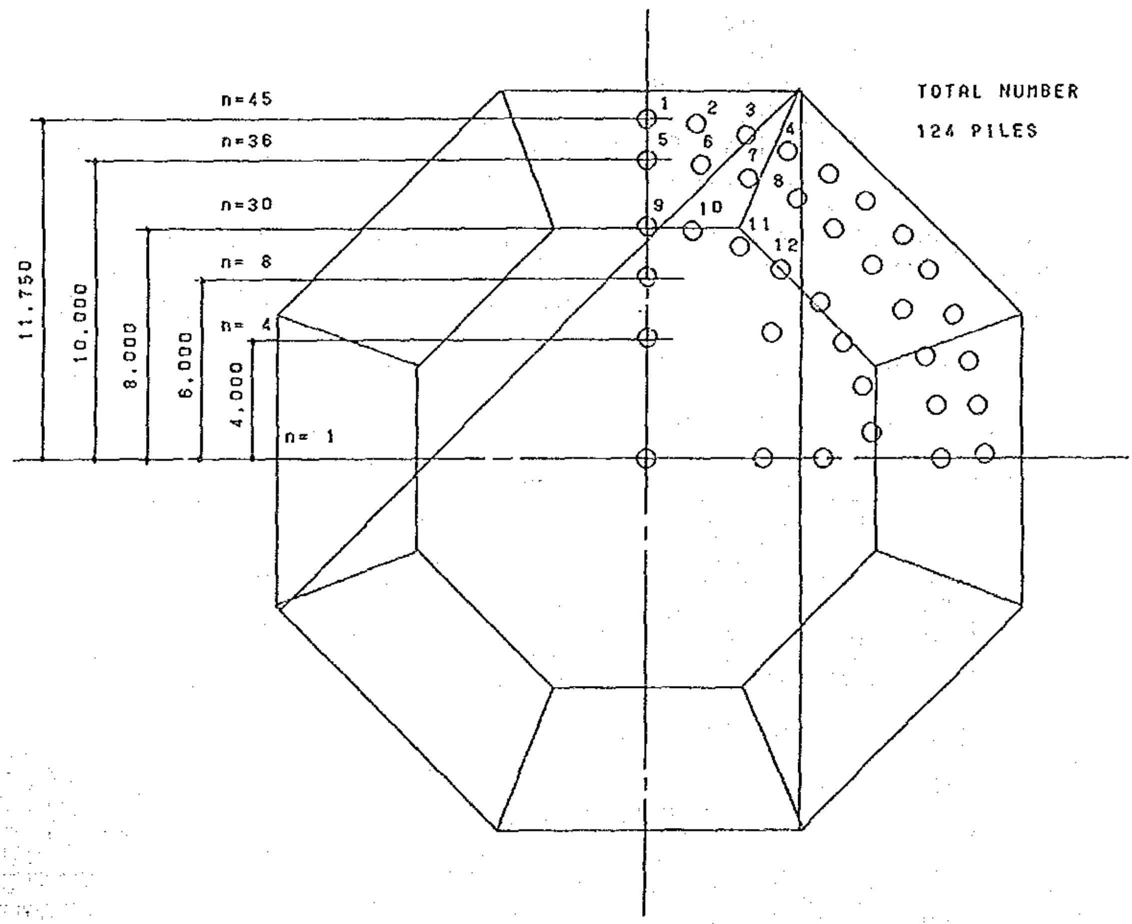
h= 6.0	L= 5.0	t= 0.50	Q= 1059		A= 20.7
	Calculation a, b, c	Req. area at (cm2)	Arrangement Size	n	(at-ao)*1/ 2 (cm2)
Tv	(ht/2)*(Q/A): 77	27.4	#8	6	av'= 14.42
Th	(Lt/2)*(Q/A): 64	22.8	#8	5	ah'= 15.20
Td	d*t*(Q/A) : 199				-
	(av'+ah')*ft: 83	41.3	#8	8	-

365

5. DESIGN OF SUBSTRUCTURE

5-1 FIGURE OF FOUNDATION





5. DESIGN OF SUBSTRUCTURE (2)
[基礎の設計]

5-2 DESIGN LOAD FOR SUBSTRUCTURE [基礎の設計用荷重]

(1) Dead load (Permanent conditions)

Superstructure	Ws =	4,560	ton	
Inner flue	Wi =	630	ton	
Foundation	Wf =	4,430	ton	
Soil	Wc =	880	ton	
Total	W =	10,500	ton	

(2) Overturning moment (Temporary conditions)

Superstructure	Mo =	42,609.3	tm	
Superstructure	Mq =	4,766.4	tm	(Q*h=1059.2*4.5)
Foundation	Mf =	443.0	tm	(=kWf*h=0.05*4430*2)
Total	M =	47,818.7	tm	

(3) Shear force (Temporary conditions)

Superstructure	Qs =	1,059.2	ton	
Foundation	Qf =	221.5	ton	(=kWf=0.05*4430)
Total	Q =	1,280.7	ton	

5-3 DESIGN OF PILE [杭の設計]

(1) Pile data

Material	:	Steel pipe pile ϕ 609.6x9
Length	:	20 m
Bearing capacity	:	120 ton (Permanent conditions)
		240 ton, -15 ton (Temporary conditions)
Number of pile	:	124
Zp	:	514.2

(1) Permanent conditions

V = W/n = 10,500/124 = 84.7 < 120 ton OK

(2) Temporary conditions

a. Vertical load

V = W/n + M/Z = 10,500/124 + 47,818.7/514.2
= 84.7 + 93.0 = 177.7 < 240 ton OK
V = W/n - M/Z = 10,500/124 - 47,818.7/514.2
= 84.7 - 93.0 = - 8.3 > -15 ton OK

b. Vertical load + Shear force

σc = V/A = 177.7/131.6 = 1.35 t/cm2
σb = M/Z = 1241.6/1940 = 0.64 t/cm2
β = khB/EI = 0.004148 cm-1 (Refer to 4-2.1)
M = Q/(2*β) = 10.3/(2*0.004148) = 1,241.6 tcm
$\Sigma \sigma$ = 1.35 + 0.64 = 1.99 t/cm2 < 2.05 t/cm2 OK

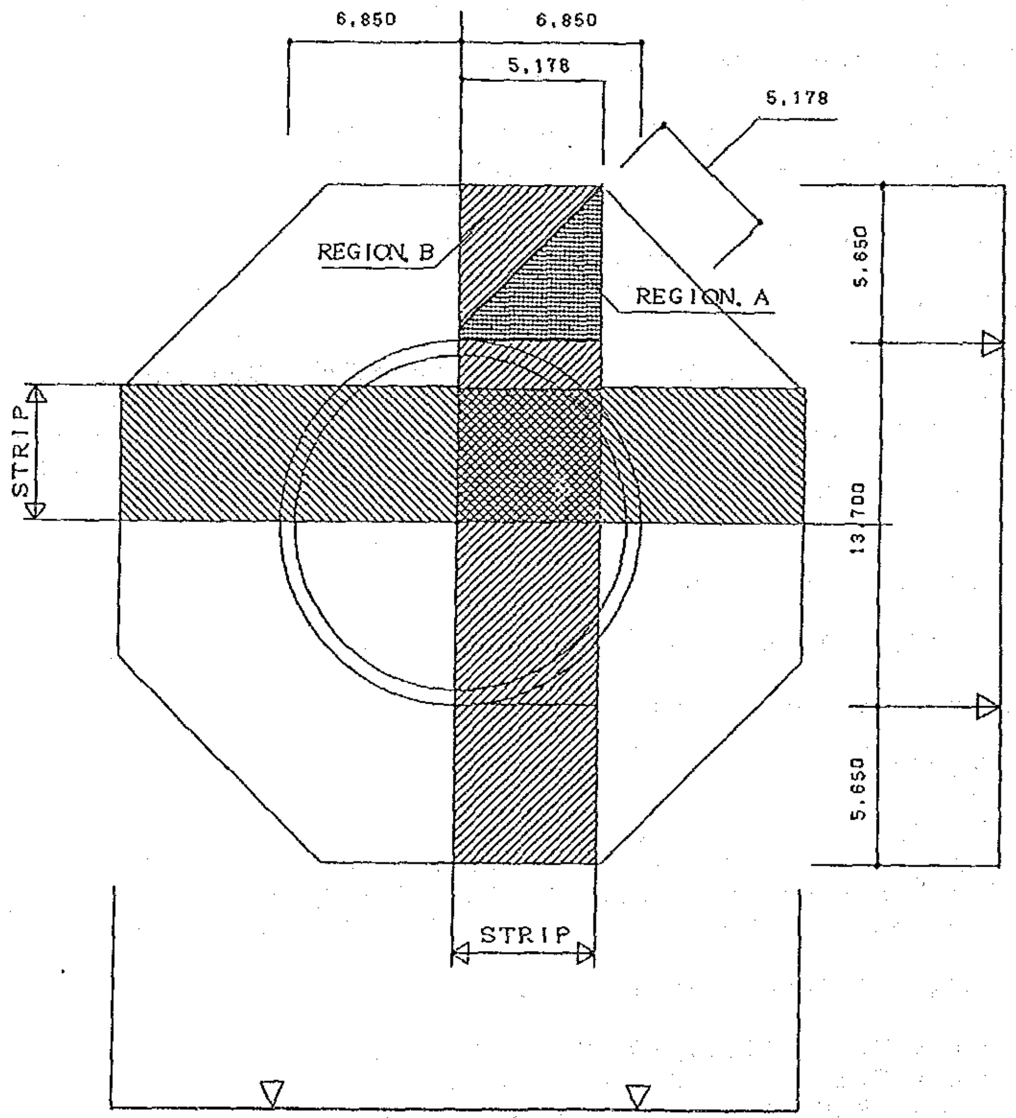
347

5. DESIGN OF SUBSTRUCTURE (3)
[基礎の設計]

5-4 DESIGN OF FOUNDATION [基礎体の設計]

(1) General

The foundation is divided into the following strip in each direction for the structural calculations. The design moment and shear force is computed as the simple beam subjected to the pile reaction. The foundation is divided into two regions, region A and B, for design purposes. The reduction factor (R=0.5) of moment and shear force is considered in the region A because it is assumed that the part is in two way slab.



5. DESIGN OF SUBSTRUCTURE (4)
[基礎の設計]

(2) Table of pile reaction

The pile raction is calculated for the foundation design and the results are shown in the following table. The figure in 5-1 OUTLINE OF FOUNDATION is refered for the pile number.

NO. OF PILE	LOCATION FROM CENTER (m)	Zp	REACTION	
			PERMANENT (ton)	EARTHQUAKE (ton)
1	11.75	514.25	84.70	92.99
2	11.64	519.11	84.70	92.12
3	11.29	535.20	84.70	89.35
4	10.73	563.13	84.70	84.92
5	10.00	604.24	84.70	79.14
6	9.85	613.44	84.70	77.95
7	9.40	642.81	84.70	74.39
8	8.66	697.74	84.70	68.53
9	8.00	755.30	84.70	63.31
10	7.83	771.70	84.70	61.97
11	7.31	826.59	84.70	57.85

(3) Calculation of bending moment and shear force

From the data of the above table bending moment and shear force of foundation are calculated as follow.

	PERMANENT		TEMPORARY	
	SHEAR FORCE (t)	MOMENT (tm)	SHEAR FORCE (t)	MOMENT (tm)
1	84.70	415.03	177.69	870.67
2	84.70	405.71	176.82	846.95
3	84.70	376.07	174.05	772.77
4	42.35	164.32	84.81	329.05
5	84.70	266.81	163.84	516.09
6	84.70	254.10	162.65	487.95
7	42.35	107.99	79.55	202.84
8	42.35	76.65	76.62	138.68
9	84.70	97.41	148.01	170.21
10	42.35	41.50	73.33	71.87
11	84.70	38.96	142.55	65.57
TOTAL	584.10	1,684.35	1,281.71	3,912.47

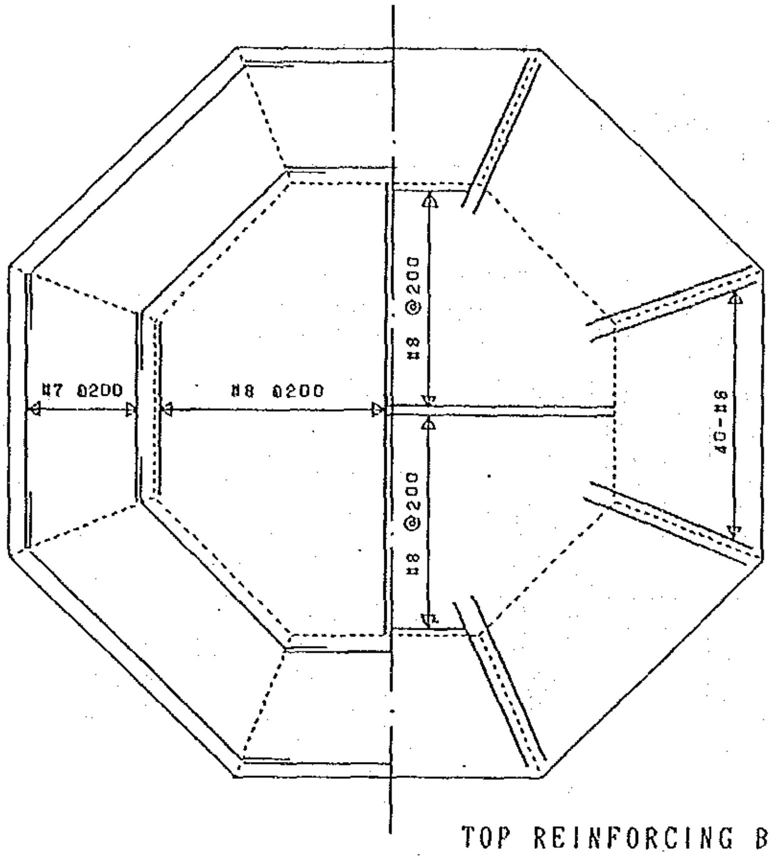
NOTE: $Q = \Sigma pRi - Qo$ (Qo = 178.20 ton)
$M = \Sigma pRi*Li - Mo$ (Mo = 560.20 tm)
Qo : Shear force by the weight of foundation
Mo : Bending moment by the weight of foundation

(4) Check of section

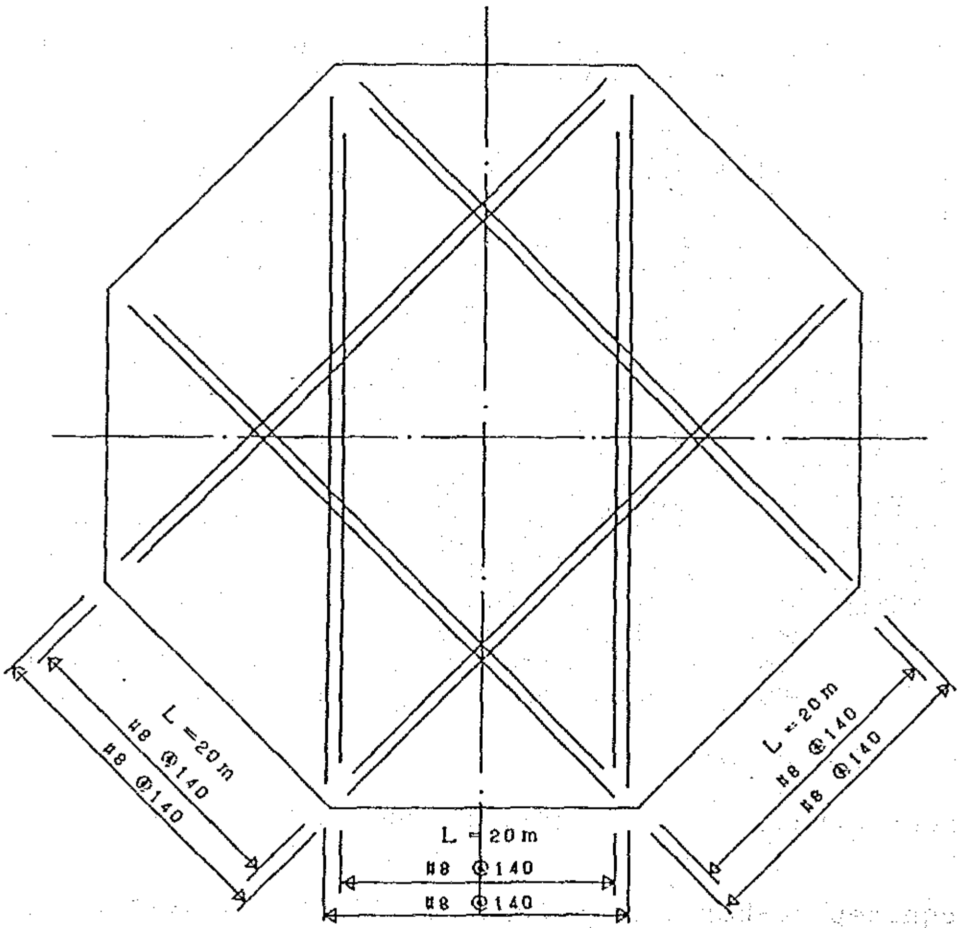
a. Shear stress : τs = 1281.71*1000/(517.8*435*(7/8))
= 6.50 t/cm2 < 11.55 t/cm2 OK

b. Required re-bar : at = 3912.47*100000/(2800*435*(7/8)*5.178)
= 70.90 cm2/m #8-14/m (#8@140 double)

(5) Arrangement of reinforcing bar



TOP REINFORCING BAR ARRANGEMENT



BOTTOM REINFORCING BAR ARRANGEMENT

III. APPENDIX

1. Dynamic Analysis Equations

(1) Slope-deflection method

The slope-deflection method is a method by which slope-① deflection equations are used.

Eq.(1) in Chapter 4.3 of "Dynamic Analysis" is obtained by the following steps.

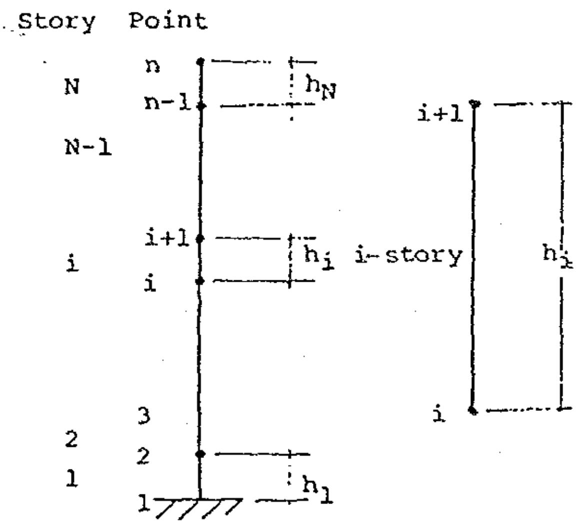


Fig.1

② The deflection energy of the elastic beam is:

$$U = U_N + U_M + U_S + U_T \quad \cdots\cdot (A)$$

where;

U : total energy due to total deflection

U_N : energy due to axial force

U_M : energy due to bending moment

U_S : energy due to shear force

U_T : energy due to torsion

We disregarded the U_N, U_S and U_T due to its having small potentials as compared with U_M(deflection component) in slender type beams such as those in the stack shaft. That is, U_M is by far the greater of the energy.

See APPENDEX - A

① P.1-67, 38. Slope-deflection Equation

② P.1-31, 19. General Form of Solution

The deflection energy (due to bending moments) can be obtained by applying Eq.(B).

$$U = U_M = \int_0^{h_i} \frac{M^2}{2EI}\,dx \quad \cdots\cdots\cdots \quad (B)$$

where;

EI : bending stiffness

M : bending moment

By applying Castigliano's theorum③ to loads M_i and M_{i+1}, Eq.(C) becomes as follows:

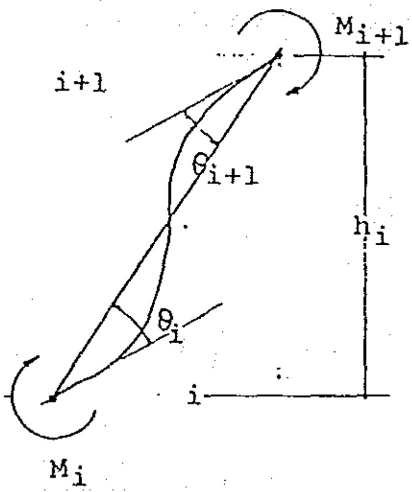


Fig.2

$$\left.\begin{aligned} \theta_i &= \frac{\partial U}{\partial M_i} = \int_0^{h_i} \frac{M(\partial M/\partial M_i)}{EI}\,dx \\ \theta_{i+1} &= \frac{\partial U}{\partial M_{i+1}} = \int_0^{h_i} \frac{M(\partial M/\partial M_{i+1})}{EI}\,dx \end{aligned}\right\} \cdots\cdots (C)$$

θ_i, θ_{i+1}: rotation of joints i and i+1

M_i, M_{i+1}: end moments in i and i+1

M, $\frac{\partial M}{\partial M_i}$ and $\frac{\partial M}{\partial M_{i+1}}$ is obtained by the following steps.

See APPENDEX - A

③ P.1-42, 27. The complimentary-energy method and Castigliano's theorum.

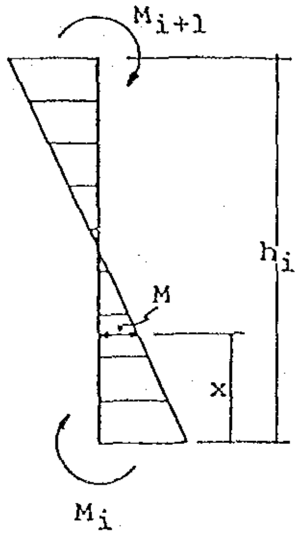


Fig.3

Fig.3 shows Bending moment distribution by bending moments M_i and M_{i+1}.
M represents the bending moment at point x, and is as follows.

$$M = M_i\left(\frac{h_i-x}{h_i}\right) - M_{i+1}\frac{x}{h_i} \cdots\cdots \quad (D)$$

Furthermore, $\frac{\partial M}{\partial M_i}$ and $\frac{\partial M}{\partial M_{i+1}}$ are obtained from Eq. (D).

$$\left.\begin{aligned} \frac{\partial M}{\partial M_i} &= \frac{h_i-x}{h_i} \\ \frac{\partial M}{\partial M_{i+1}} &= -\frac{x}{h_i} \end{aligned}\right\} \cdots\cdots \quad (E)$$

Also, by applying Eq. (D) and Eq. (E) to Eq. (C).
θ_i and θ_{i+1} can be obtained.

$$\theta_i = \int_0^{h_i} \frac{1}{EI}\left\{M_i\left(\frac{h_i-x}{h_i}\right) - M_{i+1}\frac{x}{h_i}\right\}\cdot\frac{h_i-x}{h_i}\cdot dx$$

$$= M_i\int_0^{h_i}\frac{1}{EI}\left(\frac{h_i-x}{h_i}\right)^2\cdot dx - M_{i+1}\int_0^{h_i}\frac{1}{EI}\left(\frac{x}{h_i}\right)\left(\frac{h_i-x}{h_i}\right)\cdot dx$$

$$\theta_{i+1} = \int_0^{h_i}\frac{1}{EI}\left\{M_i\left(\frac{h_i-x}{h_i}\right) - M_{i+1}\left(\frac{x}{h_i}\right)\right\}\cdot\left(-\frac{x}{h_i}\right)\cdot dx$$

$$= -M_i\int_0^{h_i}\frac{1}{EI}\left(\frac{h_i-x}{h_i}\right)\left(\frac{x}{h_i}\right)dx + M_{i+1}\int_0^{h_i}\frac{1}{EI}\left(\frac{x}{h_i}\right)^2 dx$$

Consequently,

$$\left.\begin{aligned} \theta_i &= \alpha_i \cdot M_i - \beta \cdot M_{i+1} \\ \theta_{i+i} &= -\beta \cdot M_i + \alpha_{i+1} M_{i+1} \end{aligned}\right\} \quad \cdots\cdots \text{(F)}$$

where;

$$\alpha_i = \int_0^{h_i} \frac{1}{EI}\left(\frac{h_i - x}{h_i}\right)^2 dx$$

$$\beta = \int_0^{h_i} \frac{1}{EI}\left(\frac{x}{h_i}\right)\left(\frac{h_i - x}{h_i}\right) dx$$

$$\alpha_{i+1} = \int_0^{h_i} \frac{1}{EI}\left(\frac{x}{h_i}\right)^2 dx$$

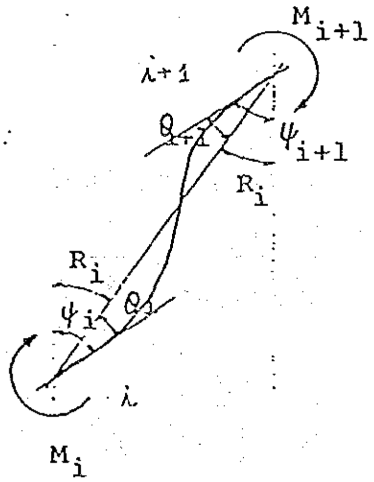


Fig.4

Taking into account the relative joint displacement of joint "i" and "i+1", the rotation of member "i~i+1" is obtained.

$$\left.\begin{aligned} \theta_i &= \psi_i - R_i \\ \theta_{i+1} &= \psi_{i+1} - R_i \end{aligned}\right\} \quad \cdots\cdots \text{(G)}$$

The bending moments M_i and M_{i+1} are obtained by applying Eq.(F) and Eq.(G).

$$\left.\begin{aligned} M_{\bar{i}} &= \frac{1}{\alpha_i \alpha_{i+1} - \beta^2}\left\{\alpha_{i+1}(\psi_i - R_i) + \beta(\psi_{i+1} - R_i)\right\} \\ M_{i+1} &= \frac{1}{\alpha_i \alpha_{i+1} - \beta^2}\left\{\alpha_i(\psi_{i+1} - R_i) + \beta(\psi_i - R_i)\right\} \end{aligned}\right\} \quad \cdots\cdots \text{(H)}$$

Consequently, Eq.(H) becomes as follows.

$$\left.\begin{aligned} M_{i,\ i+1} &= K_i(\ a_{i,\ i+1}\cdot\psi_i + b_i\cdot\psi_{i+1} + C_{i,\ i+1}\cdot R_i) \\ M_{i+1,i} &= K_i(\ b_i\cdot\psi_i + a_{i+1,i}\cdot\psi_{i+1} + C_{i+1,i}\cdot R_i) \end{aligned}\right\} \quad \ldots\ldots(1)$$

where;

$$M_{i,i+1} = M_i$$

$$M_{i+1,i} = M_{i+1}$$

$$K_i = \frac{2EI_i}{h_i}$$

EI_i ; bending stiffness

$$a_{i,i+1} = \frac{h_i}{2EI_i}\cdot\frac{\alpha_{i+1}}{\alpha_i\alpha_{i+1}-\beta^2}$$

$$a_{i+1,i} = \frac{h_i}{2EI_i}\cdot\frac{\alpha_i}{\alpha_i\alpha_{i+1}-\beta^2}$$

$$b_i = \frac{h_i}{2EI_i}\cdot\frac{\beta}{\alpha_i\alpha_{i+1}-\beta^2}$$

$$C_{i,\ i+1} = -\left(a_{i,i+1} + b_i\right)$$

$$C_{i+1,i} = -\left(a_{i+1,i} + b_i\right)$$

EXAMPLE:

In the case of a simple supported beam and EI_i = const.

$$\alpha_i = \frac{1}{EI_i} \int_0^{h_i} \left(\frac{h_i - x}{h_i}\right)^2 dx = \frac{h_i}{3EI_i}$$

$$\beta = \frac{1}{EI_i} \int_0^{h_i} \left(\frac{x}{h_i}\right)\left(\frac{h_i - x}{h_i}\right) dx = \frac{h_i}{6EI_i}$$

$$\alpha_{i+1} = \frac{1}{EI_i} \int_0^{h_i} \left(\frac{x}{h_i}\right)^2 dx = \frac{h_i}{3EI_i}$$

$$\alpha_i \, \alpha_{i+1} - \beta^2 = \frac{1}{12}\left(\frac{h_i}{EI_i}\right)^2$$

$$a_{i,i+1} = \frac{h_i}{2EI_i} \cdot \frac{\frac{h_i}{3EI_i}}{\frac{1}{12}\left(\frac{h_i}{EI_i}\right)^2} = 2$$

$$a_{i+1,i} = \frac{h_i}{2EI_i} \cdot \frac{\frac{h_i}{3EI_i}}{\frac{1}{12}\left(\frac{h_i}{EI_i}\right)^2} = 2$$

$$b_i = \frac{h_i}{2EI_i} \cdot \frac{\frac{h_i}{6EI_i}}{\frac{1}{12}\left(\frac{h_i}{EI_i}\right)^2} = 1$$

$$c_{i,i+1} = -(2+1) = -3$$

$$c_{i+1,i} = -(2+1) = -3$$

$$\left.\begin{aligned} M_{i,i+1} &= \frac{2EI_i}{h_i}\left(2\psi_i + \psi_{i+1} - 3R_i\right) \\ M_{i+1,i} &= \frac{2EI_i}{h_i}\left(\psi_i + 2\psi_{i+1} - 3R_i\right) \end{aligned}\right\} \cdots\cdots\cdots (I)$$

Eq.(I) represents the slope-deflection equation without considering the load between i and i+1.

(2) Three-moment equation

The three-moment equation is based upon the equilibrium of bending moment and shear force.

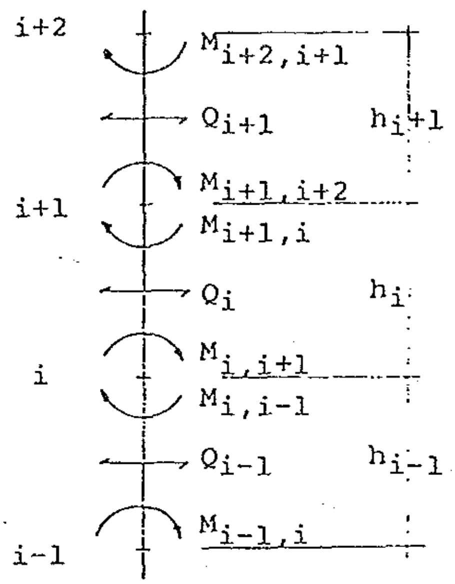


Fig.5

Bending moment equilibriums at point i and i+1 are as follows.

$$M_{i,i-1} + M_{i,i+1} = 0 \quad \cdots\cdots (J-1)$$

$$M_{i+1,i} + M_{i+1,i+2} = 0 \quad \cdots\cdots (J-2)$$

Shear force equilibriums at point i and i+1 are as follows.

$$M_{i-1,i} + M_{i,i-1} = Q_{i-1} \cdot h_{i-1} \quad \cdots\cdots (J-3)$$

$$M_{i,i+1} + M_{i+1,i} = Q_i \cdot h_i \quad \cdots\cdots (J-4)$$

$$M_{i+i,i+2} + M_{i+2,i+1} = Q_{i+1} \cdot h_{i+1} \quad \cdots (J-5)$$

Also, slope-deflection equations for each span of beam are as follows.

$$M_{i-1,i} = K_{i-1}(a_{i-1,i} \psi_{i-1} + b_{i-1} \psi_i + C_{i-1,i} R_{i-1}) \cdots\cdots (K-1)$$

$$M_{i,i-1} = K_{i-1}(b_{i-1} \psi_{i-1} + a_{i,i-1} \psi_i + C_{i,i-1} R_{i-1}) \cdots\cdots (K-2)$$

$$M_{i,i+1} = K_i(a_{i,i+1} \psi_i + b_i \psi_{i+1} + C_{i,i+1} R_i) \cdots\cdots (K-3)$$

$$M_{i+1,i} = K_i(b_i \psi_i + a_{i+1,i} \psi_{i+1} + C_{i+1,i} R_i) \cdots\cdots (K-4)$$

$$M_{i+1,i+2} = K_{i+1}(a_{i+1,i+2} \psi_{i+1} + b_{i+1} \psi_{i+2} + C_{i+1,i+2} R_{i+1}) \cdots\cdots (K-5)$$

$$M_{i+2,i+1} = K_{i+1}(b_{i+1} \psi_{i+1} + a_{i+2,i+1} \psi_{i+2} + C_{i+2,i+1} R_{i+1}) \quad (K-6)$$

The three-moment equation (Eq.(2)) can be obtained by applying Eq.(K-1) ~ Eq.(K-6) to Eq.(J-1) ~ Eq.(J-5), and by reducing the rotation of joints ($\psi_{i-1}, \psi_i, \psi_{i+1}$).

$$A_{i+1} \cdot R_{i+1} + B_i \cdot R_i + C_{i-1} R_{i-1} = D_{i+1} Q_{i+1} + E_i \cdot Q_i + F_{i-1} \cdot Q_{i-1} \qquad \cdots\cdots\cdots (2)$$

where;

R_{i+1}, R_i, R_{i-1} : rotation of i+1, i and i-1 story, respectively

Q_{i+1}, Q_i, Q_{i-1} : shear force of i+1, i and i-1 story, respectively

A_{i+1}, B_i, C_{i-1}, D_{i+1}, E_i, F_{i-1} : coefficients of three-moment equation

359 3-46

(3) Vibration equation

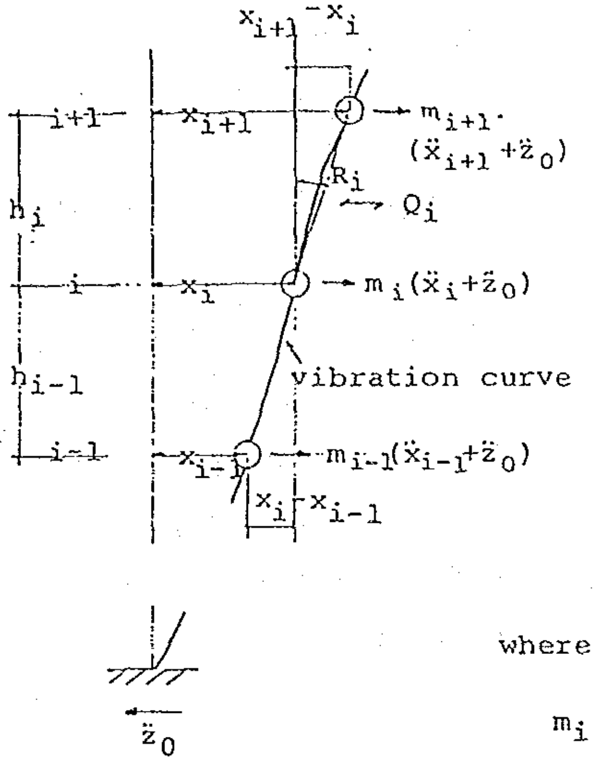


Fig.6

Fig.6 shows equilibrium based upon the vibration curve in the case of a lumped mass vibration model.

Shear force Q_i and rotation R_i of i-story are as follows.

$$Q_i = -\sum_{j=i+1}^{n} m_j(\ddot{x}_j + \ddot{z}_0) \quad ; \qquad \cdots\cdots (3)$$

$$R_i = \frac{x_{i+1} - x_i}{h_i}$$

where;

m_i : mass at i point

$\ddot{z}_0$: ground acceleration

x_i : displacement at i-point

h_i : height of i-story

Substituting Eq.(3) into Eq.(2).

n-story, i-story and 1-story, respectively.

$$B_N \frac{x_{N+1}-x_N}{h_N} + C_{N-1}\frac{x_N - x_{N-1}}{h_{N-1}} = -E_N\sum_{j=N+1}^{N+1} m_j(\ddot{x}_j+\ddot{z}_0) - F_{N-1}\sum_{j=N}^{N-1} m_j(\ddot{x}_j+\ddot{z}_0) \qquad \cdots\cdots \text{(L-1)}$$

$$A_{i+1}\frac{x_{i+2}-x_{i+1}}{h_{i+1}} + B_i\frac{x_{i+1}-x_i}{h_i} + C_{i-1}\frac{x_i - x_{i-1}}{h_{i-1}} = -D_{i+1}\sum_{j=i+2}^{N+1} m_j(\ddot{x}_j+\ddot{z}_0)$$

$$- E_i\sum_{j=i+1}^{N+1} m_j(\ddot{x}_j+\ddot{z}_0) - F_{i-1}\sum_{j=i}^{N+1} m_j(\ddot{x}_j+\ddot{z}_0) \qquad \cdots\cdots \text{(L-2)}$$

$$A_2\frac{x_3-x_2}{h_2} + B_1\frac{x_2-x_1}{h_1} = -D_2\sum_{j=3}^{N+1} m_j(\ddot{x}_j+\ddot{z}_0) - E_1\sum_{j=2}^{N+1} m_j(\ddot{x}_j+\ddot{z}_0) \qquad \cdots\cdots \text{(L-3)}$$

Consequently, equations (L-1), (L-2), and (L-3) are as follows.

$$(E_N + F_{N-1}) m_{N+1} \ddot{X}_{N+1} + F_{N-1} m_N \ddot{X}_N + \frac{B_N}{h_N} X_{N+1} + \left(\frac{C_{N-1}}{h_{N-1}} - \frac{B_N}{h_N} \right) X_N - \frac{C_{N-1}}{h_{N-1}} X_{N-1} = 0 \quad \cdots\cdots (L\text{-}1)'$$

$$(D_{i+1}+E_i+F_{i-1}) m_{N+1} \ddot{X}_{N+1} + (D_{i+1}+E_i+F_{i-1}) m_N \ddot{X}_N + \cdots\cdots$$

$$\cdots\cdots + (D_{i+1}+E_i+F_{i-1}) m_{i+2} \ddot{X}_{i+2} + (E_i+F_{i-1}) m_{i+1} \ddot{X}_{i+1} + F_{i-1} m_i \ddot{X}_i$$

$$+ \frac{A_{i+1}}{h_{i+1}} X_{i+2} + \left(\frac{B_i}{h_i} - \frac{A_{i+1}}{h_{i+1}} \right) X_{i+1} + \left(\frac{C_{i-1}}{h_{i-1}} - \frac{B_i}{h_i} \right) X_i - C_{i-1} \frac{X_{i-1}}{h_{i-1}} = 0 \quad \cdots (L\text{-}2)'$$

$$(D_2+E_1) m_{N+1} \ddot{X}_{N+1} + (D_2+E_1) m_N \ddot{X}_N + \cdots\cdots + (D_2+E_1) m_3 \ddot{X}_3 + E_1 m_2 \ddot{X}_2$$

$$+ \frac{A_2}{h_2} X_3 + \left(\frac{B_1}{h_1} - \frac{A_2}{h_2} \right) X_2 = 0 \quad \cdots\cdots\cdots (L\text{-}3)'$$

where; $\ddot{X}_j = \ddot{x}_j + \ddot{z}_0$

$X_j = x_j$

Matrix indication of equations (L-1)', and (L-2)' and (L-3)' are as follows.

$$[G]\{m\ddot{X}\} + [H]\{X\} = 0 \quad \cdots\cdots\cdots (M)$$

where;

[G] ; Coefficients matrix of $\{m\ddot{X}\}$ vector

[H] ; Coefficients matrix of $\{X\}$ vector

$\{m\ddot{X}\}$; vector$\left(=\{m_{N+1}\ddot{X}_{N+1}, m_N\ddot{X}_N, \ldots, m_i\ddot{X}_i, \ldots, m_1\ddot{X}_1\}^T\right)$

$\{X\}$; vector$\left(=\{X_{N+1}, X_N, \ldots, X_i, \ldots, X_1\}^T\right)$

Also, Eq. (M) is as follows.

$$[M]\{\ddot{x} + \ddot{z}_0\} + [K]\{x\} = 0 \qquad \cdots\cdots\cdots (4)$$

where;

$[M]$; Mass matrix $\left(= \begin{bmatrix} m_{N+1} & & 0 \\ & m_i & \\ 0 & & m_1 \end{bmatrix} \right)$

$[K]$; Stiffness matrix $\left(= [G]^{-1}[H] \right)$

$\{\ddot{x}+\ddot{z}_0\}$; Absolute acceleration vector

$\left(= \{\ddot{x}_{N+1}+\ddot{z}_0, \ldots, \ddot{x}_i+\ddot{z}_0, \ldots, \ddot{x}_1+\ddot{z}_0\}^T \right)$

$\{x\}$; Displacement vector

$\left(= \{x_{N+1}, \ldots, x_i, \ldots, x_1\}^T \right)$

Eq. (4) represents the vibration equation of a lumped mass vibration model for the superstructure of the stack shaft.

(4) Sway and rocking

A stack foundation model is set up whereby. The spring constant for horizontal displacement (sway) and rotation (rocking) are assumed based upon the resistance of piles.

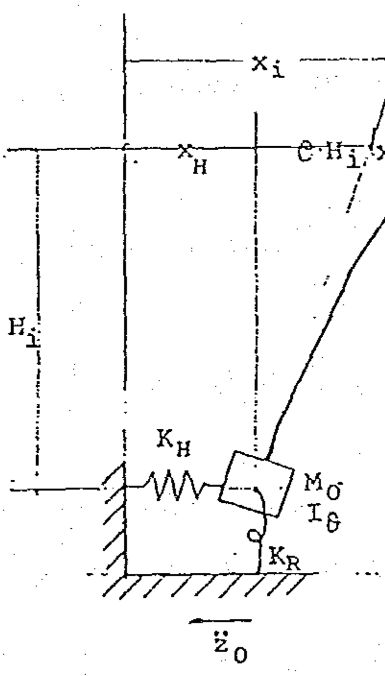


Fig.7

In this case, horizontal and rotation equilibriums as shown in Fig.7 are as follows.

$$\left.\begin{aligned} &\sum_{j=2}^{n} m_j(\ddot{x}_j+\ddot{z}_0)+M_0(\ddot{x}_H+\ddot{z}_0)+K_H\cdot x_H=0 \\ &\sum_{j=2}^{n} m_j(\ddot{x}_j+\ddot{z}_0)H_j+I_\theta\cdot\ddot{\theta}+K_R\cdot\theta=0 \end{aligned}\right\} \quad \ldots\ (5)$$

where;

x_H : horizontal displacement (sway)

K_H : sway spring constant

θ : rotation (rocking)

K_R : rocking spring constant

M_0 : mass of the foundation

I_θ : rotationary inertia of the foundation

Vector $\{x\}$ of the Eq.(4) coincides with vector $\{x'_i\}$ in Fig.7. Here, we convert the coordinates of the vector $\{x_i\}$ as follows.

$$\left.\begin{aligned} &\{x_i\}=\{x_H\}+\{\theta\cdot H_i\}+\{x_i'\} \\ &\therefore\ \{x_i'\}=\{x_i\}-\{x_H\}-\{\theta\cdot H_i\} \end{aligned}\right\} \quad \ldots\ldots\ (N)$$

Thus, vector $\{x\}$ of Eq.(4) is equal to the vector $\{x_i\}$.

$$[M]\{\ddot{x}_i+\ddot{z}_0\}+[K]\{x_i-x_H-\theta\cdot H_i\}=0 \quad \cdots\cdots\cdots(4)'$$

A second term is as follows.

$$\sum_{j=2}^{n}K_{ij}x_j-\sum_{j=2}^{n}K_{ij}\cdot x_H-\sum_{j=2}^{n}K_{ij}\cdot H_j\cdot\theta \quad \cdots\cdots\cdots(O)$$

On the other hand, $m_j(\ddot{x}_j+\ddot{z}_0)$ in the first term of Eq.(5) coincides with Eq.(O).

$$\left.\begin{aligned}&-\sum_{i=2}^{n}\left(\sum_{j=2}^{n}K_{ij}x_j-\sum_{j=2}^{n}K_{ij}x_H-\sum_{j=2}^{n}K_{ij}H_j\theta\right)+M_0(\ddot{x}_H+\ddot{z}_0)+K_H x_H=0\\&-\sum_{i=2}^{n}\left(\sum_{j=2}^{n}K_{ij}x_j-\sum_{j=2}^{n}K_{ij}x_H-\sum_{j=2}^{n}K_{ij}H_j\theta\right)H_i+I_\theta\cdot\ddot{\theta}+K_R\theta=0\end{aligned}\right\}\cdots\cdots(5)'$$

Therefore, by considering the sway and rocking, the fundamental vibration equation is obtained by applying Eq.(4)' and Eq.(5)'.

$$\left.\begin{aligned}&m_i(\ddot{x}_i+\ddot{z}_0)+\sum_{j=2}^{n}K_{ij}x_j-\sum_{j=2}^{n}K_{ij}x_H-\sum_{j=2}^{n}K_{ij}H_j\,\theta=0\\&M_0(\ddot{x}_H+\ddot{z}_0)-\sum_{i=2}^{n}\sum_{j=2}^{n}K_{ij}x_j+\left(\sum_{i=2}^{n}\sum_{j=2}^{n}K_{ij}+K_H\right)x_H+\sum_{i=2}^{n}\sum_{j=2}^{n}K_{ij}H_j\,\theta=0\\&I_\theta\ddot{\theta}-\sum_{i=2}^{n}\sum_{j=2}^{n}K_{ij}H_i x_j+\sum_{i=2}^{n}\sum_{j=2}^{n}K_{ij}H_i x_H+\left(\sum_{i=2}^{n}\sum_{j=2}^{n}K_{ij}H_iH_j+K_R\right)\theta=0\end{aligned}\right\}\cdots(P)$$

Here Eq.(P) is indicated in matrix form.

$$\begin{bmatrix} m_n & \cdots & 0 & \cdots & 0 & 0 & 0 \\ \vdots & \ddots & \vdots & & \vdots & \vdots & \vdots \\ 0 & \cdots & m_i & \cdots & 0 & 0 & 0 \\ \vdots & & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & \cdots & 0 & \cdots & m_2 & 0 & 0 \\ 0 & \cdots & 0 & \cdots & 0 & M_0 & 0 \\ 0 & \cdots & 0 & \cdots & 0 & 0 & I_\theta \end{bmatrix} \begin{Bmatrix} \ddot{x}_n + \ddot{z}_0 \\ \vdots \\ \ddot{x}_i + \ddot{z}_0 \\ \vdots \\ \ddot{x}_2 + \ddot{z}_0 \\ \ddot{x}_H + \ddot{z}_0 \\ \ddot{\theta} \end{Bmatrix} + \begin{bmatrix} K_{nn} & \cdots & K_{ni} & \cdots & K_{n2} & -\sum K_{nj} & -\sum K_{nj}H_j \\ \vdots & & \vdots & & \vdots & \vdots & \vdots \\ K_{in} & \cdots & K_{ii} & \cdots & K_{i2} & -\sum K_{ij} & -\sum K_{ij}H_j \\ \vdots & & \vdots & & \vdots & \vdots & \vdots \\ K_{2n} & \cdots & K_{2i} & \cdots & K_{22} & -\sum K_{2j} & -\sum K_{2j}H_j \\ -\sum K_{in} & \cdots & -\sum K_{ii} & \cdots & -\sum K_{i2} & a & b \\ -\sum K_{in}H_i & \cdots & -\sum K_{ii}H_i & \cdots & -\sum K_{i2}H_i & c & d \end{bmatrix} \begin{Bmatrix} x_n \\ \vdots \\ x_i \\ \vdots \\ x_1 \\ x_H \\ \theta \end{Bmatrix}$$

$$= \{0\} \qquad \cdots\cdots (6)$$

where;

$$a = \sum\sum K_{ij} + K_H$$

$$b = \sum\sum K_{ij}H_j$$

$$c = \sum\sum K_{ij}H_i$$

$$d = \sum\sum K_{ij}H_iH_j + K_R$$

Also, we may symbolize Eq.(6) as follows.

$$[M]\{\ddot{x} + \ddot{z}_0\} + [K]\{x\} = \{0\} \qquad \cdots\cdots (6)'$$

(5) Free vibration equation

The free vibration equation is derived from Eq.(6) when the external force is zero.

$$[M]\{\ddot{x}\} + [K]\{x\} = \{0\} \quad \cdots\cdots\cdots (Q)$$

Eq.(Q) is solved by the following assumption.

$$\left.\begin{aligned} \{x\} &= \{y\} \cdot e^{i\omega t} \\ \{\ddot{x}\} &= -\{y\} \cdot \omega^2 e^{i\omega t} \end{aligned}\right\} \quad \cdots\cdots\cdots (R)$$

Substituting Eq.(R) into Eq.(Q).

$$-\omega^2[M]\{y\} + [K]\{y\} = \{0\} \quad \cdots\cdots\cdots (7)$$

Furthermore,

$$[K]\{y\} = \omega^2[M]\{y\} \quad \cdots\cdots\cdots (S)$$

Eq.(S) can be solved by the matrix interaction method, that is, the eigenvalue factor.

Circular frequency ω and eigen vector $\{y\}$ are obtained from each modes of the vibration.

Natural period of the model gives us the following equation.

$$T_j = \frac{2\times\pi}{\omega j} \quad \cdots\cdots\cdots (T)$$

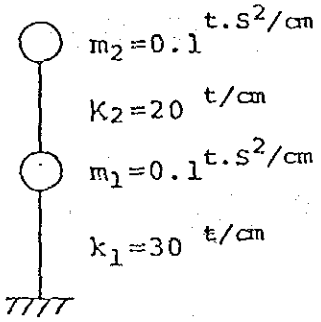
where;

T_j : j^{th} natural period

ω_j : j^{th} circular frequency

EXAMPLE :

In the case of two mass models as shown in Fig.8.



$$[M] = \begin{bmatrix} 0.1 & 0 \\ 0 & 0.1 \end{bmatrix}$$

$$[K] = \begin{bmatrix} 20 & -20 \\ -20 & 50 \end{bmatrix}$$

Fig.8

$$-\omega^2[M]\{Y\} + [K]\{Y\} = \{0\}$$

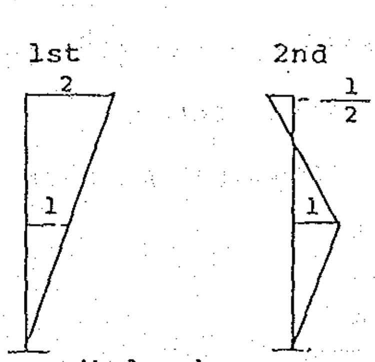
$$\begin{bmatrix} 20-0.1\omega^2 & -20 \\ -20 & 50-0.1\omega^2 \end{bmatrix} \begin{Bmatrix} Y_1 \\ Y_2 \end{Bmatrix} = \{0\}$$

by $\{Y\} \fallingdotseq 0$

$$\begin{vmatrix} 20-0.1\omega^2 & -20 \\ -20 & 50-0.1\omega^2 \end{vmatrix} = 0$$

$$\omega^4 - 700\,\omega^2 + 60000 = 0$$

$$\therefore\ \omega_1^2 = 100\ ,\quad \omega_2^2 = 600$$



$T_1 = \frac{2\pi}{\omega_1} = 0.628^s$, $T_2 = \frac{2\pi}{\omega_2} = 0.256^s$

$\frac{Y_2}{Y_1} = 2$ when $\omega_1^2 = 100$

$\frac{Y_2}{Y_1} = -\frac{1}{2}$ when $\omega_2^2 = 600$

Mode shape

Fig.9

(6) Forced vibration equation

The forced vibration equation is obtained by adding a damping term to Eq.(6).
Assuming that the damping factor is viscous damping, we obtain the following.

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = -[M]\{\ddot{z}_0\} \quad \cdots\cdots\cdots(8)$$

where;

[C] : damping matrix

$\{\dot{x}\}$: velocity vector

Eq.(8) can be solved by the following steps.
Vector $\{\ddot{x}\}$, $\{\dot{x}\}$ and $\{x\}$ are analyzed as the normal modes of vibration.

$$\{x\} = \sum_{j=1}^{m} q_j \{y_j\} \quad \cdots\cdots\cdots(U)$$

The same analysis is applied for the unit vector $\{1\}$.

$$\{1\} = \sum_{j=1}^{m} \beta_j \{y_j\}$$

where;

q_j : coefficient for j^{th} eigen vector

$\{y_j\}$: j^{th} eigen vector

β_j : j^{th} participation factor for mode

$$\beta_j = \frac{\sum_{i=1}^{m} m_i y_{ij}}{\sum_{i=1}^{m} m_i y_{ij}^2}$$

Substituting the said vectors in the privious page into Eq.(8).

$$\sum [M]\{y_j\}\ddot{q}_j + \sum [C]\{y_j\}\dot{q}_j + \sum [K]\{y_j\}q_j = -\{\ddot{z}_0\}\sum [M]\{y_j\}\beta_j \cdots\cdots\cdots\cdots (8)'$$

Next, we multiply the vector $\{y_j\}^T$ by the Eq.(8)'.

$$\sum \{y_j\}^T[M]\{y_j\}\ddot{q}_j + \sum \{y_j\}^T[C]\{y_j\}\dot{q}_j + \sum \{y_j\}^T[K]\{y_j\}q_j = -\{\ddot{z}_0\}\sum \{y_j\}^T[M]\{y_j\}\beta_j \cdots\cdots (8)''$$

We obtain the following from the property of the matrix [M] and [K].

$$\{y_r\}^T [M] \{y_s\} \begin{cases} = 0 & (r \neq s) \\ \neq 0 & (r = s) \end{cases}$$

$$\{y_r\}^T [K] \{y_s\} \begin{cases} = 0 & (r \neq s) \\ \neq 0 & (r = s) \end{cases}$$

By assuming that the element C_{rs} of matrix [C] can be disregarded, we obtain the following.

$$\{y_r\}^T [C] \{y_s\} \begin{cases} \fallingdotseq 0 & (r \neq s) \\ \neq 0 & (r = s) \end{cases}$$

Rewriting Eq.(8).:

$$\ddot{q}_j + 2h_j\omega_j\dot{q}_j + \omega_j^2 q_j = -\ddot{z}_0\beta_j \quad \cdots\cdots\cdots(9)$$

where;

ω_j ; circular frequency

$$\left(\omega_j^2 = \frac{K_j}{M_j}\right)$$

h_j ; Damping factor

$$\left(h_j = \frac{C_j}{2M_j\omega_j}\right)$$

$$M_j = \{y_j\}^T[M]\{y_j\}$$

$$K_j = \{y_j\}^T[K]\{y_j\}$$

$$C_j = \{y_j\}^T[C]\{y_j\}$$

The solution of Eq.(9) is as follows.

$$q_j = \beta_j q_{j0}$$

$$q_{j0} = -\frac{1}{\sqrt{1-h_j^2}\,\omega_j}\int_0^t \ddot{z}_0(\tau)e^{-h_j\omega_j(t-\tau)}\sin\left\{\sqrt{1-h_j^2}\,\omega_j(t-\tau)\right\}d\tau \quad \cdots(V)$$

The integration of Eq.(V) can be solved according to ④Newmark's β-mothod or other methods.

SEE APPENDEX - B

④ P.71. Eq.(2), Eq.(3)

The displacement, velocity and acceleration vectors as response values are obtained as follows.

$$\{x\} = \sum_{j=1}^{m}\{Y_j\}\beta_j\, q_{j0}$$

$$\{\dot{x}\} = \sum_{j=1}^{m}\{Y_j\}\beta_j\, \dot{q}_{j0}$$

$$\{\ddot{x}\} = \sum_{j=1}^{m}\{Y_j\}\beta_j\, \ddot{q}_{j0} \qquad \cdots\cdots (10)$$

$$\{\ddot{z}_0\} = \ddot{z}_0\{1\} = \ddot{z}_0 \sum_{j=1}^{m}\{Y_j\}\beta_j$$

$$\{\ddot{x}+\ddot{z}_0\} = -\sum_{j=1}^{m}\{Y_j\}\beta_j\,\{2h_j\omega_j\dot{q}_{j0} + \omega_j^2 q_{j0}\}$$

$$\left(\because\ \ddot{q}_{j0}+\ddot{z}_0 = -2h_j\omega_j\dot{q}_{j0}-\omega_j^2 q_{j0}\right.$$

From a response value of one mass model)

NOTE: Eq.(10) in Chapter 4.3 of "Dynamic Analysis" contains the following typing mistakes.

Original	Correction
q_j	q_{j0}
$\dot{q}_j$	$\dot{q}_{j0}$

AR-4. Structural Calculation Sheets for Administration Building

CONTENTS

§1 GENERAL

1.1 OUTLINE OF BUILDING

1) Name of building

ADMINISTRATION BUILDING

2) Building dimensions

(1)	Building area	:	633.75	m^2
(2)	Total floor area	:	2577.25	m^2
	Ground floor area	:	633.75	m^2
(3)	Maximum building height	:	21.4	m
(4)	Building volume storey	:	11077.95	m^3
(5)	Number of story	:	4	

3) Weight of building

Superstructure	:	4630.03	t
Substructure	:	1022.45	t
Total weight	:	5652.48	t

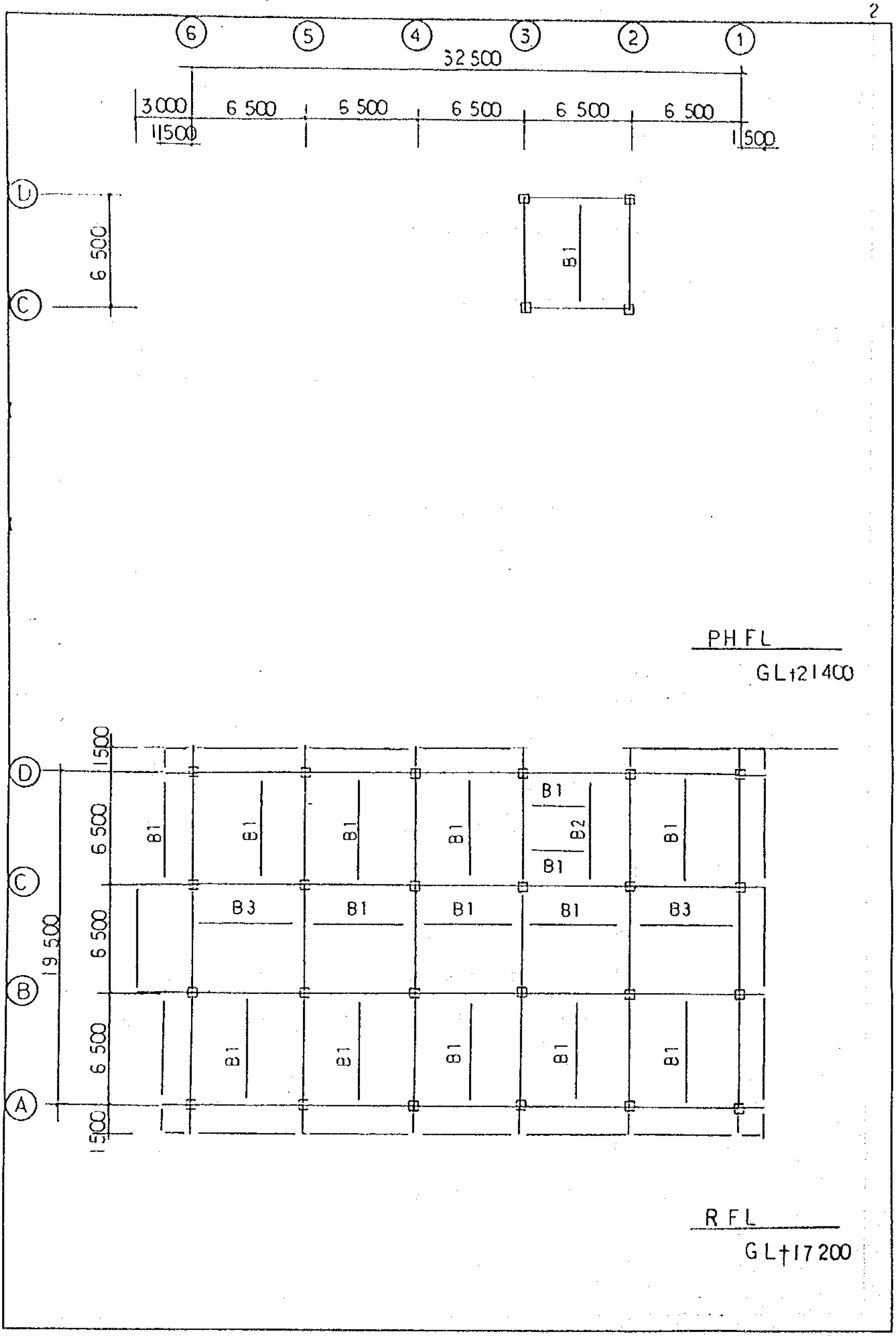
4) General design conception

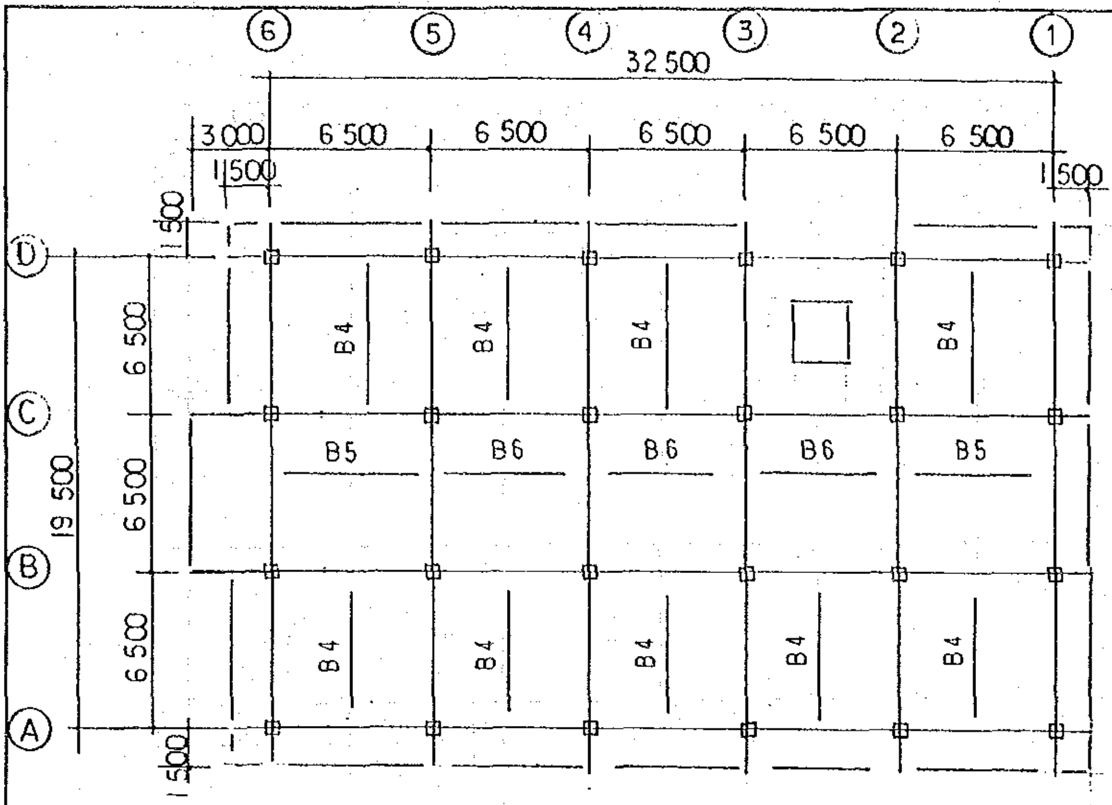
Design calculation to be analyzed as rigid frame with taken design rigidity of foundation girder in to considenation.

Stress analysis to be used by Electric computer with stiffness matrix method.

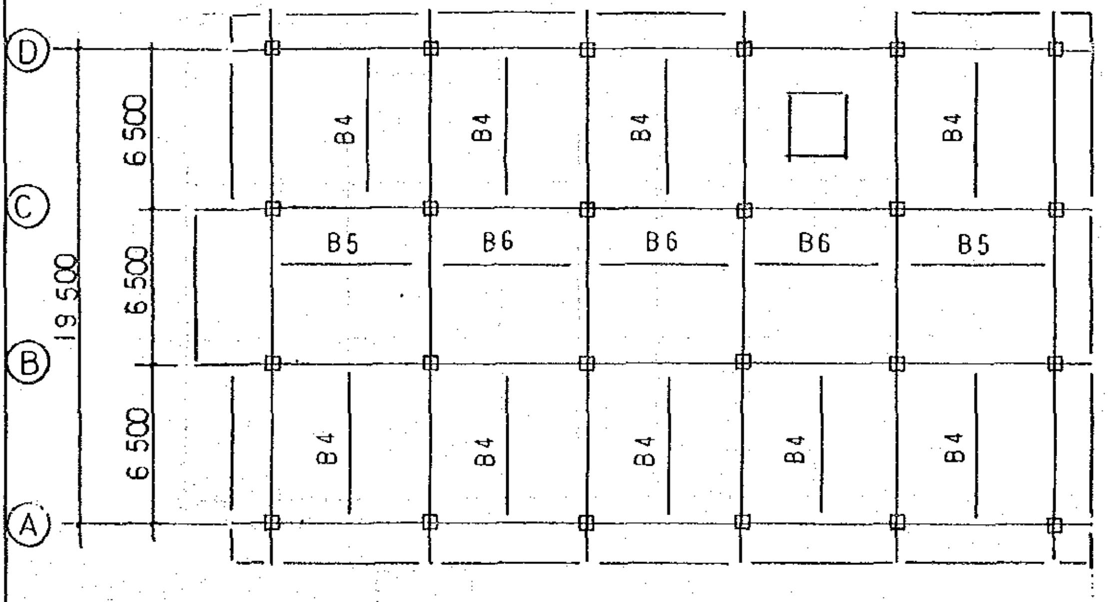
374

5) GENERAL DRAWING



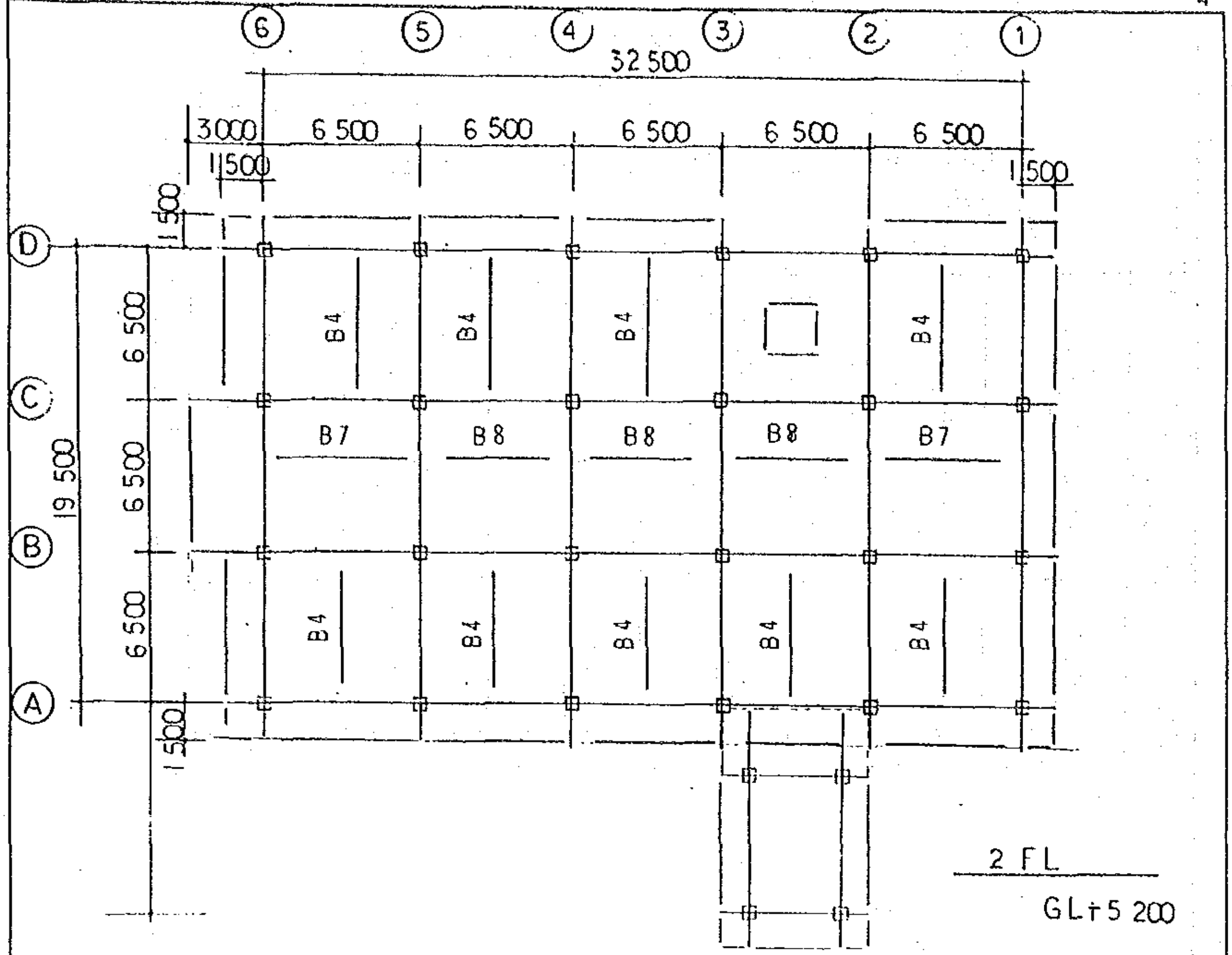


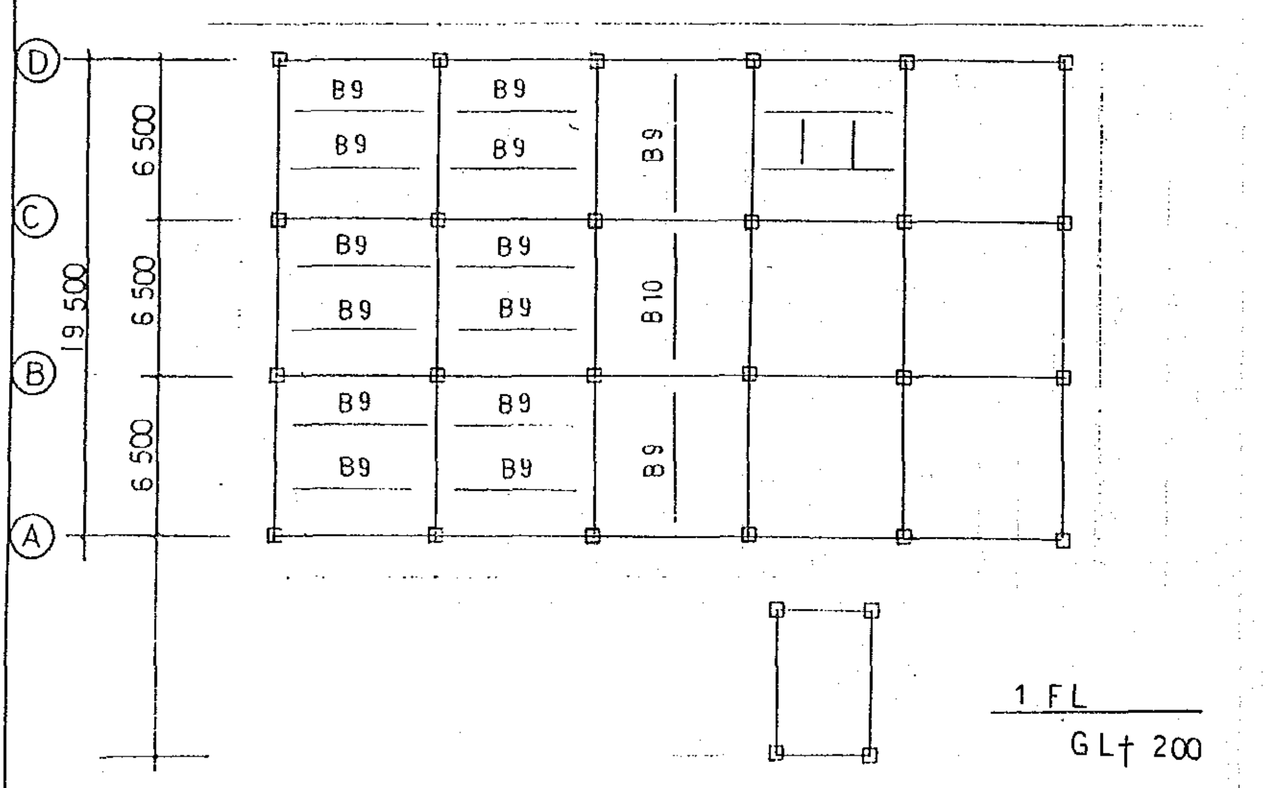
4 FL
GL+13,200

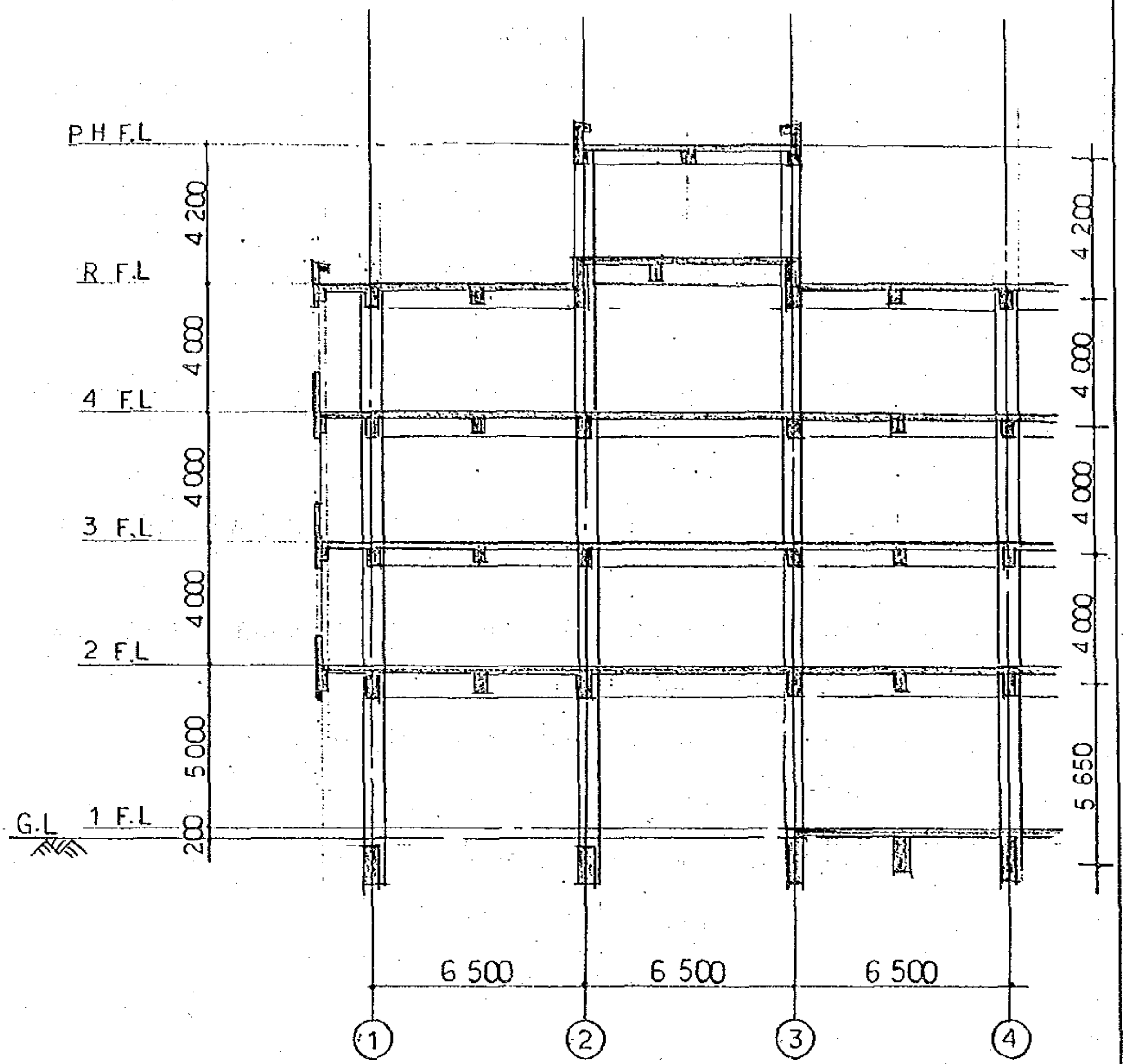


3 FL
GL+9 200

ADMINISTRATION BUILDING






PH F.L
R F.L
4 F.L
3 F.L
2 F.L
G.L
1 F.L
4 200
4 000
4 000
4 000
5 000
200
4 200
4 000
4 000
4 000
5 650
6 500
6 500
6 500
1
2
3
4

SECTION

1.2 APPLICABLE CODES AND STANDARDS

1) For design and allowable stress of structural materials

Reinforced concrete structure

AIJ : "Standards for calculation of reinforced concrete structures"

Foundation

AIJ : "Standards for structural design of building foundation"

* AIJ : Architectural Institute of Japan

1.3 STRUCTURAL MATERIALS TO BE USED AND ALLOWABLE UNIT STRESS

1) Qualities of materials

Concrete ; Comperessive strength of 28 days

$Fc' = 210 \ kg/cm^2$

Reinforcement ; Deformed reinforcement

ASTM A615 Grade 40

$fy = 2,812 \ kg/cm^2$

2) Physical constants for structural materials

Modulus of elasticity

Concrete	$210 \ t/cm^2$
Reinforcement	$2100 \ t/cm^2$

3) ALLOWABLE UNIT STRESS

i) Allowable Unit Stress of Concrete (kg/cm^2)

Materials \ stresses		Permanent Stresses					Temporary Stresses		
		Compress	Shear	Bond			Compress	shear	Bond
				A	B	C			
Normal concrete Fc-210	Plain bar	70	7.0	8.4	12.6	8.4	Permanent Stresses x 2.0	Permanent Stresses x 1.5	
	Deformed bar			14.0	21.0	14.0			

* Remarks A ; Top bar of flexural members

B : Bar, except "Item A", of flexural members

C : Anchors and lap splices

ii) Allowable Unit Stress of Reinforcing Bars (kg/cm^2)

Materials \ Stresses	Permanent Stresses		Temporary Stresses	
	Tension Compression	Shear Reinforcement	Tension Compression	shear Reinforcement
Deformed bar ASTM A615 Grade 40	1,870	1,870	2,812	2,812

380

1.4 LOAD COMBINATION

1) Load combination for steel and concrete structure

Long term loading

i) D.L+L.L+M.L+C.L

Short term loading

i) D.L+L.L+M.L+C.D+W.L

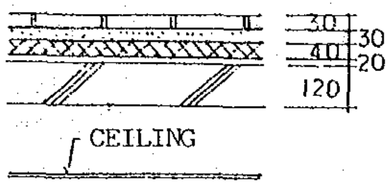
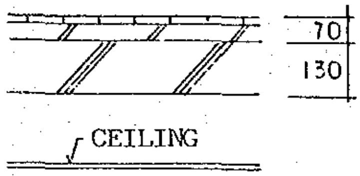
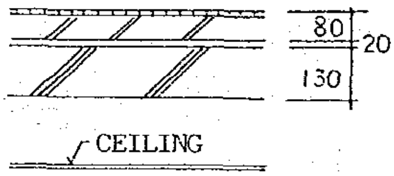
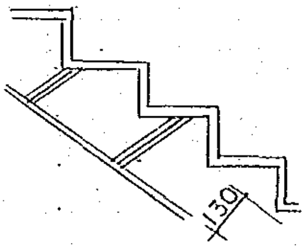
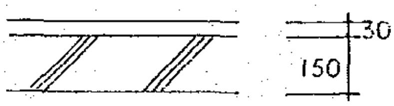
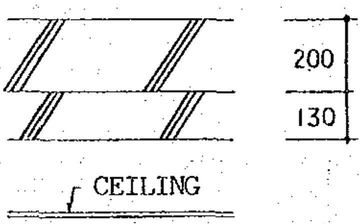
ii) D.L+L.L+M.L+C.D+S.L

where;

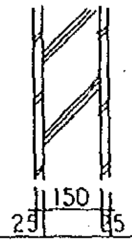
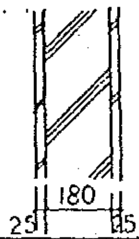
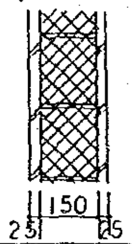
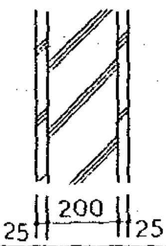
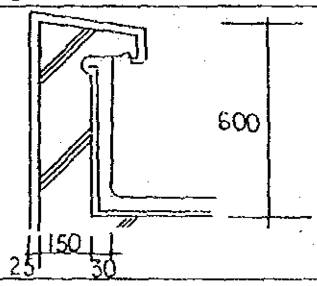
D.L	;	Dead load
L.L	;	Live load and over burden load
M.L	;	Machine load
C.L	;	Crane operation load
C.D.L	;	Crane dead load
W.L	;	Wind load
S.L	;	Seismic load

1.5 DESIGN LOAD

DEAD LOAD (1)
【固定荷重】

ROOM NAME OR LOCATION	FIGURE (mm)	MATERIALS (THICKNESS-mm)	WEIGHT (kg/m2)	TOTAL (kg/m2)
ROOF		CONCRETE BLOCK (30)	60	
		SAND (30)	60	
		INSULATION (40)	5	
		ASPHALT W/PROOFING (20)	30	
		CONCRETE SLAB (120)	288	
		CEILING	15	
			458	→ 460
FLOOR		TERRAZZO BLOCK FINISHING (70)	140	
		CONCRETE SLAB (130)	312	
		CEILING	15	
			467	→ 470
REST ROOM SHOWER ROOM		MOSAIC TILE FINISHING (80)	160	
		ASPHALT W/PROOFING (20)	30	
		CONCRETE SLAB (130)	312	
		CEILING	15	
			517	→ 520
STAIR		TERRAZZO BLOCK FINISHING (50)	100	
		CONCRETE SLAB (200)	480	
		CEILING	15	
			595	→ 600
1F FLOOR (MACHINE ROOM)		MORTAR (30)	60	
		CONCRETE SLAB (150)	360	
			420	→ 420
ELEVATOR MACHINE ROOM		CONCRETE SLAB (200)	480	
		CONCRETE SLAB (130)	312	
		CEILING	15	
			807	→ 810

DEAD LOAD (2)
[固定荷重]

ROOM NAME OR LOCATION	FIGURE (mm)	MATERIALS (THICKNESS-mm)		WEIGHT (kg/m2)	TOTAL (kg/m2)
CONCRETE WALL 150		CONCRETE	(150)	360	
		MORTAR			
		EXT	(25)	50	
		INT	(25)	50	
				460	→ 460
CONCRETE WALL 180		CONCRETE	(180)	432	
		MORTAR			
		EXT	(25)	50	
		INT	(25)	50	
				532	→ 535
CONCRETE BLOCK WALL		C.B	(150)	200	
		MORTAR			
		EXT	(25)	50	
		INT	(25)	50	
				300	→ 300
CONCRETE WALL 200		CONCRETE	(200)	480	
		MORTAR			
		EXT	(25)	50	
		INT	(25)	50	
				580	→ 580
PARAPET		CONCRETE	(200)	288	
		ASPHALT			
		W/PROOFING	(20)	14	
		MORTAR	(55)	66	
				368	→ 370

NOTE: DL --- DEAD LOAD　　PHL --- PIPE HANGER LOAD
LL --- LIVE LOAD　　TL --- TOTAL FLOOR LOAD

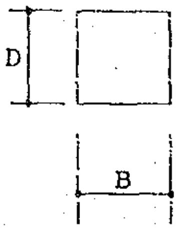
FLOOR LOAD
【設計用床荷重】

Unit: kg/m2

FLOOR	ROOM NAME	SLAB			GIRDER				BEAM				COLUMN & FOUND.				SEISMIC			
		DL	LL	TL	DL	LL	PHL	TL	DL	LL	PHL	TL	DL	LL	PHL	TL	DL	LL	PHL	TL
	ROOF	460	300	760	460	180		640	460	180		640	460	180		640	460	80		540
	PENTHOUSE ROOF	460	90	550	460	60		520	460	60		520	460	60		520	460	—		460
	FLOOR	470	300	770	470	180		650	470	180		650	470	180		650	470	80		550
	REST ROOM SHOWER ROOM	520	300	820	520	180		700	520	180		700	520	180		700	520	80		600
	STAIR	600	300	900	600	180		780	600	180		780	600	180		780	600	80		680
	1F FLOOR (MACHINE ROOM)	420	500	920	420	300		720	420	300		720	420	300		720	420	200		620
	STORAGE ROOM	470	500	970	470	300		770	470	300		770	470	300		770	470	200		670
	ELEVATOR MACHINE ROOM	810	500	1310	810	300		1110	810	300		1110	810	300		1110	810	200		1010

CALCULATION OF THE WEIGHT OF COLUMN, GIRDER OR BEAM (   )
【柱、大梁、小梁、基礎梁の自重計算】

FIGURE



THICKNESS OF FINISHING
t = 25 mm

UNIT WEIGHT OF FINISHING
w =   t/m3

NAME	FLOOR	SIZE (mm) B	SIZE (mm) D	w (t/m) CONC.	w (t/m) FINISH	Σ w (t/m)	REMARKS
COLUMN		500	500	0.60	0.20	0.80	
		550	550	0.73	0.20	0.93	
		600	600	0.86	0.20	1.06	
		700	700	1.18	0.20	1.38	
GIRDER		350	600	0.50		0.50	
		350	650	0.55		0.55	
		350	700	0.59		0.59	
		400	750	0.72		0.72	
		450	850	0.92		0.92	
FOUNDATION GIRDER		400	900	0.86		0.86	
BEAM		300	550	0.40		0.40	
		350	600	0.50		0.50	
		350	700	0.59		0.59	
		450	900	0.97		0.97	

NOTE: NAME --- COLUMN, GIRDER, BEAM OR UNDERGROUND BEAM
SPECIFIC GRAVITY OF REINFORCED CONCRETE IS 2.4 t/m3.

SEISMIC LOAD
【地震荷重】

ITEM	CALCULATION	
ZONE FACTOR (Z)	Z = 1.0	
STANDARD SHEAR COEFFICIENT (Co)	Co = 0.1	
GROUND CONDITION (Tc)	Tc = 0.6	
Hard	Tc = 0.4 ☐	
Medium	Tc = 0.6 ☒	
Soft	Tc = 0.8 ☐	
DIRECTION	X DIRECTION ( )	Y DIRECTION ( )
NATURAL PERIOD OF BUILDING (T)	T = 0.344	T = 0.344
Heigh h= m	Length of Span D= m	Length of Span D= m
T=(0.01*α+0.02)*h	= 0.344	= 0.344
T=0.05*h/4√D	=	=
T=h/70	=	=
CHARACTERISTICS OF VIBRATION OF THE BUILDING (Rt)	Rt = 1.0	Rt = 1.0

		T	Rt		T	Rt
Rt=1			= 1.0			= 1.0
	Tc	-	-	Tc	-	-
Rt=1-0.2*(T/Tc-1)^2			=			=
	2*Tc	-	-	2*Tc	-	-
Rt=1.6*Tc/T			=			=

	X DIRECTION	Y DIRECTION
2*T/(1+3*T)	= 0.339	= 0.339
SEISMIC LOAD FOR EACH FLOOR (Qi)		

STORY	Wi	α i	Ai	Ci	Qi	Wi	α i	Ai	Ci	Qi
4	801.18	0.185	1.724	0.172	137.80	801.18	0.185	1.724	0.172	137.80
3	1923.5	0.444	1.357	0.136	261.59	1923.5	0.444	1.357	0.136	261.59
2	3078.24	0.711	1.160	0.116	357.07	3078.24	0.711	1.160	0.116	357.07
1	4328.16	1.0	1.0	0.1	432.81	4328.16	1.0	1.0	0.1	432.81

NOTE: α --- RATIO OF THE HEIGHT OF WHICH STRUCTURE IS STEEL AGAINST THE BUILDING HEIGHT h

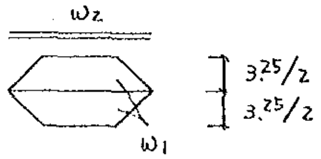
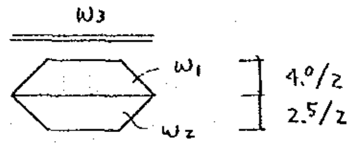
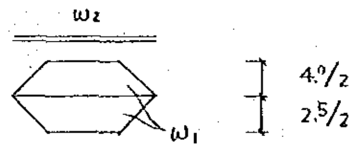
$\alpha i = Wi/\Sigma W$

$Ai = 1 + (1/\sqrt{\alpha i} - \alpha i)*2*T/(1 + 3*T)$

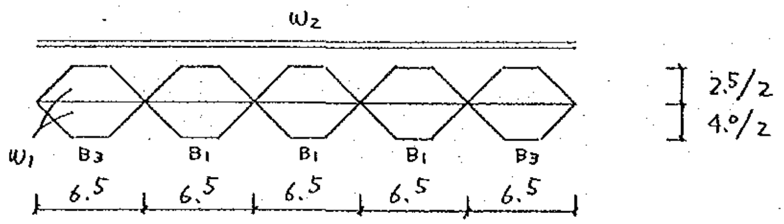
$Ci = Z*Rt*Ai*Co$

§2 DESIGN OF SECONDARY MEMBER

2.1 DESIGN OF BEAM

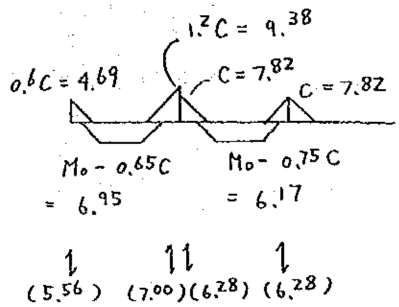
NO	SPAN m	LOADING CONDITION	C tm	Mo tm	Qo t	Member
B1	6.5	 $w_1 = 0.64$ t/m² $w_2 = 0.40$ t/m	7.93	12.18	6.37	
B2	6.5	 $w_1 = 1.11$ t/m² $w_2 = 0.78$ t/m² $w_3 = 0.3 \times 3.3 + 0.50 = 1.49$ t/m	15.01	23.00	12.39	
B4	6.5	 $w_1 = 0.70$ t/m² $w_2 = 0.3 \times 4.0 + 0.50 = 1.70$ t/m	12.99	19.83	10.97	

R FL

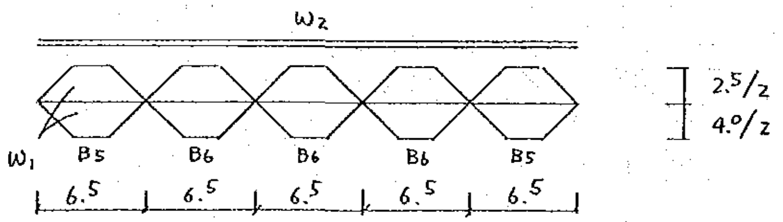


$w_1 = 0.64$ t/m² $w_2 = 0.40$ t/m

(C = 7.82
Mo = 12.03
Q = 6.28

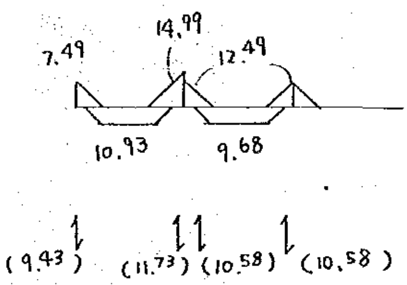


3,4 FL

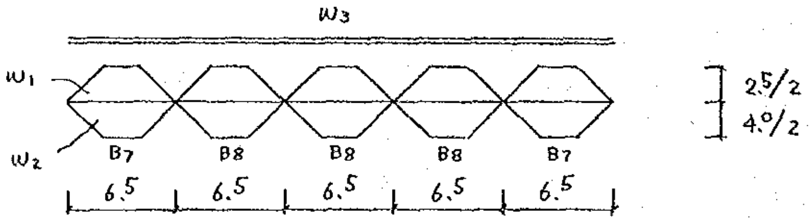


$w_1 = 0.65$ t/m² $w_2 = 0.3 \times 4.0 + 0.50 = 1.70$ t/m

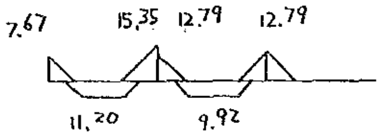
(C = 12.49
Mo = 19.05
Q = 10.58



2 F



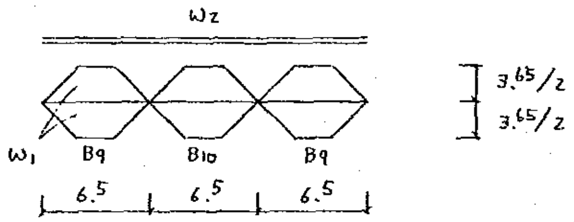
$w_1 = 0.65$ t/m² $w_2 = 0.70$ t/m² $w_3 = 0.3 \times 4.0 + 0.50 = 1.70$ t/m



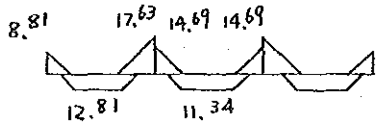
(9.62) (11.98) (10.80) (10.80)

C = 12.79
M₀ = 19.51
Q = 10.80

1 F



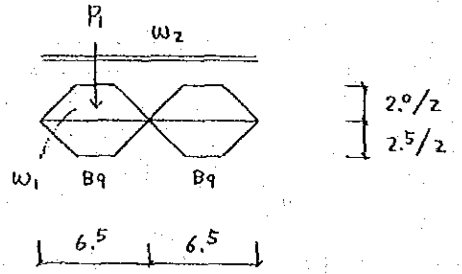
$w_1 = 0.72$ t/m² $w_2 = 0.3 \times 5.0 + 0.59 = 2.09$ t/m



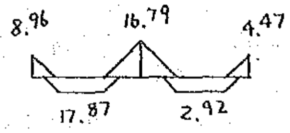
(11.13) (13.85) (12.49) (12.49)

C = 14.69
M₀ = 22.36
Q = 12.49

1 F

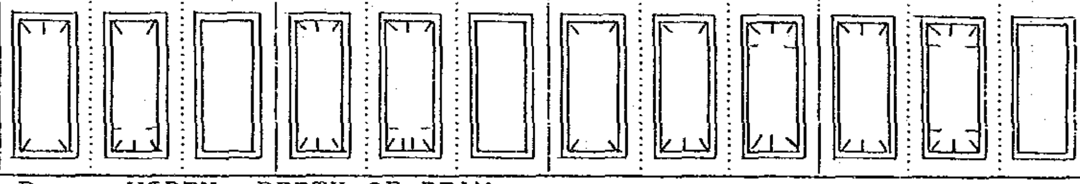


$w_1 = 0.72\ t/m^2$ $w_2 = 0.59\ t/m$ $P_1 = 9.2\ t$



(8.30) (13.40) (8.80) (3.70)

DICISION OF BEAM SECTION ( )
[小梁の断面算定]

NUMBER	B1			B2			B3			B4		
LOCATION	E	C	E	E	C	E	E	C	E	E	C	E
b x D (cm)	30 × 55			35 × 60			30 × 55			35 × 60		
d [j] (cm)	48 (42.0)			53 (46.38)			48 (42.0)			53 (46.38)		
bxd^2(cm3)	69120			98315			69120			98315		
M (tm) U	4.76		4.76	9.01		9.01	4.69		9.38	7.79		7.79
M (tm) L		9.40			17.75			6.95			15.28	
Q (t)	6.37		6.37	12.39		12.39	5.56		7.00	10.97		10.97
C=M/(bxd^2) (kg/cm2)	6.89	13.60		9.16	18.05		6.79	10.05	13.57	7.92	15.54	
Pt (%)					1.20							
at (cm2)	6.06	11.97		10.39	22.26		5.97	8.85	11.94	9.92	17.62	
ψ (cm)	10.83			19.08					11.90	16.89		
n												
min at(cm2)												
Q/bj	5.06			7.63					5.56	6.76		
Pw (%)	0.20			0.22					0.20	0.20		
STIRRUP	□ #3 @ 200			□ #3 @150			□ #3 @ 200			□ #3 @ 200		
MAIN BAR U	3-#7	2-#7		3-#7	3-#7		2-#7	2-#7	5-#7	3-#7	5-#7	
MAIN BAR L	2-#7	5-#7		3-#7	6-#7		2-#7	3-#7	3-#7	3-#7	5-#7	
RE-BAR ARRANGEMENT												

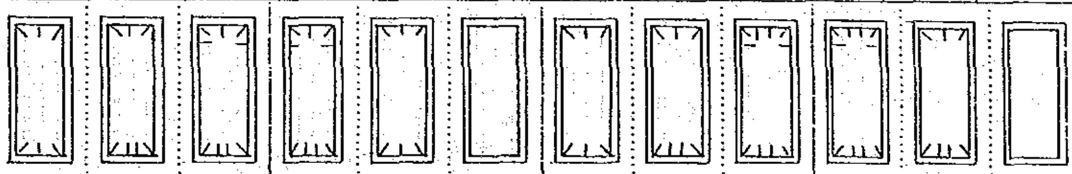
NOTATION: b,D --- WIDTH, DEPTH OF BEAM
d --- DISTANCE BETWEEN TENSILE RE-BAR AND COMPRESSION END
j --- (7/8) x d
U,L --- UPPER SIDE, LOWER SIDE
M,Q --- BENDING MOMENT, SHEAR FORCE
Pt --- TENSILE RE-BAR RATIO; = at/(bxd)
at --- SECTION AREA OF TENSILE RE-BAR
ψ --- REQUIRED CIRCUMFERENCE OF MAIN RE-BAR; = Q/faj
fa --- ALLOWABLE BOND STRESS (t/cm2)
n --- REQUIRED NUMBER OF MAIN RE-BAR
Pw --- STIRRUP RATIO; = aw/(bxX)
aw,X --- SECTION AREA OF A SET OF STIRRUP (cm2), PITCH OF STIRRUP (cm)

MAIN BAR at (cm2)		D16	D19	D22	D25	D29
	2	3.98	5.74	7.74	10.14	12.84
	3	5.97	8.61	11.61	15.21	19.26
	4	7.98	11.48	15.48	20.28	25.68
	5	9.95	14.35	19.35	25.35	32.10
	6	11.94	17.22	23.22	30.42	38.52
	7	13.93	20.09	27.09	35.49	44.94

STIRRUP Pw (%)		D10 @200	D10 @150	D13 @200	D13 @150
	30	0.237	0.316	0.423	0.564
	35	0.203	0.270	0.363	0.484
	40	-	0.237	0.318	0.423
	45	-	0.210	0.282	0.376
	50	-	-	0.254	0.339

DICISION OF BEAM SECTION (   )

[小梁の断面算定]

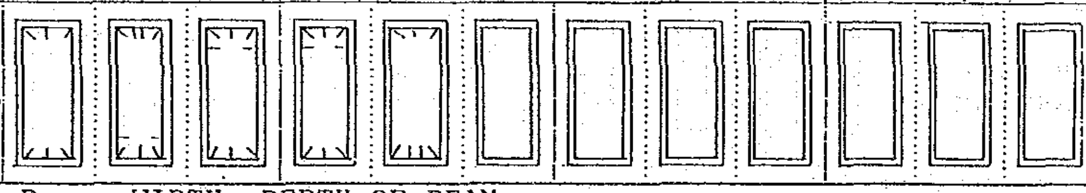
NUMBER	B5			B6			B7			B8		
LOCATION	E	C	E	E	C	E	E	C	E	E	C	E
b x D (cm)	35 × 60			35 × 60			35 × 60			35 × 60		
d [j] (cm)	53	(46.38)		53	(46.38)		53	(46.38)		53	(46.38)	
bxd^2(cm3)	98315			98315			98315			98315		
M (tm) U	7.49		14.99	12.49		12.49	7.67		15.35	12.79		12.79
L	-	10.93			9.68			11.20			9.92	
Q (t)	9.43		11.73	10.58		10.58	9.62		11.98	10.80		10.80
C=M/(bxd^2) (kg/cm2)	7.62	11.12	15.25	12.70	9.85		7.80	11.39	15.61	13.01	10.09	
Pt (%)			0.9						1.05			
at (cm2)	8.64	12.60	16.70	14.40	11.16		8.84	12.91	19.98	14.75	11.44	
ψ (cm)			18.07	16.29					18.45	16.63		
n												
min at(cm2)												
Q/bj			7.23	6.52					7.38	6.83		
Pw (%)			0.20	0.20					0.20	0.20		
STIRRUP	D #3 @ 200			D #3 @ 200			D #3 @200			D #3 @200		
MAIN BAR U	3-#7	3-#7	5-#7	5-#7	3-#7		3-#7	3-#7	6-#7	6-#7	3-#7	
L	3-#7	4-#7	4-#7	4-#7	3-#7		3-#7	4-#7	4-#7	4-#7	4-#7	
RE-BAR ARRANGEMENT												

NOTATION: b,D --- WIDTH, DEPTH OF BEAM
d --- DISTANCE BETWEEN TENSILE RE-BAR AND COMPRESSION END
j --- (7/8) x d
U,L --- UPPER SIDE, LOWER SIDE
M,Q --- BENDING MOMENT, SHEAR FORCE
Pt --- TENSILE RE-BAR RATIO; = at/(bxd)
at --- SECTION AREA OF TENSILE RE-BAR
ψ --- REQUIRED CIRCUMFERENCE OF MAIN RE-BAR; = Q/faj
fa --- ALLOWABLE BOND STRESS (t/cm2)
n --- REQUIRED NUMBER OF MAIN RE-BAR
Pw --- STIRRUP RATIO; = aw/(bxX)
aw,X --- SECTION AREA OF A SET OF STIRRUP (cm2), PITCH OF STIRRUP (cm)

MAIN BAR at (cm2)		D16	D19	D22	D25	D29
	2	3.98	5.74	7.74	10.14	12.84
	3	5.97	8.61	11.61	15.21	19.26
	4	7.98	11.48	15.48	20.28	25.68
	5	9.95	14.35	19.35	25.35	32.10
	6	11.94	17.22	23.22	30.42	38.52
	7	13.93	20.09	27.09	35.49	44.94

STIRRUP Pw (%)		D10 @200	D10 @150	D13 @200	D13 @150
	30	0.237	0.316	0.423	0.564
	35	0.203	0.270	0.363	0.484
	40	-	0.237	0.318	0.423
	45	-	0.210	0.282	0.376
	50	-	-	0.254	0.339

DICISION OF BEAM SECTION (   )
[小梁の断面算定]

NUMBER	B 9			B 10								
LOCATION	E	C	E	E	C	E	E	C	E	E	C	E
b x D (cm)	35 × 70			35 × 70								
d [j] (cm)	63 (55.13)			63 (55.13)								
bxd^2(cm3)	138915			138915								
M (tm) U	8.96		17.63	14.69		14.69						
L		17.87			11.34							
Q (t)	11.13		13.85	12.49		12.49						
C=M/(bxd^2) (kg/cm2)	6.45	12.86	12.69	10.57	8.16							
Pt (%)												
at (cm2)	8.69	17.33	17.10	14.25	11.00							
ψ (cm)			17.94	16.18								
n												
min at(cm2)												
Q/bj			7.18	6.47								
Pw (%)			0.20	0.20								
STIRRUP	D #3 @ 150			D #3 @ 150								
MAIN BAR U	3-#7	4-#7	5-#7	5-#7	3-#7							
L	3-#7	5-#7	3-#7	3-#7	4-#7							
RE-BAR ARRANGEMENT												

NOTATION: b,D --- WIDTH, DEPTH OF BEAM
d --- DISTANCE BETWEEN TENSILE RE-BAR AND COMPRESSION END
j --- (7/8) x d
U,L --- UPPER SIDE, LOWER SIDE
M,Q --- BENDING MOMENT, SHEAR FORCE
Pt --- TENSILE RE-BAR RATIO; = at/(bxd)
at --- SECTION AREA OF TENSILE RE-BAR
ψ --- REQUIRED CIRCUMFERENCE OF MAIN RE-BAR; = Q/faj
fa --- ALLOWABLE BOND STRESS (t/cm2)
n --- REQUIRED NUMBER OF MAIN RE-BAR
Pw --- STIRRUP RATIO; = aw/(bxX)
aw,X --- SECTION AREA OF A SET OF STIRRUP (cm2), PITCH OF STIRRUP (cm)

MAIN BAR at (cm2)		D16	D19	D22	D25	D29
	2	3.98	5.74	7.74	10.14	12.84
	3	5.97	8.61	11.61	15.21	19.26
	4	7.98	11.48	15.48	20.28	25.68
	5	9.95	14.35	19.35	25.35	32.10
	6	11.94	17.22	23.22	30.42	38.52
	7	13.93	20.09	27.09	35.49	44.94

STIRRUP Pw (%)		D10 @200	D10 @150	D13 @200	D13 @150
	30	0.237	0.316	0.423	0.564
	35	0.203	0.270	0.363	0.484
	40	-	0.237	0.318	0.423
	45	-	0.210	0.282	0.376
	50	-	-	0.254	0.339

3/93

2.2 DESIGN OF SLAB

CALCULATION SHEET (SLAB)

SIGN	S1			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)	3.25		6.5	
λ	2.0		2.0	
α	0.083	0.053	0.057	0.028
w (t/ m²)	0.288 + 0.442 = 0.73		0.73	
M (t.m)	0.64	0.41	0.44	0.22
t (cm)	12		12	
d (cm)	9		9	
at (cm²)	4.06	2.60	3.14	1.57
REINFORCED CONCRETE	#3. #4 @ 200	#3 @ 200	#3 @ 200	#3 @ 200
REMARK	$t = 0.02 \times \left(\frac{2.0-0.7}{2.0-0.6}\right) \times \left(1 + \frac{442}{1000} + \frac{325}{1000}\right) \times 325$ $= 10.67$			

SIGN	S2			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)	4.0 (3.675)		6.5 (6.15)	
λ	1.625 (1.67)		1.625 (1.67)	
α	0.079	0.049	0.057	0.028
w (t/ m²)	0.288 + 0.442 = 0.73		0.73	
M (t.m)	0.92	0.57	0.66	0.33
t (cm)	13		13	
d (cm)	9		8	
at (cm²)	5.84	3.62	4.71	2.36
REINFORCED CONCRETE	#3. #4 @ 150	#3 @ 150	#3 @ 150	#3 @ 150
REMARK	$t = 0.02 \times \left(\frac{1.67-0.7}{1.67-0.6}\right) \times \left(1 + \frac{442}{1000} + \frac{367.5}{1000}\right) \times 367.5$ $= 12.06$			

CALCULATION SHEET (SLAB)

SIGN	S3			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)	2.5		6.5	
λ	2.6		2.6	
α	0.083	0.055	0.057	0.028
w (t/ m²)	0.288 + 0.442 = 0.73		0.73	
M (t.m)	0.38	0.25	0.26	0.13
t (cm)	12		12	
d (cm)	9		8	
at (cm²)	2.41	1.59	1.86	0.93
REINFORCED CONCRETE	#3, #4 @ 200	#3 @ 200	#3 @ 200	#3 @ 200
REMARK	$t = 0.02 \times \left(\frac{2.6-0.7}{2.6-0.6}\right) \times \left(1+\frac{442}{1000}+\frac{250}{1000}\right) \times 250 = 8.04$			

SIGN	S4			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)	3.25		6.5	
λ	2.0		2.0	
α	0.083	0.053	0.057	0.028
w (t/ m²)	0.312 + 0.64 = 0.952		0.952	
M (t.m)	0.83	0.53	0.57	0.28
t (cm)	13		13	
d (cm)	9		8	
at (cm²)	5.27	3.37	4.07	2.00
REINFORCED CONCRETE	#3, #4 @150	#3, #4 @150	#3, #4 @150	#3, #4 @150
REMARK	$t = 0.02 \times \left(\frac{2.0-0.7}{2.0-0.6}\right) \times \left(1+\frac{640}{1000}+\frac{325}{1000}\right) \times 325 = 11.86$			

CALCULATION SHEET (SLAB)

SIGN	S5			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)	3.25		6.5	
λ	2.0		2.0	
α	0.083	0.053	0.057	0.028
w (t/ m²)	0.312 + 0.44 = 0.752		0.752	
M (t.m)	0.66	0.42	0.45	0.22
t (cm)	13		13	
d (cm)	9		8	
at (cm²)	4.19	2.67	3.21	1.57
REINFORCED CONCRETE	#3.#4 @200	#3 @200	#3 @200	#3 @200
REMARK	$t=0.02\times(\frac{2.0-0.7}{2.0-0.6})\times(1+\frac{440}{1000}+\frac{325}{1000})\times 325 = 10.65$			

SIGN	S6			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)	4.0		6.5	
λ	1.625		1.625	
α	0.079	0.049	0.057	0.028
w (t/ m²)	0.312 + 0.38 = 0.692		0.692	
M (t.m)	0.87	0.54	0.63	0.31
t (cm)	13		13	
d (cm)	9		8	
at (cm²)	5.52	3.43	4.50	2.21
REINFORCED CONCRETE	#3.#4 @150	#3.#4 @150	#3.#4 @150	#3.#4 @150
REMARK	$t=0.02\times(\frac{1.625-0.7}{1.625-0.6})\times(1+\frac{380}{1000}+\frac{400}{1000})\times 400 = 12.85$			

376

SIGN	S7			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)	4,0 (3,675)		6,5 (6,15)	
λ	1,625 (1,67)		1,625 (1,67)	
α	0,079	0,049	0,057	0,028
w (t/ m²)	0,312 + 0,44 = 0,752		0,752	
M (t.m)	0,95	0,59	0,69	0,34
t (cm)	13		13	
d (cm)	9		8	
at (cm²)	6,03	3,75	4,93	2,43
REINFORCED CONCRETE	#3, #4 @ 150	#3 @ 150	#3 @ 150	#3 @ 150
REMARK	$t = 0,02 \times \left(\frac{1,67-0,7}{1,67-0,6}\right) \times \left(1+\frac{440}{1000}+\frac{367,5}{1000}\right) \times 367,5 = 12,04$			

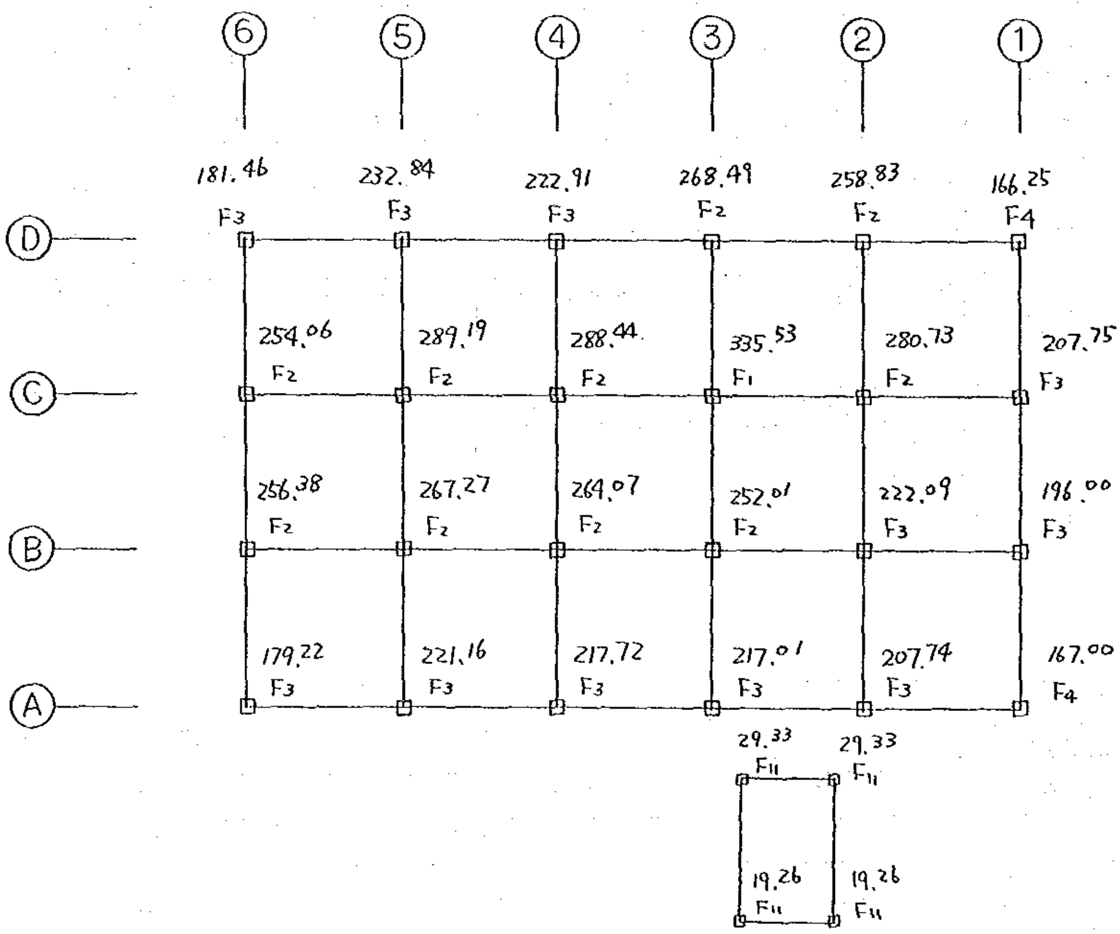
SIGN	S8			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)	2,5		6,5	
λ	2,6		2,6	
α	0,083	0,054	0,057	0,028
w (t/ m²)	0,312 + 0,44 = 0,752		0,752	
M (t.m)	0,39	0,25	0,27	0,13
t (cm)	13		13	
d (cm)	9		8	
at (cm²)	2,48	1,59	1,93	0,93
REINFORCED CONCRETE	#3 @ 200	#3 @ 200	#3 @ 250	#3 @ 250
REMARK	$t = 0,02 \times \left(\frac{2,6-0,7}{2,6-0,6}\right) \times \left(1+\frac{440}{1000}+\frac{250}{1000}\right) \times 250 = 8,03$			

CALCULATION SHEET (SLAB)

SIGN	Sg			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)	3.25		6.5	
λ	2.0		2.0	
α	0.083	0.053	0.057	0.028
w (t/m²)	0.36 + 0.56 = 0.92		0.92	
M (t.m)	0.81	0.52	0.55	0.27
t (cm)	15		15	
d (cm)	11		10	
at (cm²)	4.21	2.70	3.14	1.54
REINFORCED CONCRETE	#3. #4 @ 200	#3. #4 @ 200	#3 @ 200	#3 @ 200
REMARK	$t = 0.02 \times \left(\frac{2.0-0.7}{2.0-0.6}\right) \times \left(1 + \frac{560}{1000} + \frac{325}{1000}\right) \times 325 = 11.38$			

SIGN	S			
DIRECTION	SHORT		LONG	
POSITION	END	CENTER	END	CENTER
ℓ (m)				
λ				
α				
w (t/m²)				
M (t.m)				
t (cm)				
d (cm)				
at (cm²)				
REINFORCED CONCRETE				
REMARK				

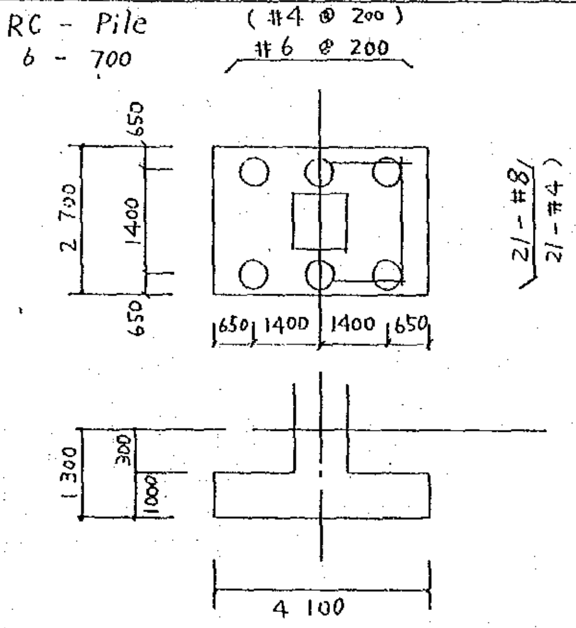
§3 DESIGN OF FOUNDATION
AXIAL LOAD



DESIGN OF FOUNDATION

OUTLINE OF FOUNDATION F1

RC - Pile
6 - 700



Foundation weight

$Nf = 2.0 \times 4.1 \times 2.7 \times 1.3 = 28.78$ t

LOADING

	N (t)	Hx (t)	Hy (t)
D.L	335.53 (D.L + L.L)		
L.L			
S.Lx			
S.Ly			
W.Lx			
W.Ly			

Stress at bottom of foundation

$N = 335.53 + 28.78 = 364.31$ t

M = ——

CHECK OF BEARING PRESSURE

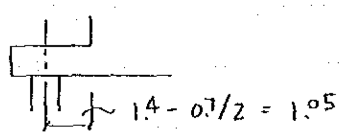
Check of Pile Reaction

$P_1 = 364.31 / 6 = 60.72$ t/Pile < 65 t/Pile

$P_1' = 335.53 / 6 = 55.90$ t/Pile

DESIGN OF FOOTING

Factored Load			Pile Reaction	
Load case	ΣN (t)	ΣM (t, m)	P1 (t/n)	P1' (t/n)
D.L+ L.L	335.53	——	60.72	55.90
D.L+ L.L+W.L				
D.L+ L.L+S.L				
D.L+ W.L				



Stress

$QF = 55.90 \times 2 = 111.80$ t

$MF = 111.80 \times 1.05 = 117.39$ t·m

Reinforcement

D = 100 cm, d = 85 cm, j = 7/8d = 74.38 cm

$\text{nec } At = \dfrac{MF}{ft \cdot j} = 84.40\ cm^2$

$\phi = \dfrac{Q}{fa \cdot j} = 71.58$ cm

21 - #8 ($at = 107.1\ cm^2$, $\phi = 168.0$ cm)

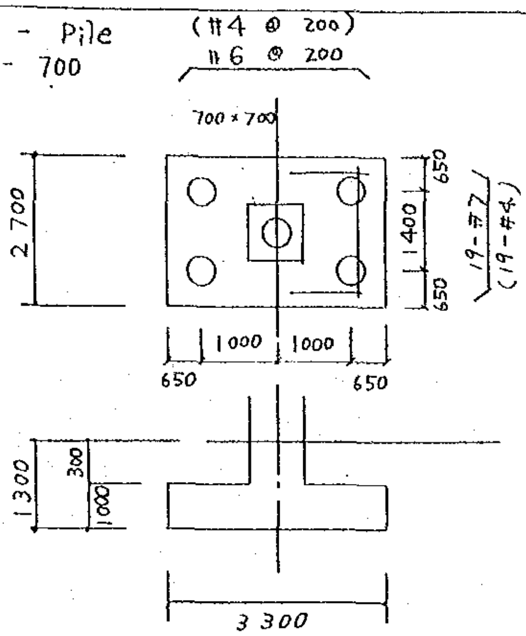
$\tau = \dfrac{Q}{b \cdot j} = 5.57\ Kg/cm^2 < 7.0\ Kg/cm^2$

207

DESIGN OF FOUNDATION

OUTLINE OF FOUNDATION F 2

RC - Pile
5 - 700



Foundation weight

$N_f = 2.^{0} \times 3.^{3} \times 2.^{7} \times 1.^{3} = 23.^{17}\ t$

LOADING

	N (t)	Hx (t)	Hy (t)
D.L	289.19		
L.L			
S.Lx			
S.Ly			
W.Lx			
W.Ly			

Stress at bottom of foundation

$N = 289.^{19} + 23.^{17} = 312.^{36}\ t$

M = ——

CHECK OF BEARING PRESSURE

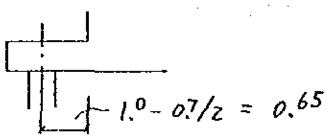
Check of Pile Reaction

$P_1 = 312.^{36} / 5 = 62.^{47}$ t/Pile < 65 t/Pile

$P_1' = 289.^{19} / 5 = 57.^{84}$ t/Pile

DESIGN OF FOOTING

Factored Load			Pile Reaction	
Load case	ΣN (t)	ΣM (t,m)	P1 (t/n)	P1' (t/n)
D.L+ L.L	289.19	—	62.47	57.84
D.L+ L.L+W.L				
D.L+ L.L+S.L				
D.L+ W.L				



Stress

$Q_F = 57.^{84} \times 2 = 115.^{68}\ t$

$M_F = 115.^{68} \times 0.^{65} = 75.^{19}\ t\cdot m$

Reinforcement

$D = 100\ cm,\quad d = 85\ cm,\quad j = 7/8d = 74.^{38}\ cm$

$nec\ A_t = \dfrac{M_F}{f_t \cdot j} = 54.^{06}\ cm^2$

$\phi = \dfrac{Q}{f_a \cdot j} = 74.^{06}\ cm$

19 - #7 ($a_t = 73.^{53}\ cm^2$, $\phi = 133.^{0}\ cm$)

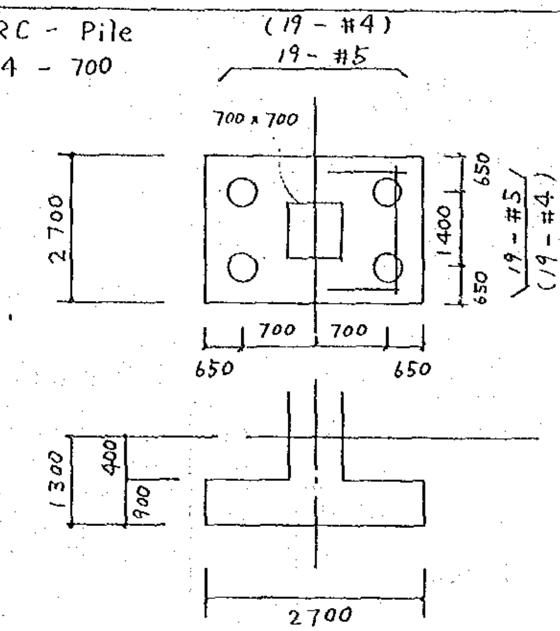
$\tau = \dfrac{Q}{b \cdot j} = 5.76\ kg/cm^2 < 7.^{0}\ kg/cm^2$

107

DESIGN OF FOUNDATION

OUTLINE OF FOUNDATION F3

RC - Pile
4 - 700



Foundation weight

$Nf = 2.0 \times 2.7 \times 2.7 \times 1.3 = 18.95$ t

LOADING

	N (t)	Hx (t)	Hy (t)
D.L	232.84		
L.L			
S.Lx			
S.Ly			
W.Lx			
W.Ly			

Stress at bottom of foundation

$N = 232.84 + 18.95 = 251.79$ t

M = ——

CHECK OF BEARING PRESSURE

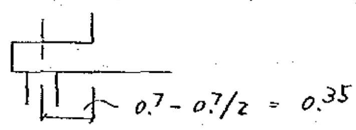
Check of Pile Reaction

$P_1 = 251.79 / 4 = 62.95$ t/Pile < 65 t/Pile

$P_1' = 232.84 / 4 = 58.21$ t/Pile

DESIGN OF FOOTING

Factored Load			Pile Reaction	
Load case	ΣN (t)	ΣM (t,m)	P1 (t/n)	P1' (t/n)
D.L+ L.L	232.84	—	62.95	58.21
D.L+ L.L+W.L				
D.L+ L.L+S.L				
D.L+ W.L				



Stress

$QF = 58.21 \times 2 = 116.42$ t

$MF = 116.42 \times 0.35 = 40.75$ t·m

Reinforcement

D = 90 cm, d = 75 cm, j = 7/8d = 65.63 cm

$$\text{nec At} = \frac{MF}{ft \cdot j} = 33.20 \text{ cm}^2$$

$$\phi = \frac{Q}{fa \cdot j} = 84.49 \text{ cm}$$

19 - #5 ($at = 38.0$ cm², $\phi = 95.0$ cm)

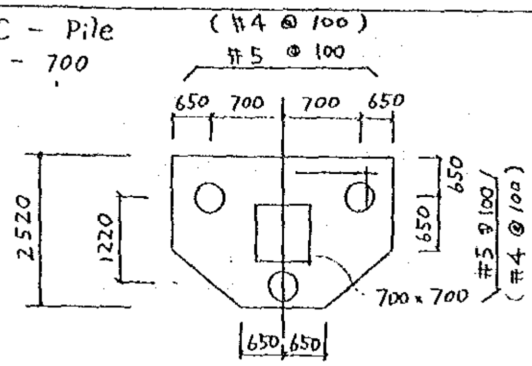
$$\tau = \frac{Q}{b \cdot j} = 6.57 \text{ kg/cm}^2 < 7.0 \text{ kg/cm}^2$$

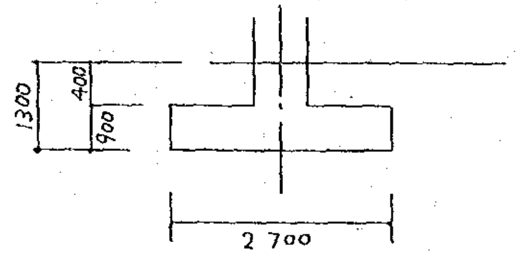
1403

DESIGN OF FOUNDATION

OUTLINE OF FOUNDATION F4

RC - Pile
3 - 700





Foundation weight

$Nf = 2.0 \times (2.52 \times 2.7 - 0.7 \times 1.22) \times 1.3 = 15.47^{t}$

LOADING

	N (t)	Hx (t)	Hy (t)
D.L	167.00		
L.L			
S.Lx			
S.Ly			
W.Lx			
W.Ly			

Stress at bottom of foundation

$N = 167.00 + 15.47 = 182.47^{t}$

$M =$ ——

CHECK OF BEARING PRESSURE

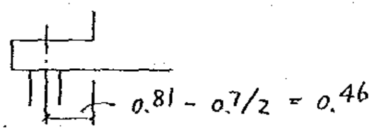
Check of Pile Reaction

$P_1 = 182.47 / 3 = 60.82\ t/Pile < 65\ t/Pile$

$P_1' = 167.00 / 3 = 55.67\ t/Pile$

DESIGN OF FOOTING

Factored Load			Pile Reaction	
Load case	ΣN (t)	ΣM (t, m)	P1 (t/n)	P1' (t/n)
D.L+ L.L	167.00	—	60.82	55.67
D.L+ L.L+W.L				
D.L+ L.L+S.L				
D.L+ W.L				



Stress

$QF = 55.67^{t}$

$MF = 55.67 \times 0.46 = 25.61\ t\cdot m$

Reinforcement

$D = 90$ cm, $d = 75$ cm, $j = 7/8d = 65.63$ cm

$\ell = 1.3$ m
14 - #5
($at = 28.0\ cm^2$, $\phi = 70.00$ cm)

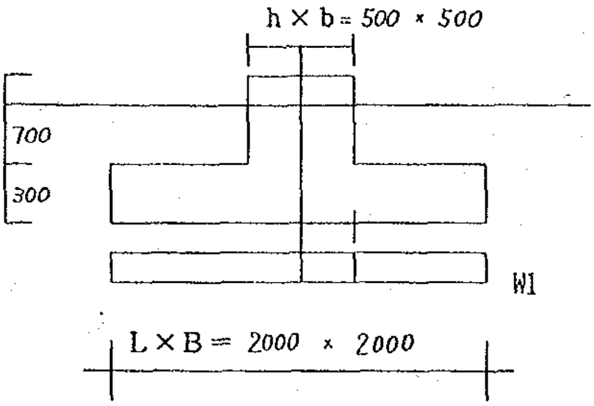
$$\text{nec } At = \frac{MF}{ft \cdot j} = 20.87\ cm^2$$

$$\phi = \frac{Q}{fa \cdot j} = 40.39\ cm$$

$$\tau = \frac{Q}{b \cdot j} = 6.52\ kg/cm^2 < 7.0\ kg/cm^2$$

FOUNDATION

DESIGN OF FOOTING F 11



Factored Load		Design Stress
Load case	ΣN	W1
D+L	29.33	7.33
D+L+W		
D+L+E		
D+W		

Stress

$QF = 7.33 \times (2.0 - 0.5)/2 \times 2.0 = 11.00$ t

$MF = 7.33 \times \{(2.0 - 0.5)/2\}^2 \times 2.0 \times 1/2 = 4.12$ t·m

Reinforcement

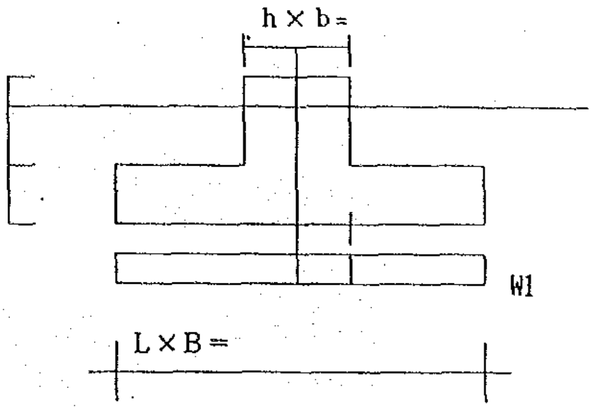
D = 30 d = 20 j = 7/8d = 17.5

$\text{nec } A_t = \dfrac{MF}{f_t \cdot j} = \dfrac{4.12 \times 10^5}{1870 \times 17.5} = 12.59 \text{ cm}^2$

T 11 − #4 (14.19 cm²)

$\tau = \dfrac{Q}{b \cdot j} = \dfrac{11.00 \times 10^3}{200 \times 17.5} = 3.14 \text{ kg/cm}^2 < 7.0$

DESIGN OF FOOTING



Factored Load		Design Stress
Load case	ΣN	W1
D+L		
D+L+W		
D+L+E		
D+W		

Stress

QF =

MF =

Reinforcement

D = d = j = 7/8d

$\text{nec } A_t = \dfrac{MF}{f_t \cdot j} =$

$\tau = \dfrac{Q}{b \cdot j} =$