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Table 1 The Most Economical Depth of Pile Caps [10]

Pile size (mm.)	300	350	400	450	500	550	600	750
Depth of cap (mm.)	700	800	900	1000	1100	1200	1400	1800

Table 2 Mechanical Properties of Steel

Specimen	Diameter (cm.)	Tensile Stress		Modulus of Elasticity
		f_y (ksc.)	f_u (ksc.)	E_s (10^6 ksc.)
Ø9, plain bar	0.90	3,254	5,187	1.972
		3,458	5,580	1.976
		3,301	5,124	1.953
		3,521	5,612	2.108
		3,482	5,406	2.048
	Average	3,403	5,382	2.011

Table 3 Mechanical Properties of Concrete

Specimen	Concrete Strength f'_c, (ksc.)	Average f'_c, (ksc.)	Modulus of Rupture of Concrete f_r, (ksc.)	Modulus of Elasticity E_c, (10^6 ksc.)
P3-1	260 270 244	258	31.93	0.230
P3-2	280 262 272	271	32.73	0.239
P3-3	207 230 248	228	30.02	0.221
P3-4	283 254 227	255	31.75	0.229
P4-1	220 222 235	226	29.89	0.213
P4-2	223 181 229	210	28.81	0.208
P4-3	232 236 228	232	30.28	0.220
P4-4	248 226 250	241	30.86	0.223

Note; $f_r = 1.99\sqrt{f'_c}$

Table 4 Properties of Test Specimens and Test Results

Specimen	Effective Depth, d (cm.)	Steel Content	Concrete Strength f'_c,(ksc.)	Cracking Load, P_{cr} (ton)	Ultimate Load, P_u (ton)
P3-1	25	9-Ø9mm.	258	40.0	76.8
P3-2	25	9-Ø9mm.	271	46.0	76.6
P3-3	25	9-Ø9mm.	228	40.0	69.2
P3-4	25	9-Ø9mm.	255	45.0	86.5
P4-1	25	12-Ø9mm.	226	38.0	82.1
P4-2	25	12-Ø9mm.	210	35.0	80.0
P4-3	25	12-Ø9mm.	232	37.0	89.1
P4-4	25	12-Ø9mm.	241	44.0	83.1

Notes :
1. The reinforcement arrangements of test specimens are shown in Fig. 3.11-3.12 .
2. All cracking loads observed from load-strain curves of the reinforcement.
3. Column size, c = 15 cm.

Table 5 Comparison of Experimental and Theoretical Cracking Loads

Specimen	Observed Cracking Load, P_{cr}	Beam Analogy, P'_{cr}	$\frac{P_{cr}}{P'_{cr}}$	Truss Analogy, P''_{cr}	$\frac{P_{cr}}{P''_{cr}}$
P3-1	40.0	47.6	0.84		
P3-2	46.0	48.8	0.94	34.2	1.35
P3-3	40.0	44.8	0.89		
P3-4	45.0	47.4	0.95	19.1	2.36
P4-1	38.0	45.2	0.84		
P4-2	35.0	43.5	0.80	25.2	1.39
P4-3	37.0	45.8	0.81	21.0	1.76
P4-4	44.0	46.6	0.94	27.4	1.61

Note; 1. All load values are in tons.

2. Sample of calculations are shown in Appendix B.

Table 6 Comparison of Experimental and Theoretical Ultimate Loads

Specimen	Observed Ultimate Load, P_u	Beam Analogy, P'_u	$\frac{P_u}{P'_u}$	Truss Analogy, P''_u	$\frac{P_u}{P''_u}$
P3-1	76.8	33.6	2.29		
P3-2	76.6			45.9	1.67
P3-3	69.2	54.8	1.26		
P3-4	86.5			26.5	3.26
P4-1	82.1	55.6	1.48		
P4-2	80.0			39.5	2.03
P4-3	89.1			55.9	1.59
P4-4	83.1			44.9	1.85

Note; 1. All load values are in tons.

2. Sample of calculations are shown in Appendix B.

Table 7 Comparison of Experimental Ultimate Loads and Calculated Design Loads (Working Stress Design)

Specimen	Observed Ultimate Load, P_u	Calculated Design Load, P_d	$F.S. = \frac{P_u}{P_d}$	$\frac{(F.S.)_{cap}}{(F.S.)_{pile}}$
P3-1	76.8	16.79	4.57	1.52
P3-2	76.6	22.97	3.33	1.11
P3-3	69.2	27.97	2.47	0.82
P3-4	86.5	13.26	6.52	2.17
P4-1	82.1	28.42	2.89	0.96
P4-2	80.0	19.75	4.05	1.35
P4-3	89.1	27.93	3.19	1.06
P4-4	83.1	22.47	3.70	1.23

Notes; 1. All load values are in tons.

2. $(F.S.)_{pile} = 3.0$

Table 8 Comparison of Factor of Safety in Each Specimen

Specimen	$F_1 = \frac{P_u}{P_{cr}}$	$F_2 = \frac{P_{cr}}{P_d}$	$F_3 = \frac{P_u}{P_d}$	$\frac{(F_1)}{(F_1)^*}$	$\frac{(F_2)}{(F_2)^*}$	$\frac{(F_3)}{(F_3)^*}$
P3-1*	1.92	2.38	4.57	1.00	1.00	1.00
P3-2	1.67	2.00	3.33	0.87	0.84	0.73
P3-3	1.73	1.43	2.47	0.90	0.60	0.54
P3-4	1.92	3.39	6.52	1.00	1.42	1.43
P4-1*	2.16	1.34	2.89	1.00	1.00	1.00
P4-2	2.29	1.77	4.05	1.06	1.32	1.40
P4-3	2.41	1.32	3.19	1.12	0.99	1.10
P4-4	1.89	1.96	3.70	0.88	1.46	1.28

Note; * coresponding to the conventional type of reinforcement

Table 9 Comparison of Calculated Ultimate Loads Capacity Due to Shear and Flexure and Experimental Ultimate Loads at First Yield of Reinforcement

Specimen	Observed Ultimate Load, P_u	Yield Load of Steel, P_y	Cal. Ultimate Load	
			Shear, P_{vu}	Flexure, P'_u
P3-1	76.8	*	85.7	33.6
P3-2	76.6	60.5	88.3	45.9
P3-3	69.2	63.0	80.6	54.8
P3-4	86.5	*	80.2	26.5
P4-1	82.1	66.2	68.6	55.6
P4-2	80.0	53.8	66.2	39.5
P4-3	89.1	65.5	73.8	55.9
P4-4	83.1	71.5	72.3	44.9

Note; 1. All load values are in tons.

2. P_y observed from load-strain curves of the reinforcement.

3. P_{vu}, see Appendix B.

Table 10 Prediction for Strength of Full-Scale Caps from Model Test Results

Specimen	Cracking Load (ton)	Ultimate Load (ton)
P3-1	360	691.2
P3-2	414	689.4
P3-3	360	622.8
P3-4	405	778.5
P4-1	342	738.9
P4-2	315	720.0
P4-3	333	801.9
P4-4	396	747.9

Note ; The prediction for strength of full-scale caps from model tests are obtained by multiplying the force scale factor, 9.0, to the model test results.

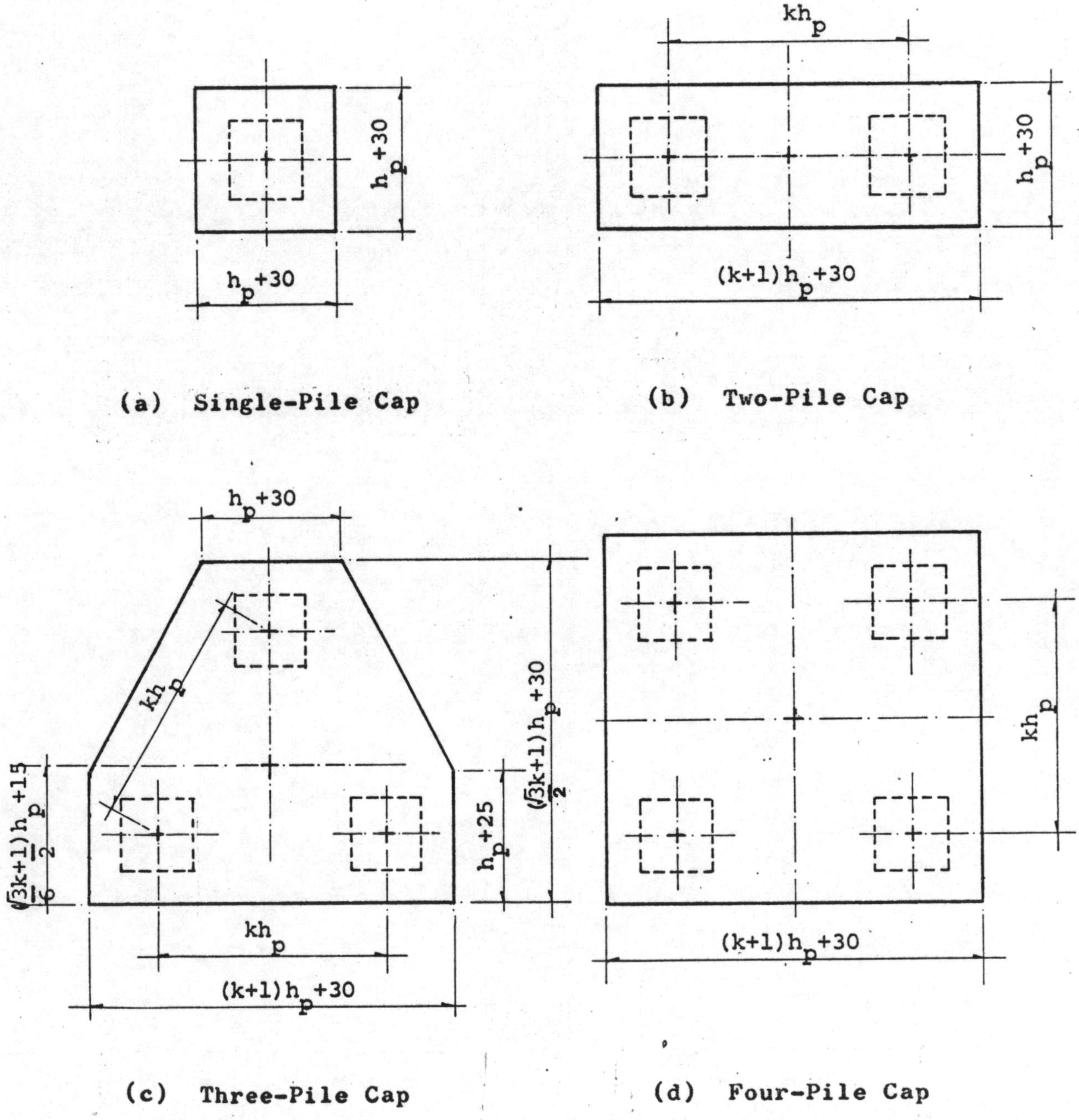
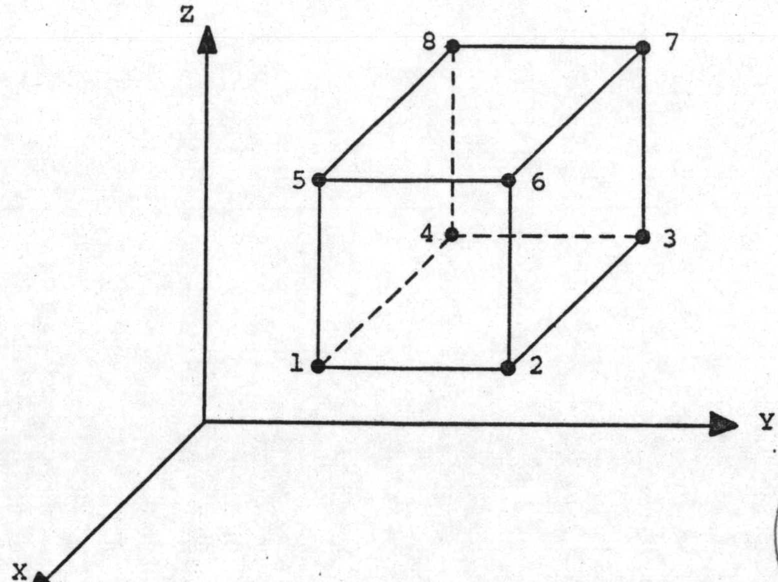
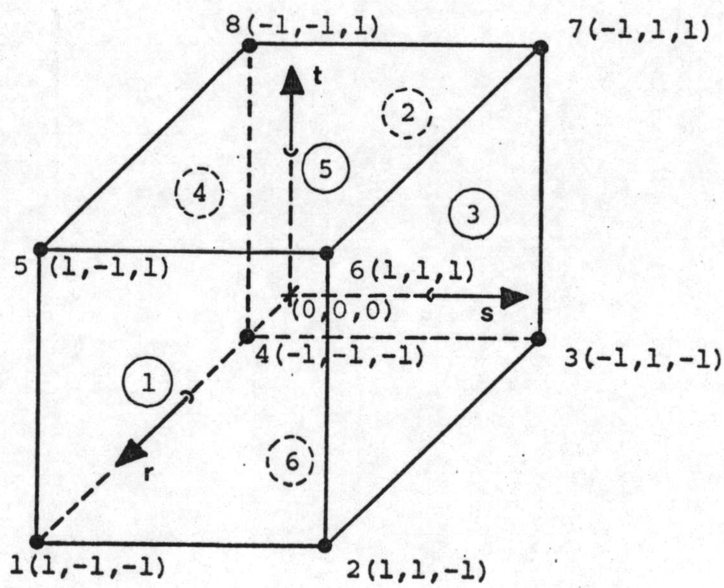


Fig. 3.1 Standard Pile Caps



(a) Global Mapping



(b) Local Mapping

Fig. 3.2 Three Dimensional Finite Element in Global and Local System of Coordinates

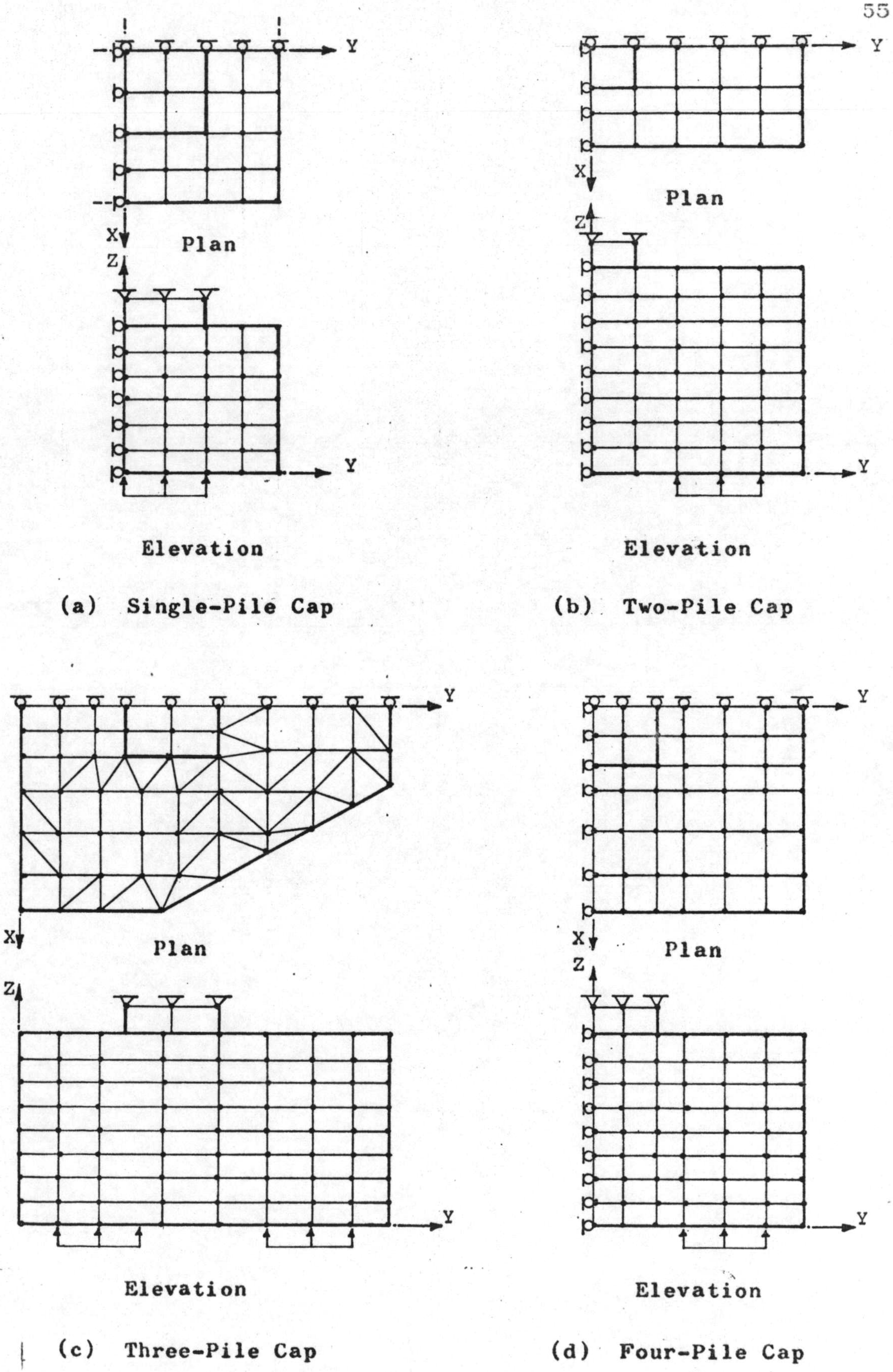


Fig. 3.3 Finite Element Models for Standard Pile Caps

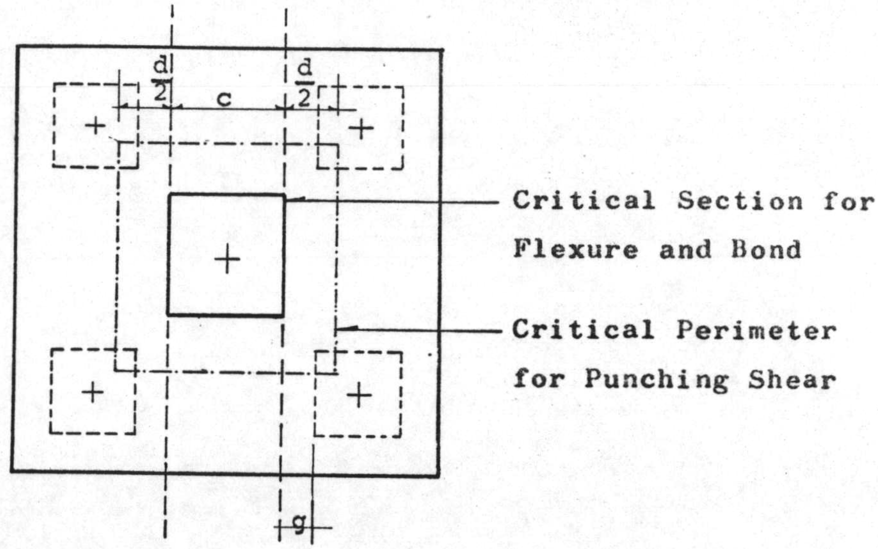
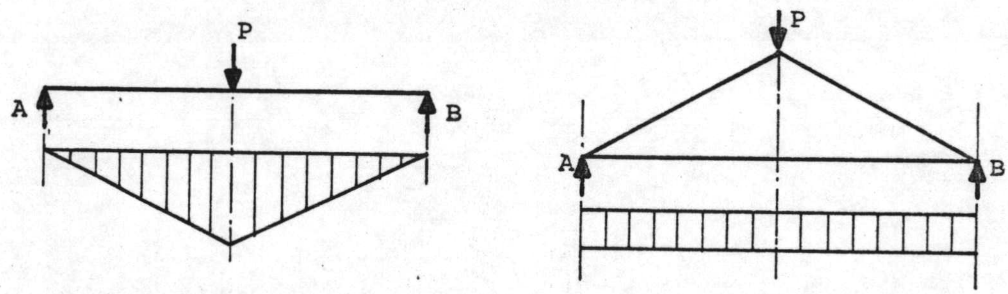


Fig. 3.4 Critical Sections for Flexure, Bond and Shear in Pile Cap Based on Beam Analogy



(a) Beam Reinforcement **(b) Tie Reinforcement**

Fig. 3.5 Variation of Tension in Reinforcement

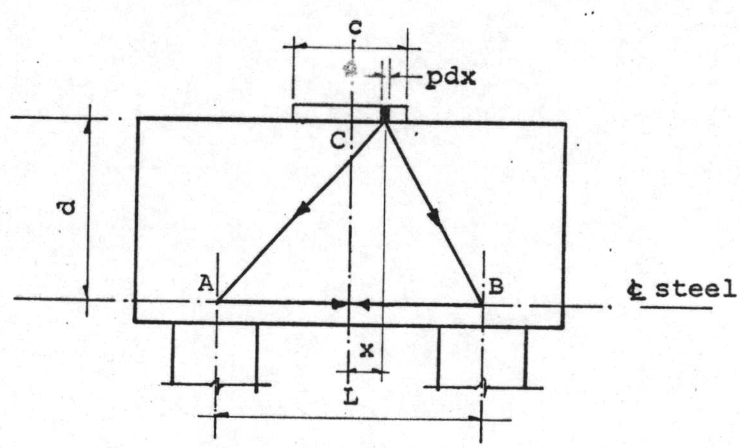
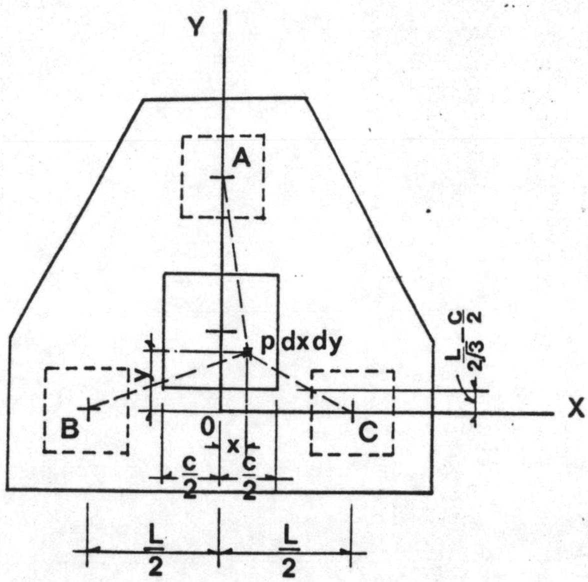


Fig. 3.6 Internal Force System in Two-Pile Cap Based on Truss Analogy



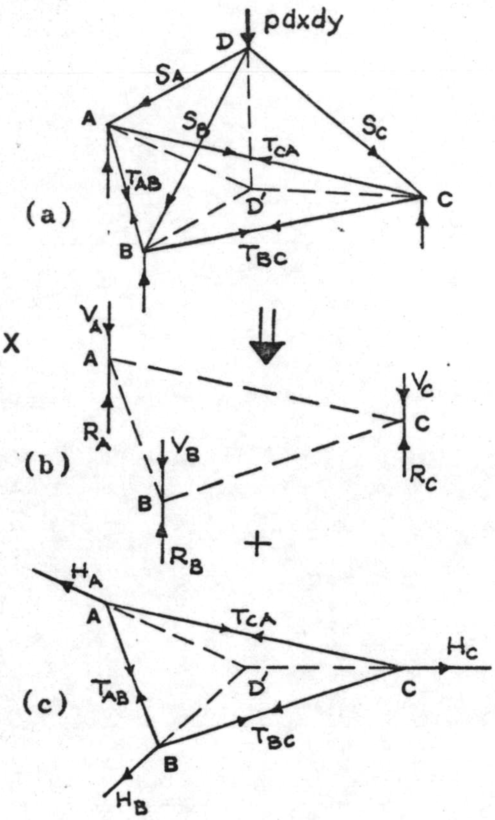
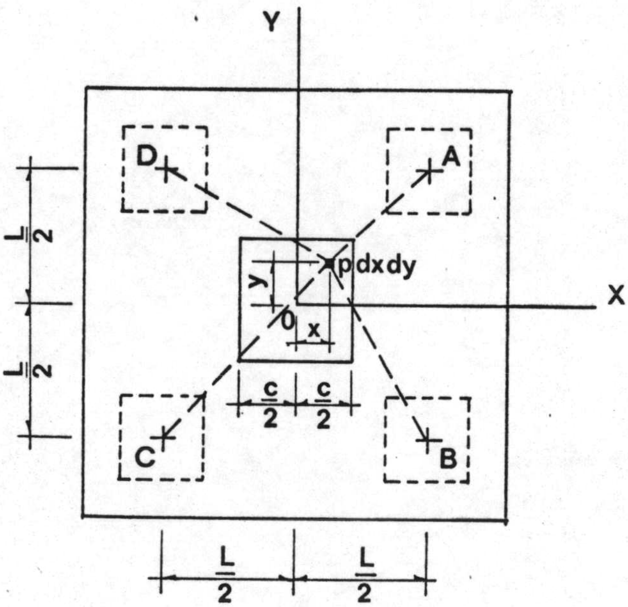


Fig. 3.7 Internal Force System in Three-Pile Cap Based on Truss Analogy



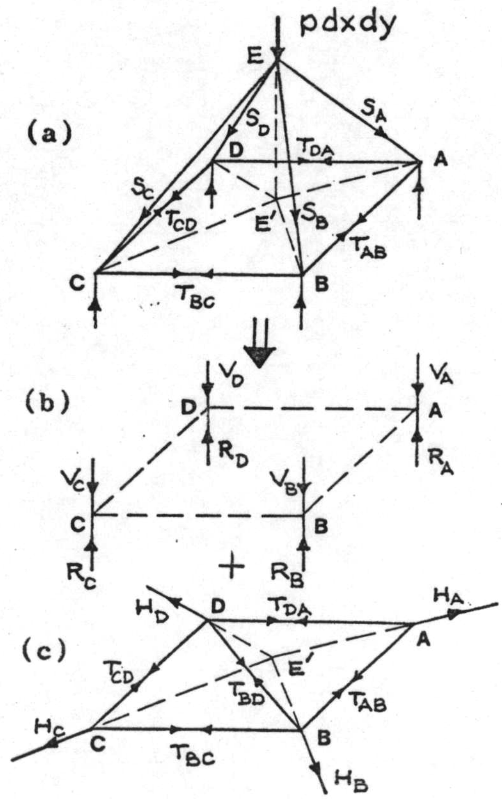


Fig. 3.8 Internal Force System in Four-Pile Cap Based on Truss Analogy

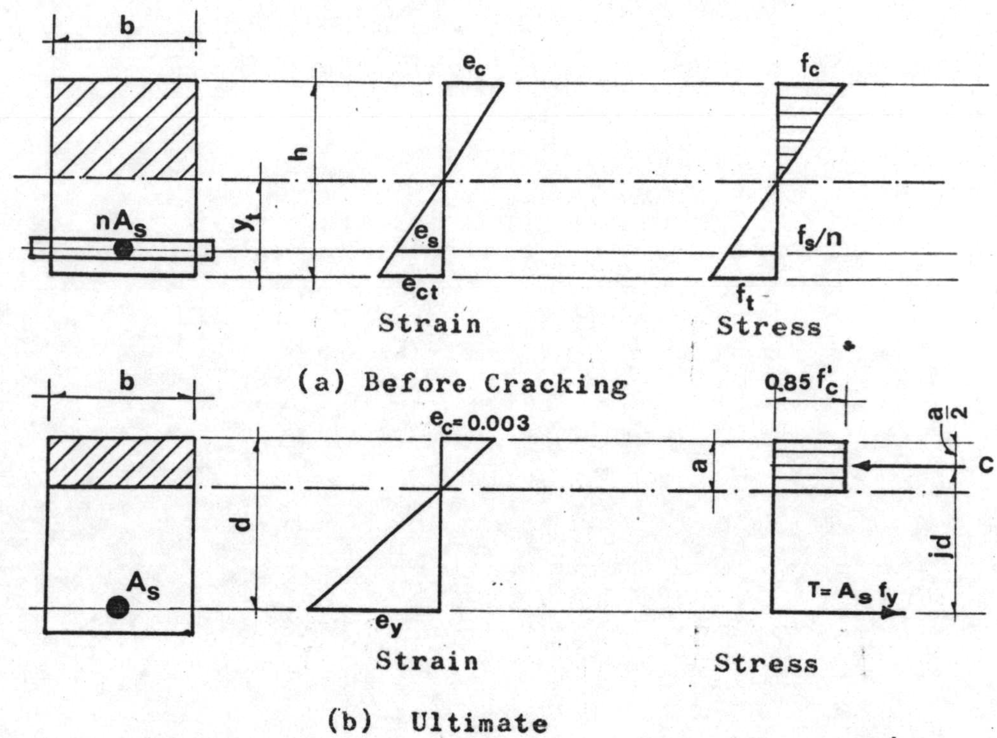


Fig. 3.9 **Stress Distribution in Concrete on Beam Cross Section Under Bending Moment at Cracking and Ultimate Conditions**

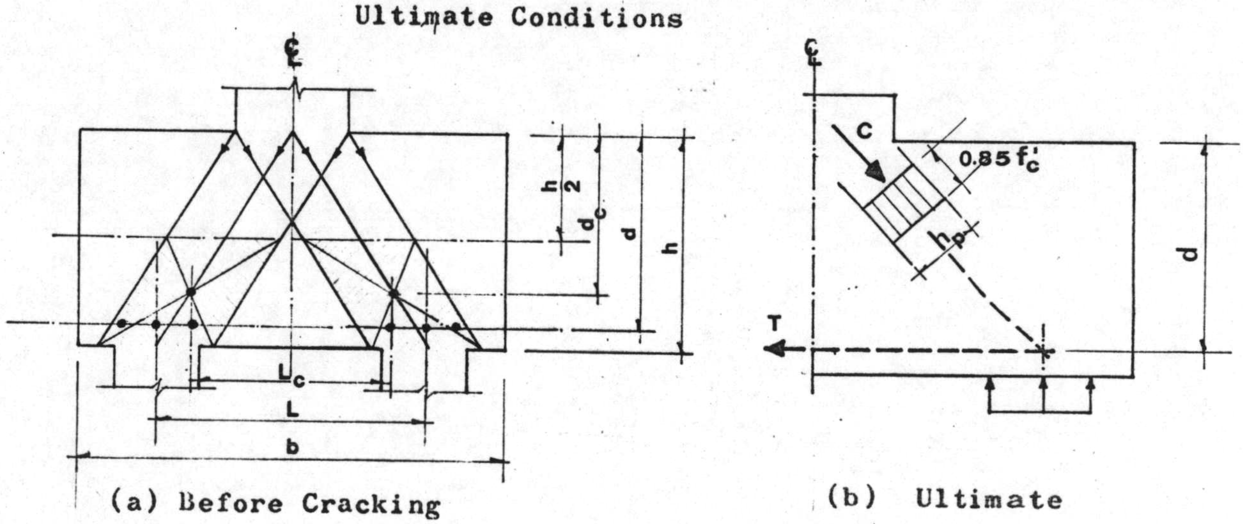
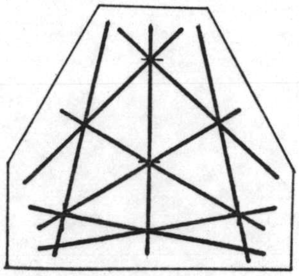
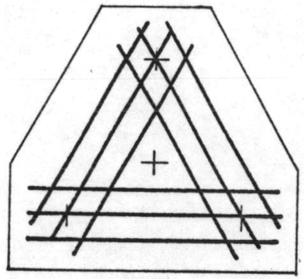


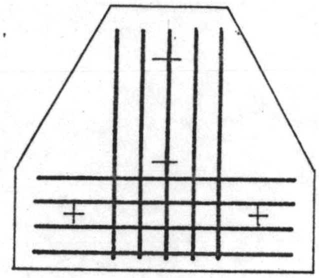
Fig. 3.10 **Equivalent Transformed Section of Concrete Subjected to Tension Based on Truss Analogy at Cracking and Ultimate Conditions**



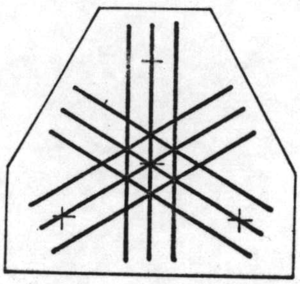
(a) P3-1



(b) P3-2

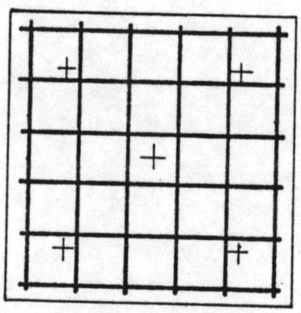


(c) P3-3

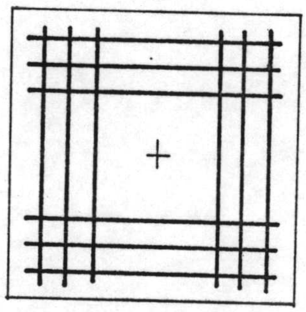


(d) P3-4

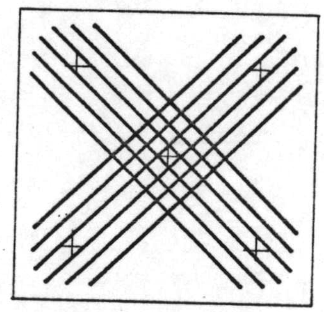
Fig. 3.11 Proposed Reinforcement Arrangements in Three-Pile Caps



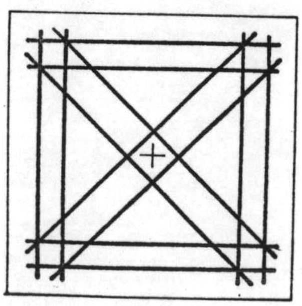
(a) P4-1



(b) P4-2

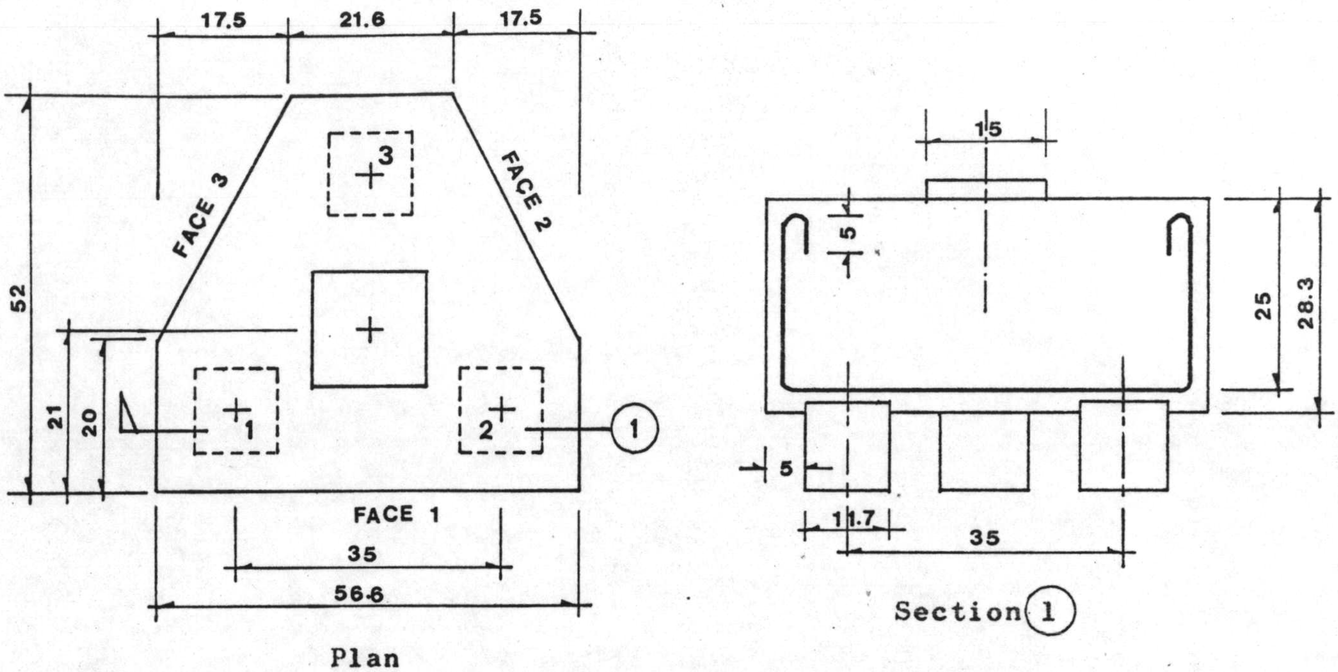


(c) P4-3

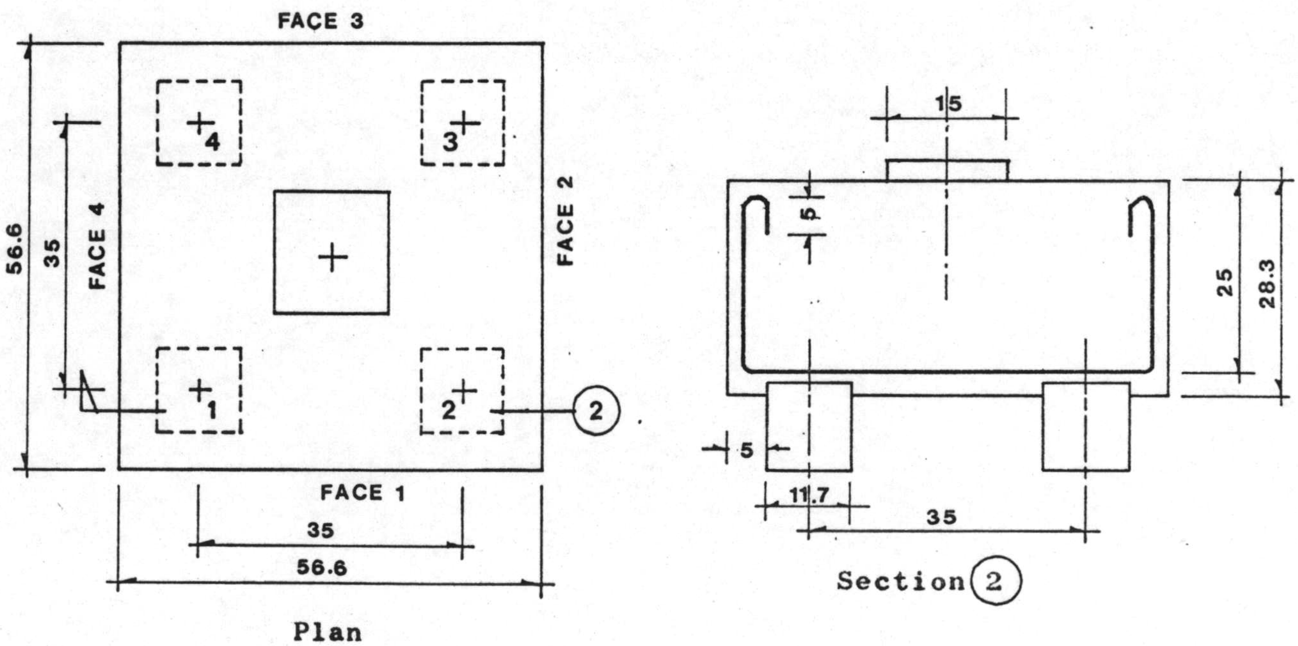


(d) P4-4

Fig. 3.12 Proposed Reinforcement Arrangements in Four-Pile Caps



(a) Three-Pile Cap Model



(b) Four-Pile Cap Model

Fig. 5.1 Typical Dimensions of Model Specimens and Details of Reinforcement

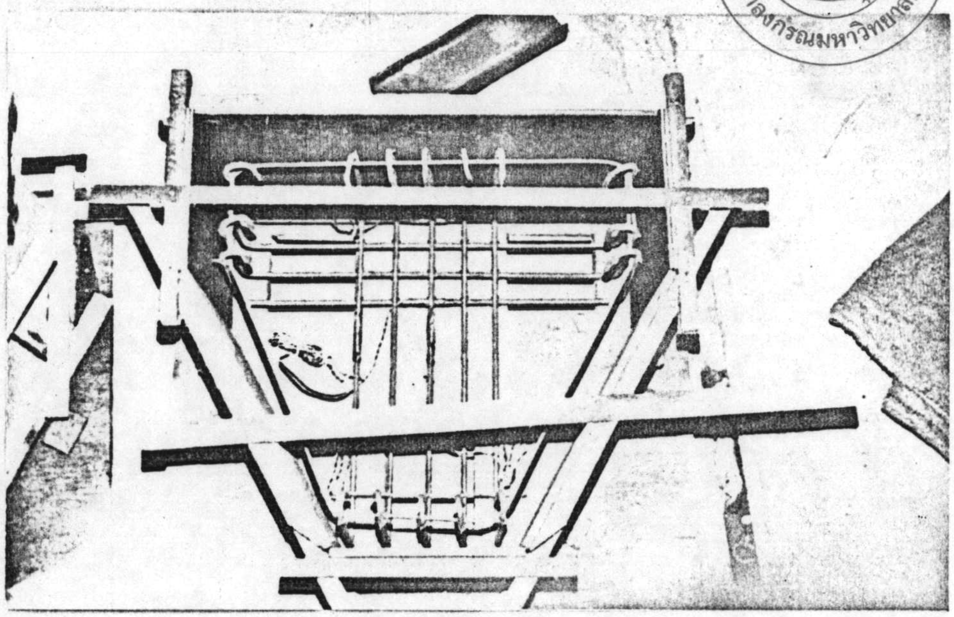


Fig. 5.2 Set-Up for Casting Three-Pile Cap Model

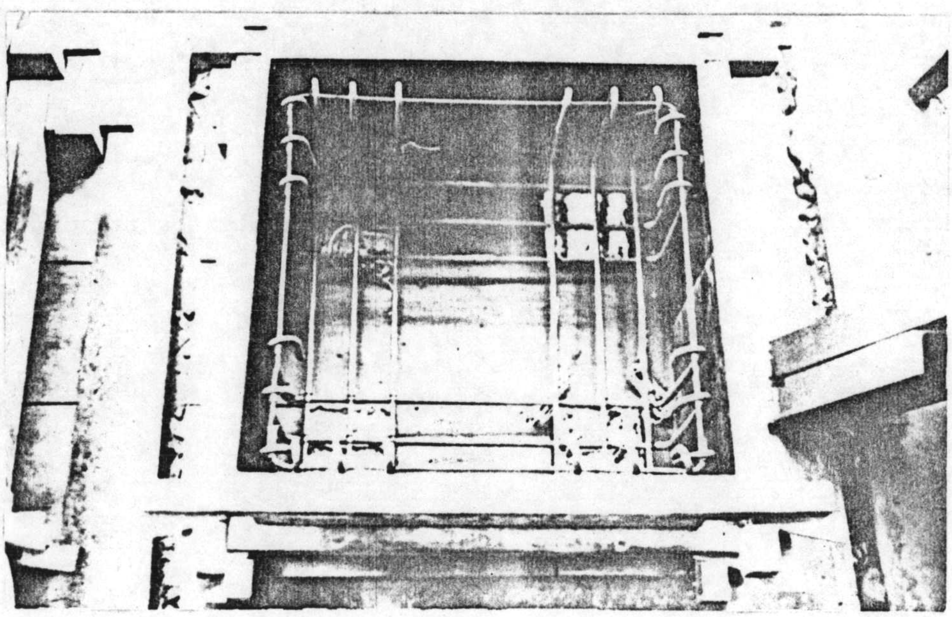


Fig. 5.3 Set-Up for Casting Four-Pile Cap Model

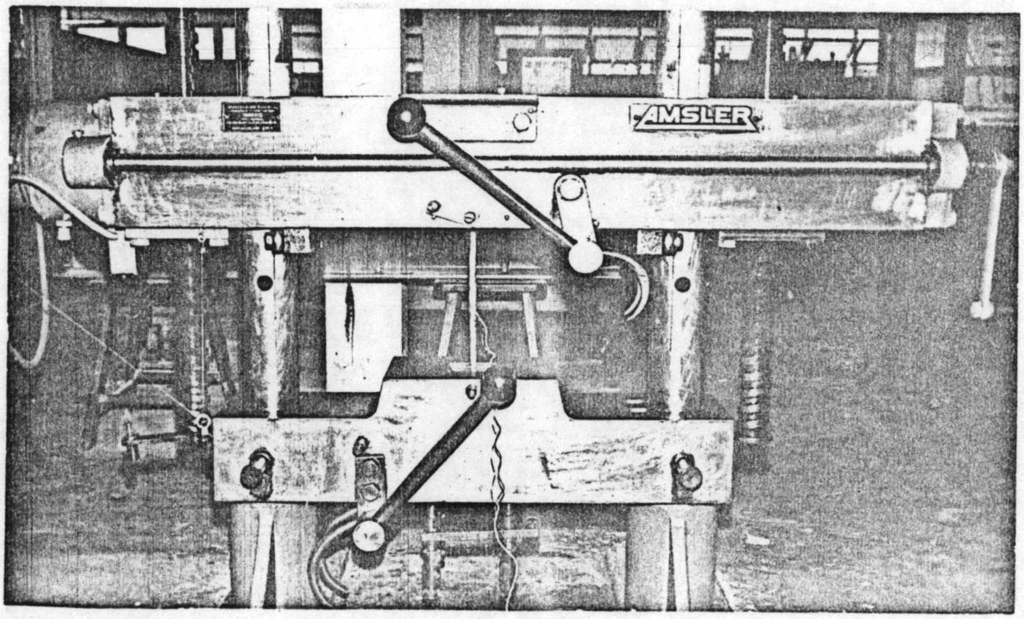


Fig. 5.4 Testing for Strength of Steel Under Direct Tension

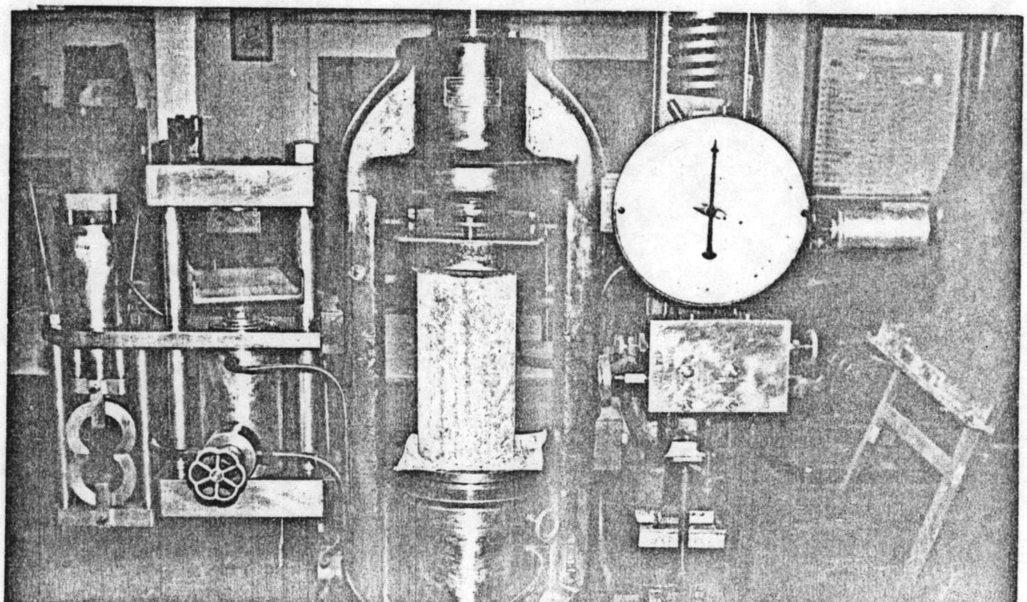


Fig. 5.5 Testing for Strength of Concrete Under Axial Compression

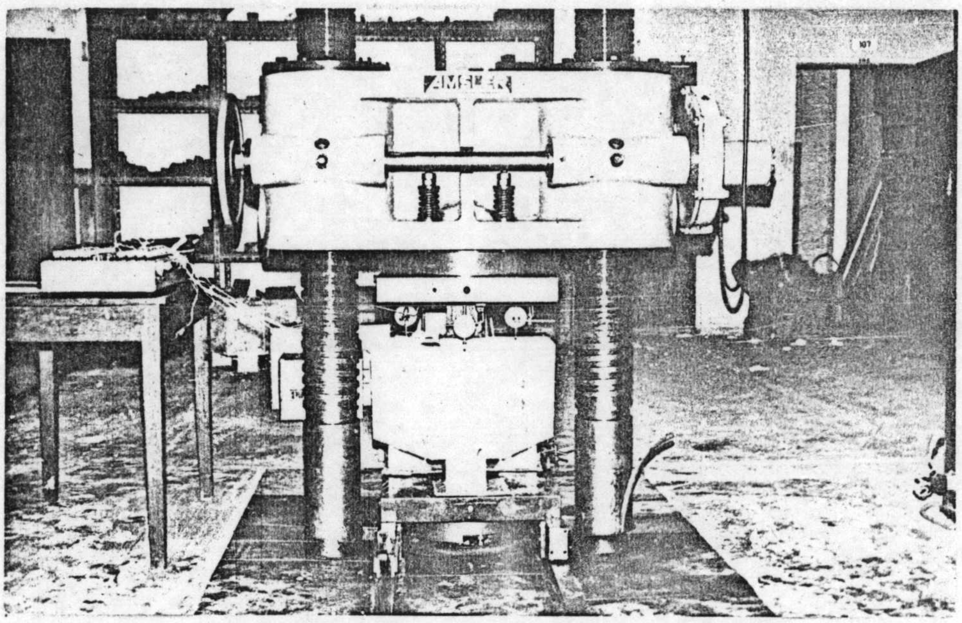


Fig. 5.6 General View of Pile Cap Test Set-Up

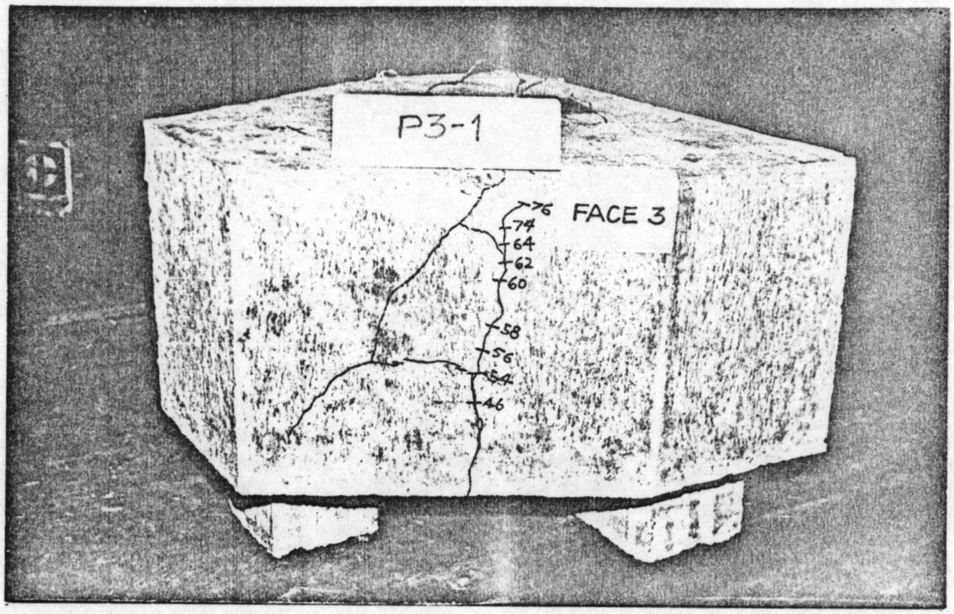


Fig. 5.7 Model P3-1 After Testing

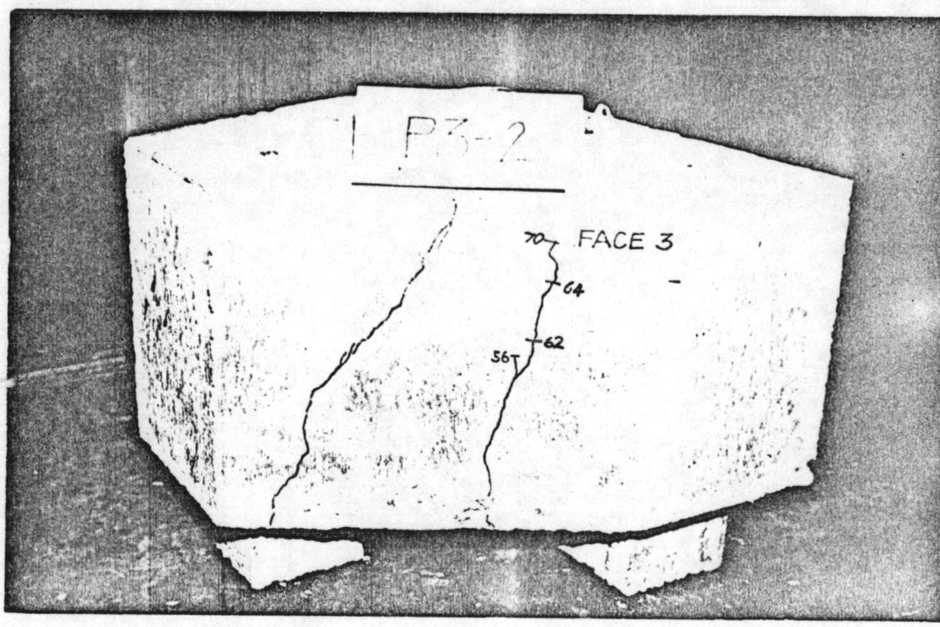


Fig. 5.8 Model P3-2 After Testing

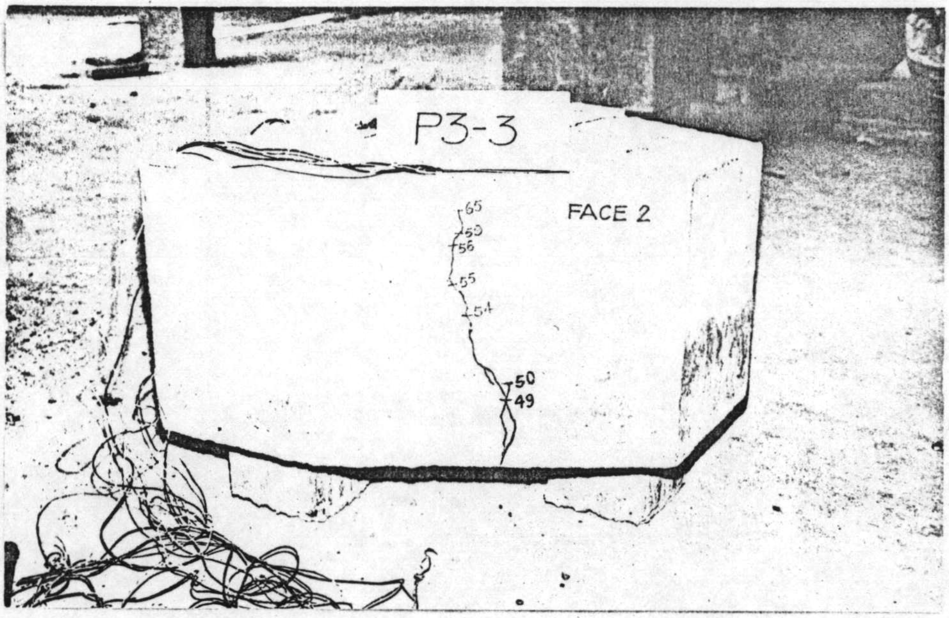


Fig. 5.9 Model P3-3 After Testing

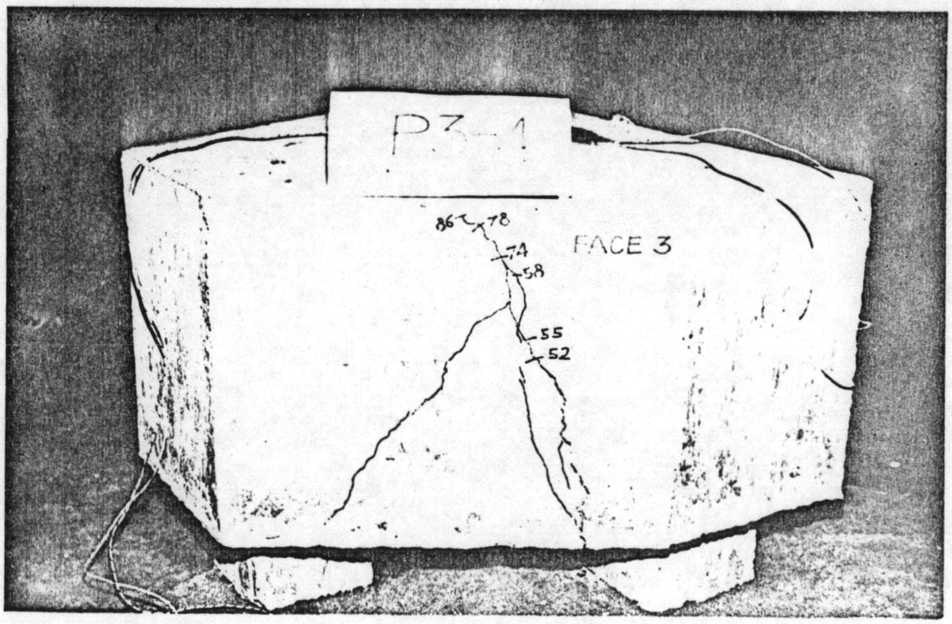


Fig. 5.10 Model P3-4 After Testing

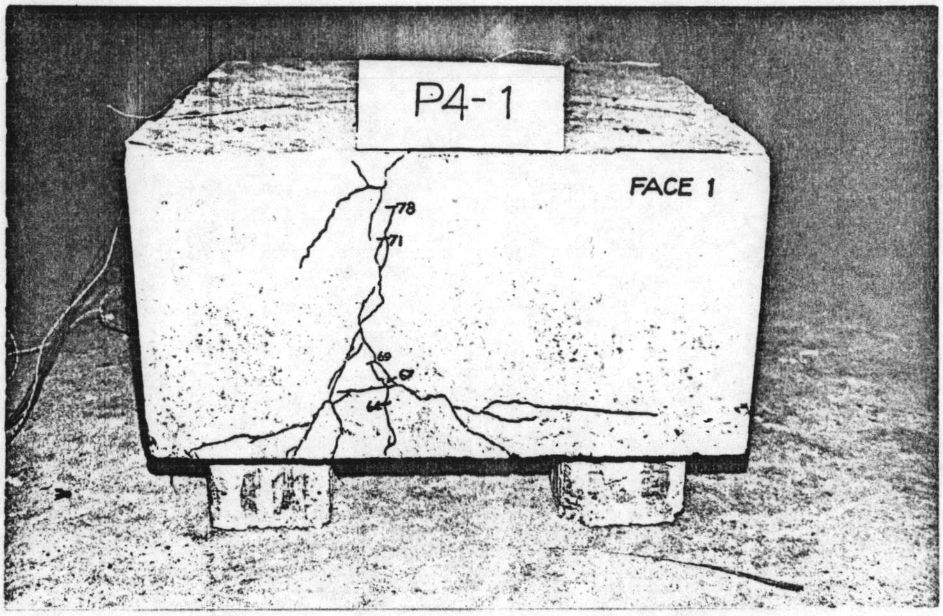


Fig. 5.11 Model P4-1 After Testing

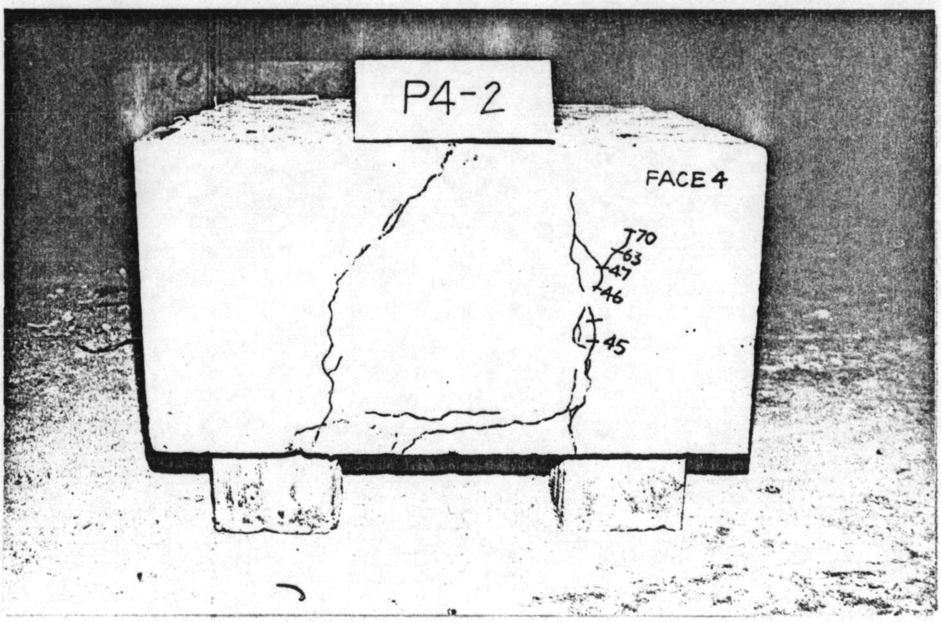


Fig. 5.12 Model P4-2 After Testing

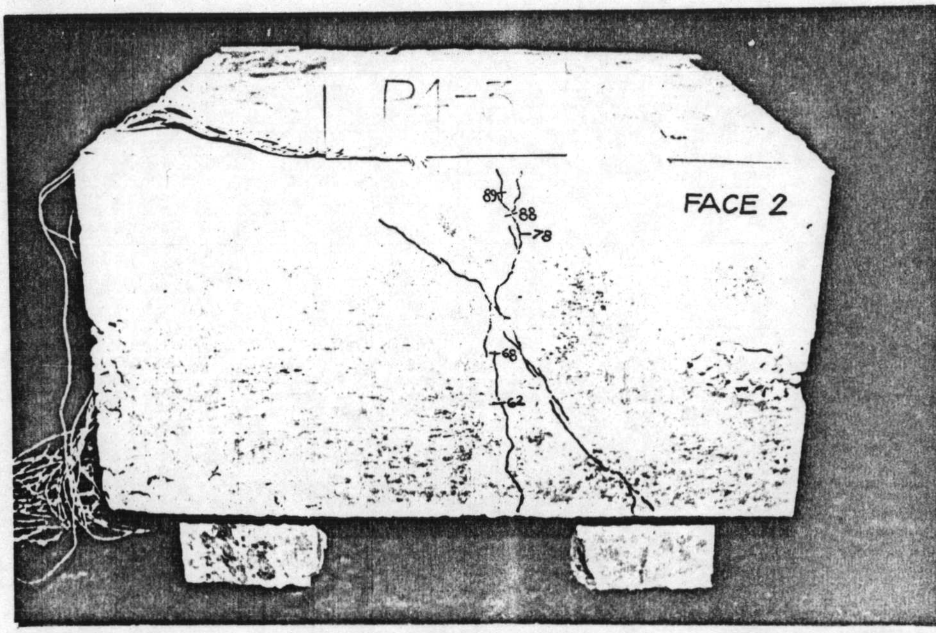


Fig. 5.13 Model P4-3 After Testing

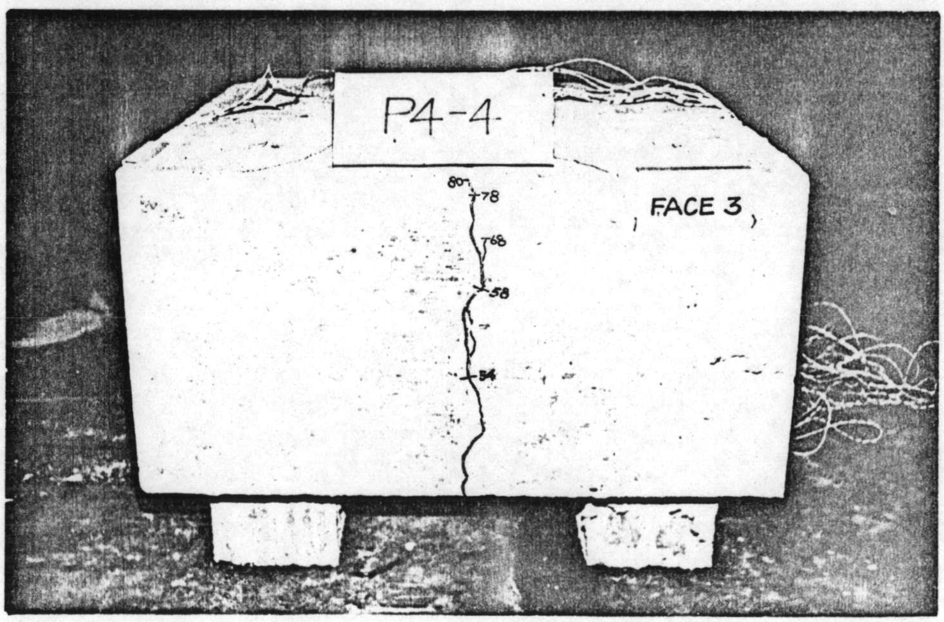


Fig. 5.14 Model P4-4 After Testing

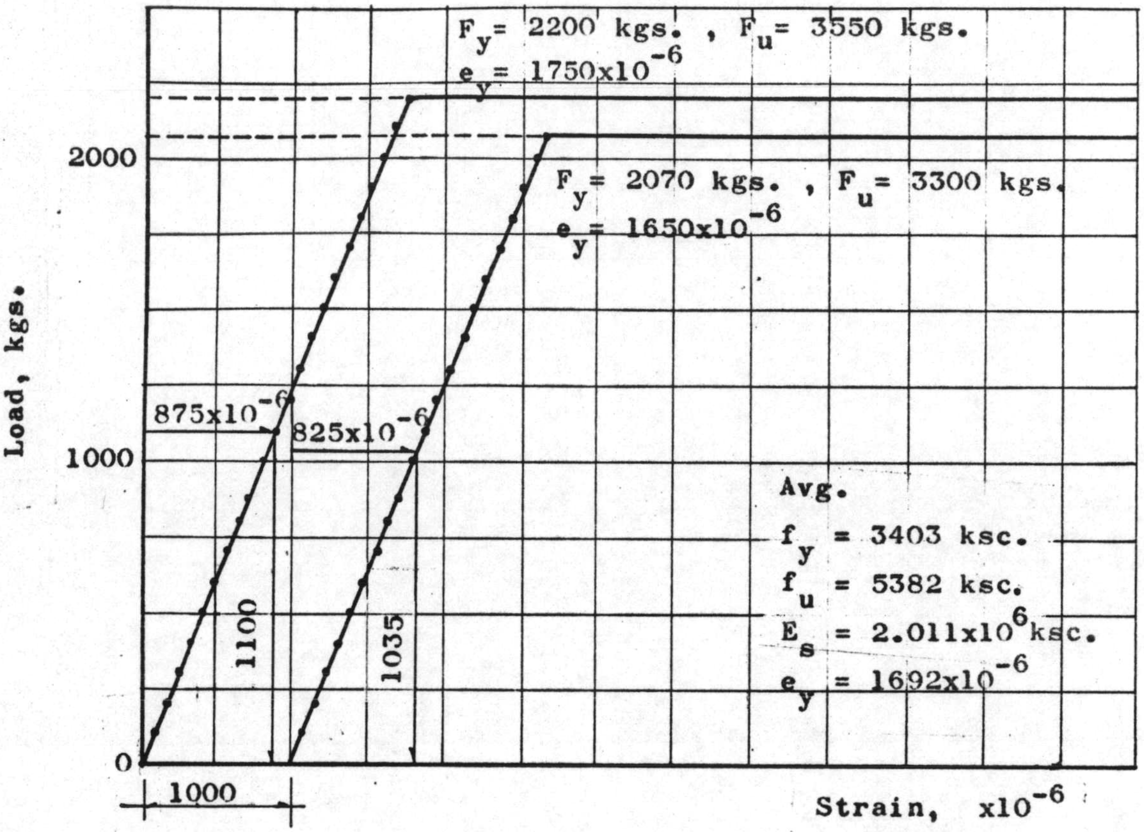


Fig. 6.1 Typical Stress-Strain Curves for Steel Under Direct Tension

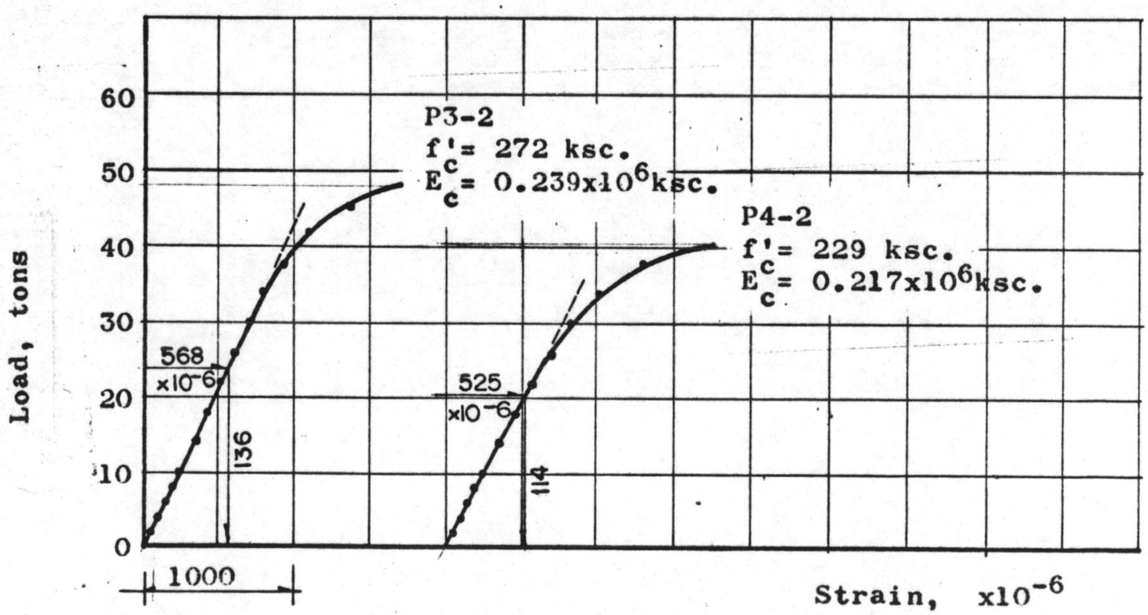


Fig. 6.2 Typical Stress-Strain Curves for Concrete Under Axial Compression

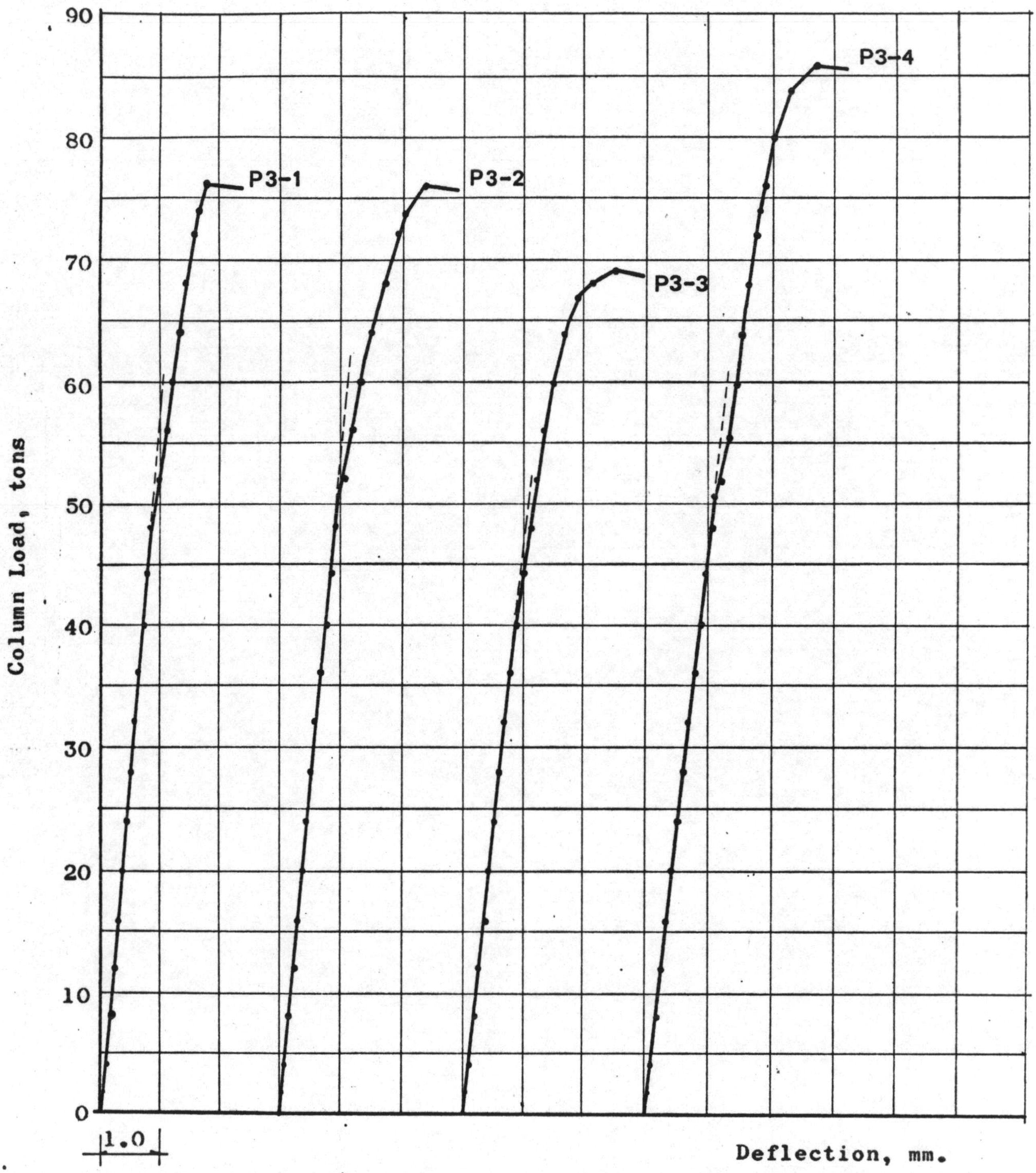


Fig. 6.3 Comparison of Load-Deflection Curves Between Three-Pile Cap Models

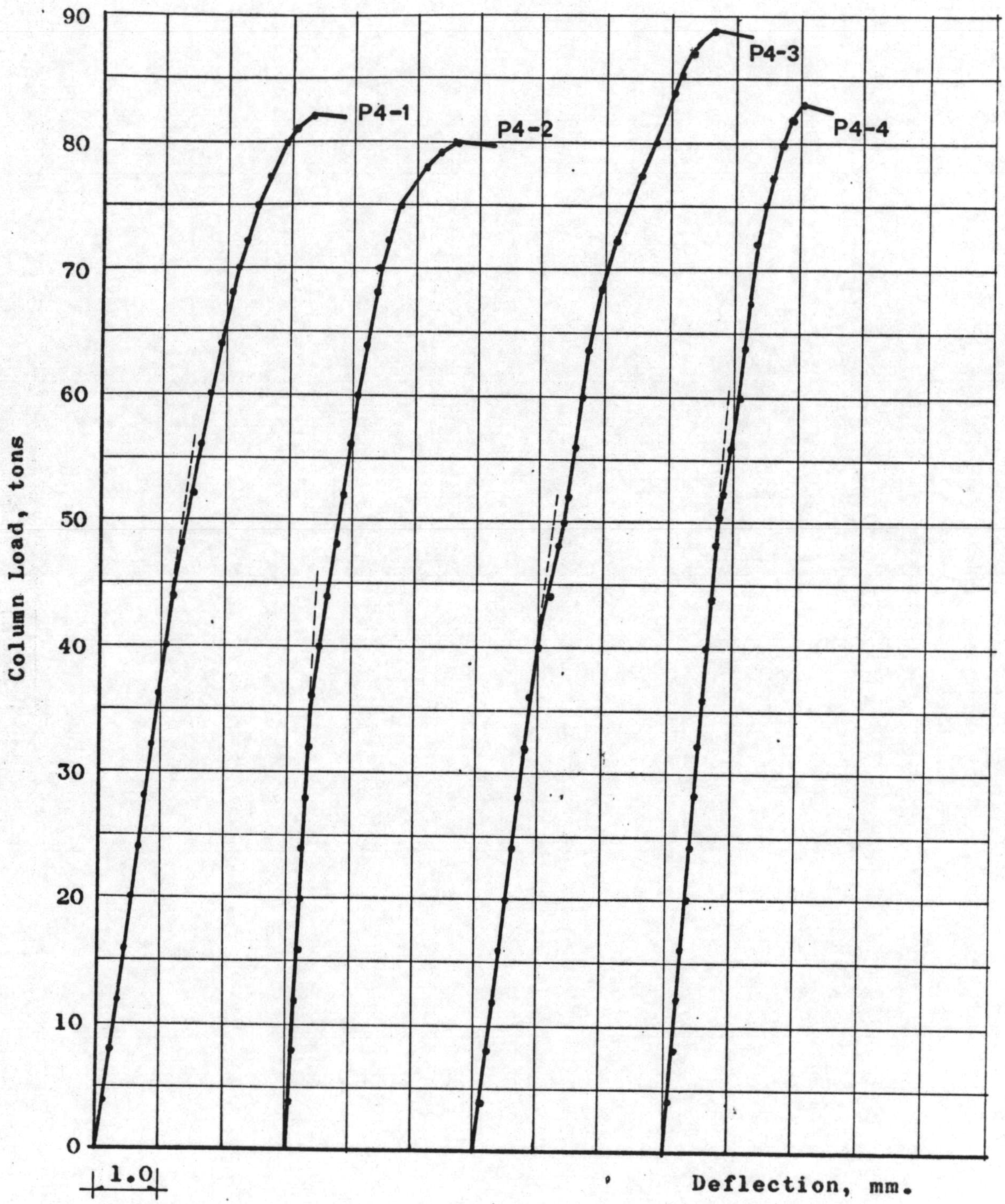


Fig. 6.4 Comparison of Load-Deflection Curves Between Four-Pile Cap Models

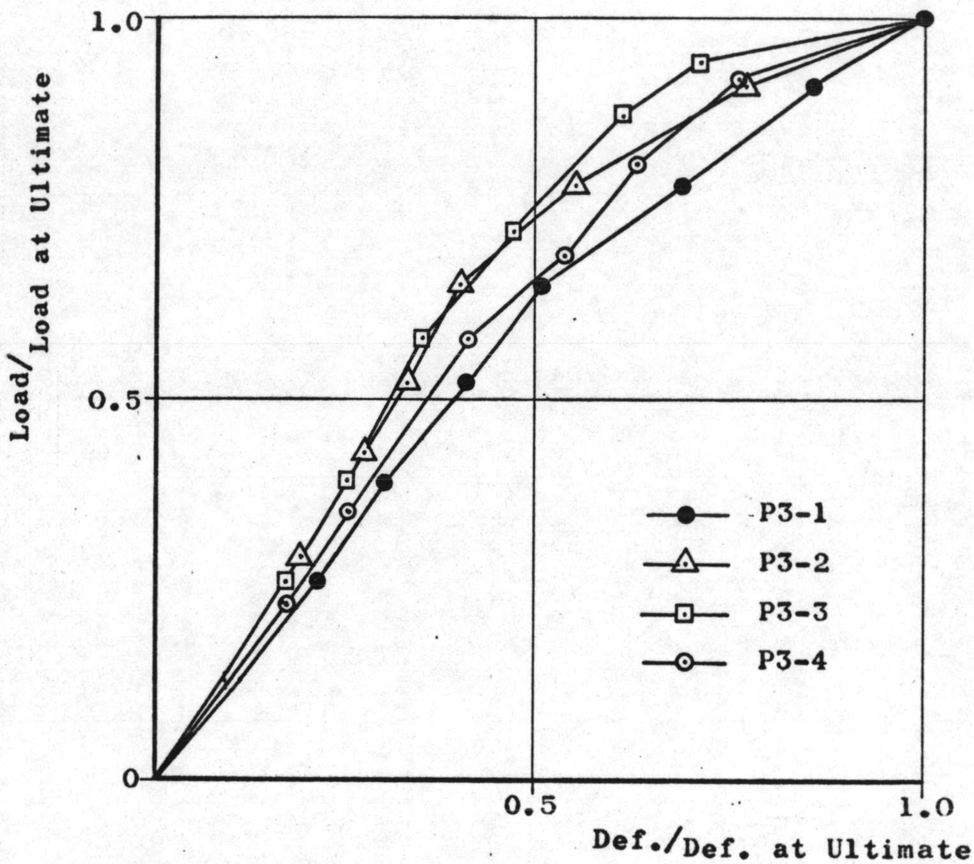


Fig. 6.5 Normalized Load-Deflection Curves for Three-Pile Cap Models

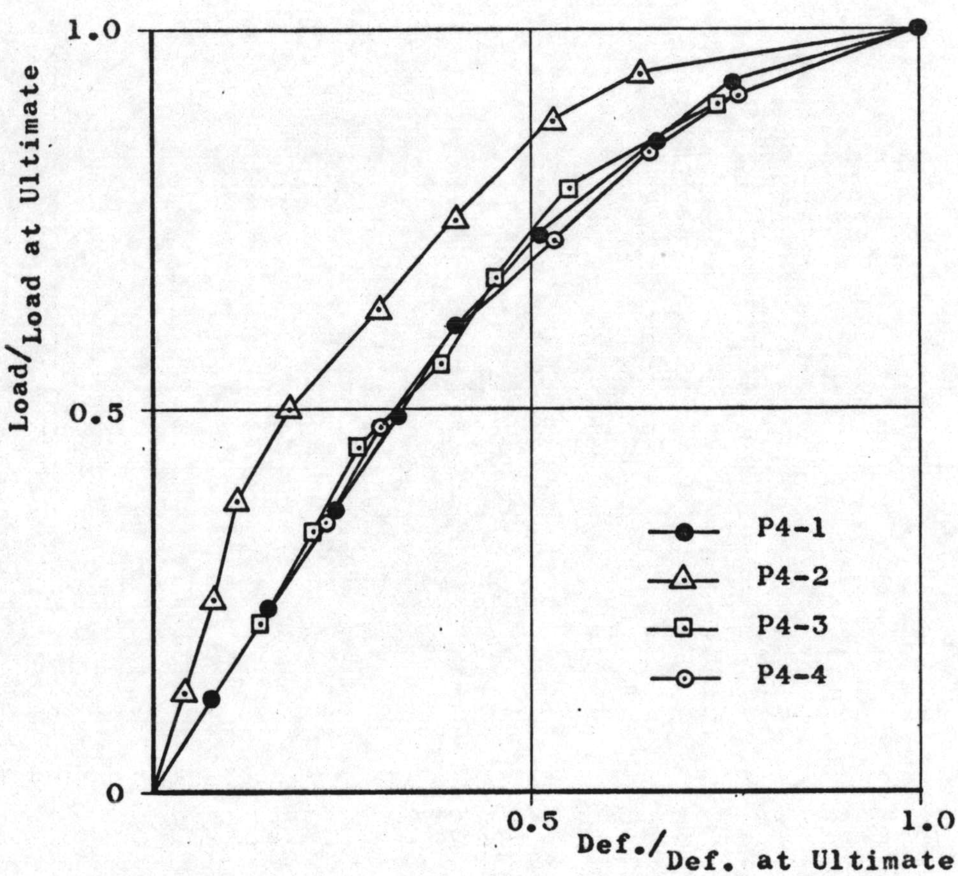


Fig. 6.6 Normalized Load-Deflection Curves for Four-Pile Cap Models

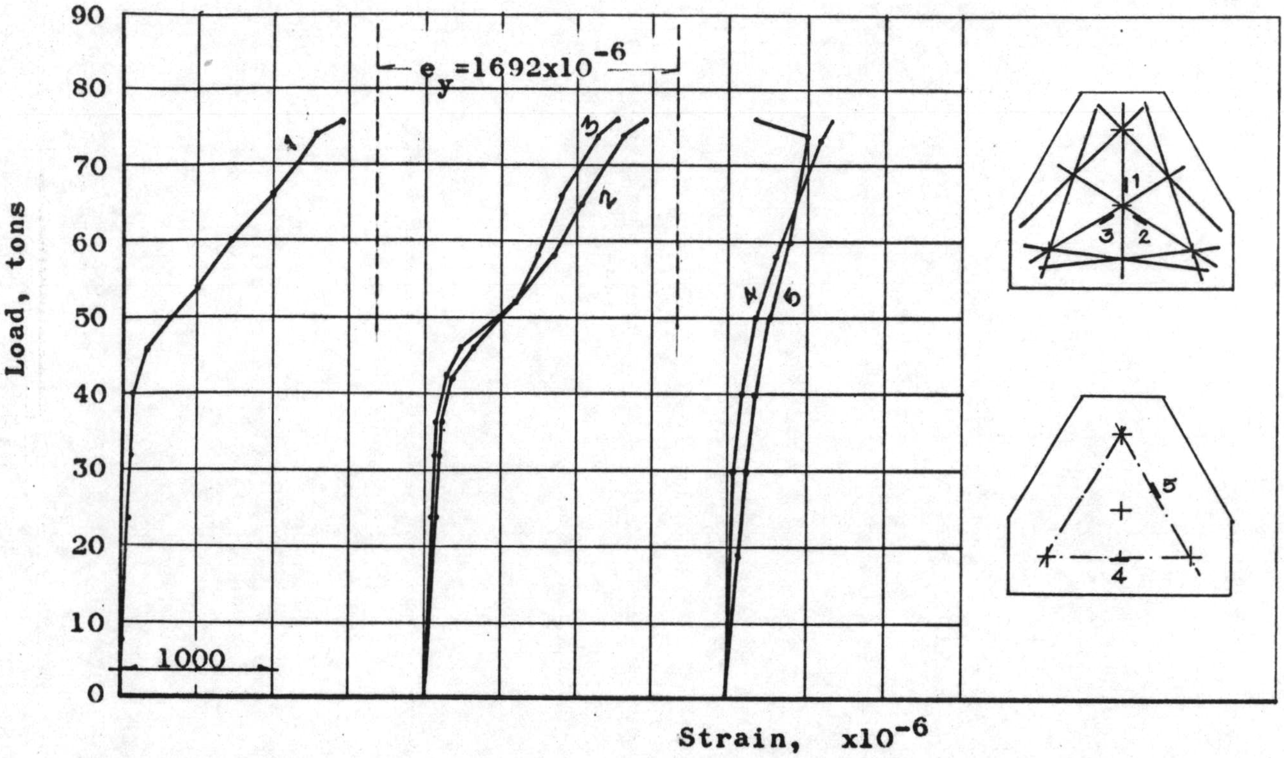


Fig. 6.7 Load-Strain Curves of Steel and Concrete for P3-1

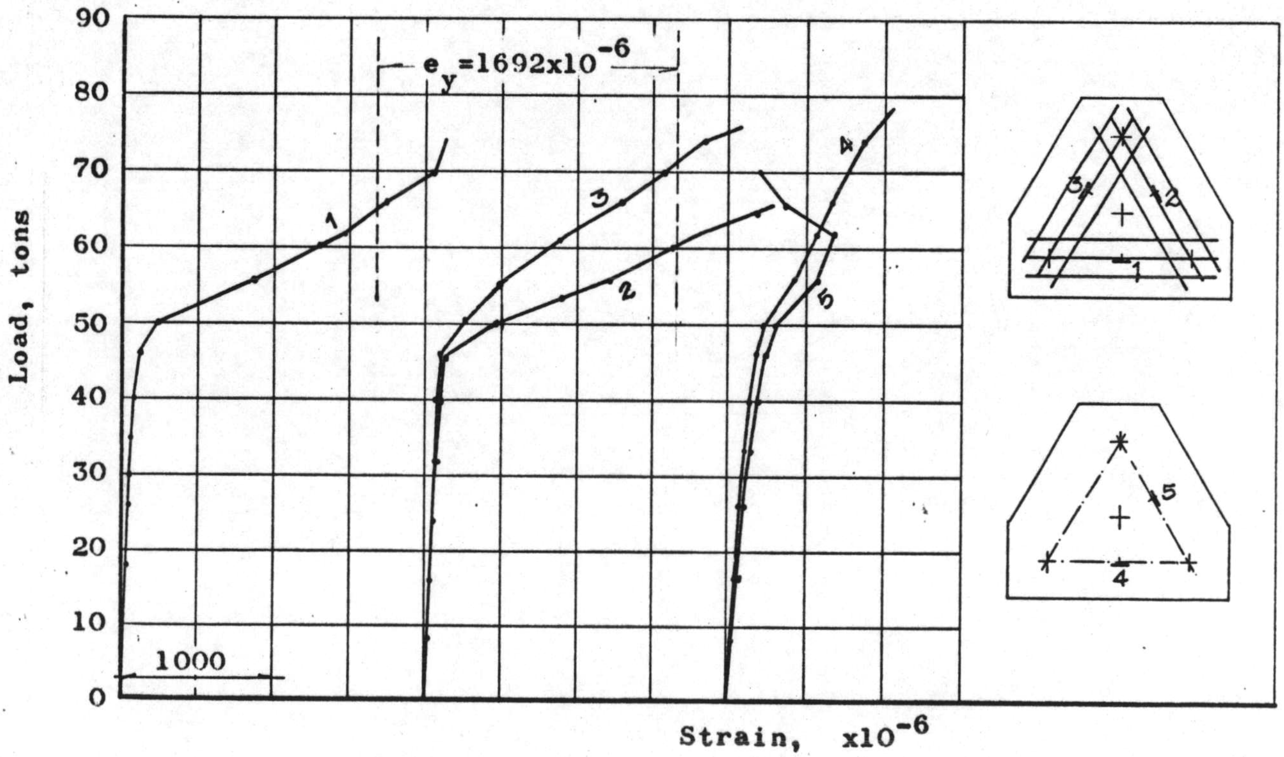


Fig. 6.8 Load-Strain Curves of Steel and Concrete for P3-2

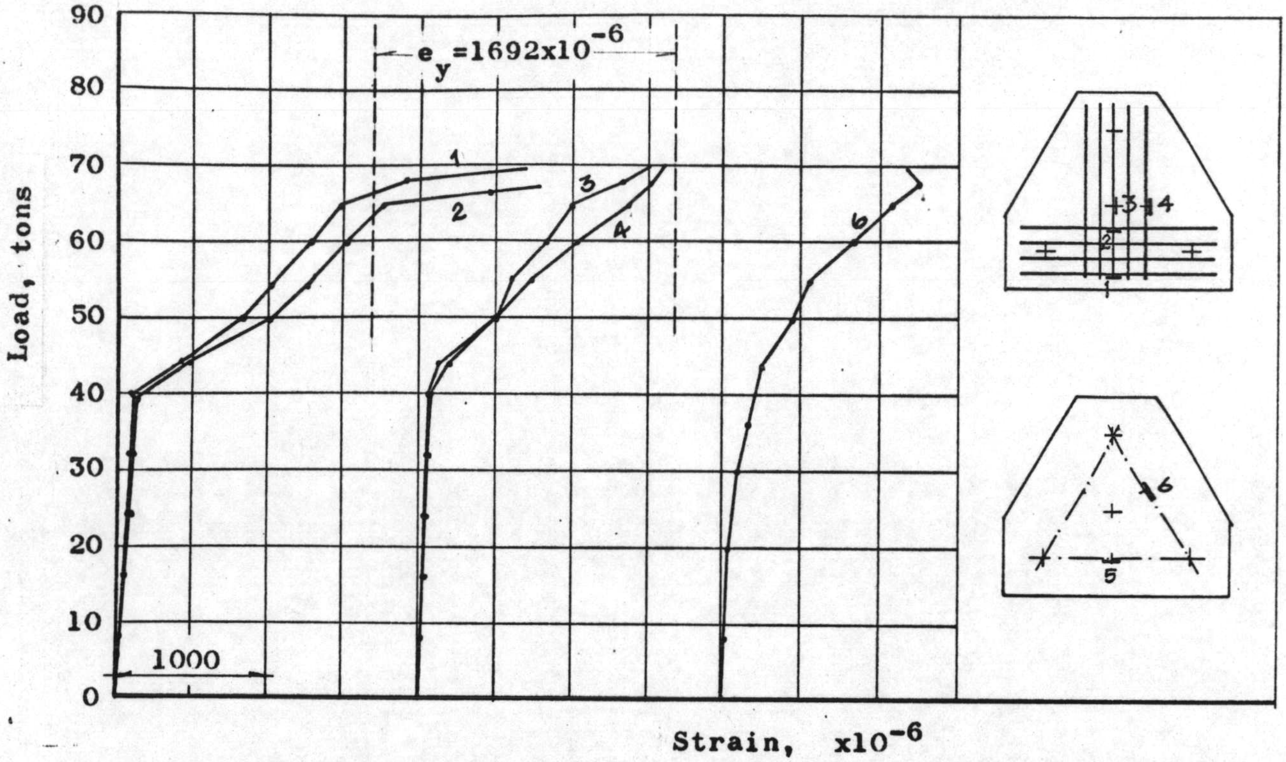


Fig. 6.9 Load-Strain Curves of Steel and Concrete for P3-3

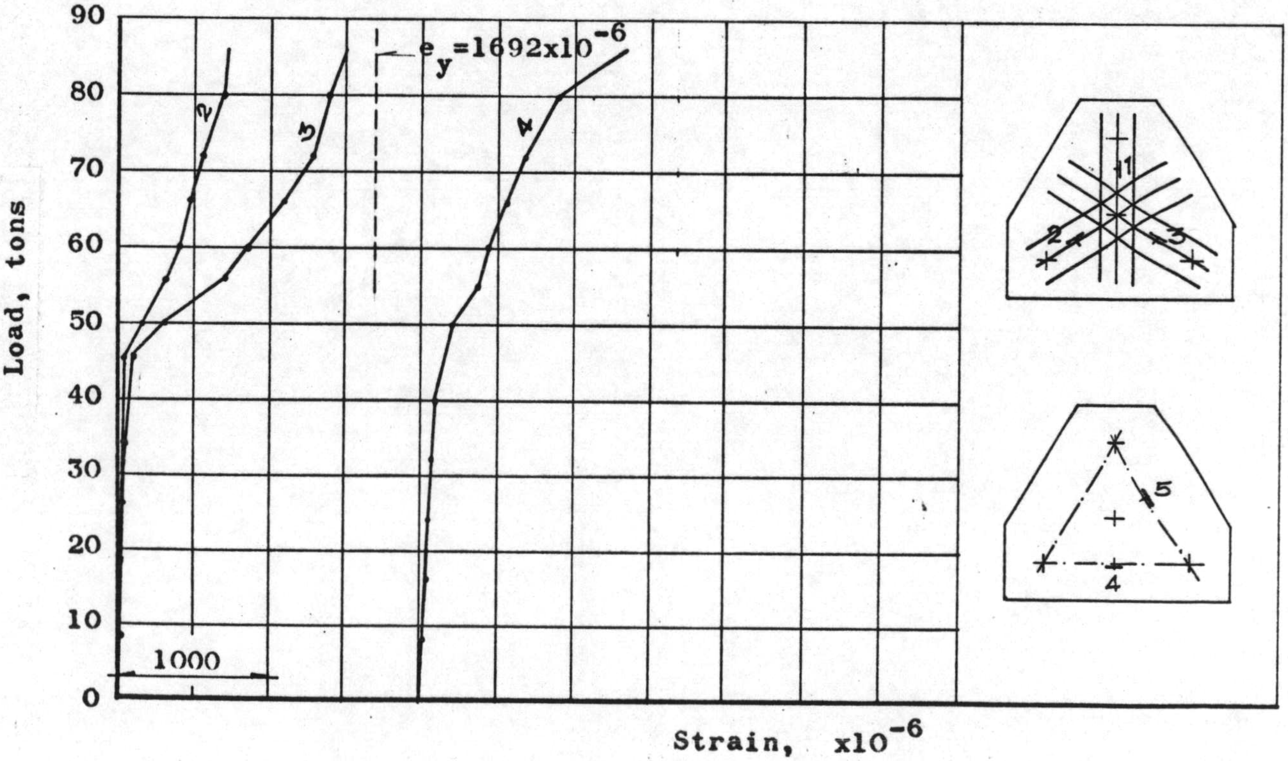


Fig. 6.10 Load-Strain Curves of Steel and Concrete for P3-4

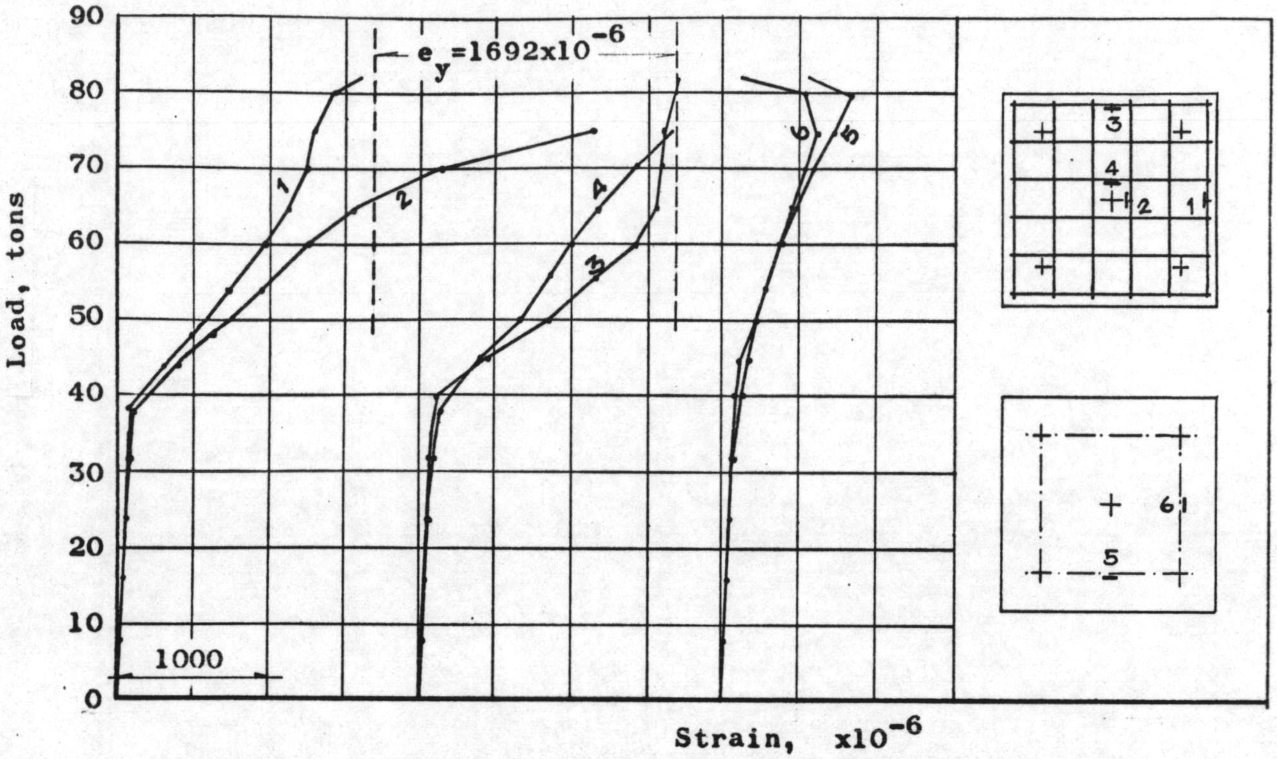


Fig. 6.11 Load-Strain Curves of Steel and Concrete for P4-1

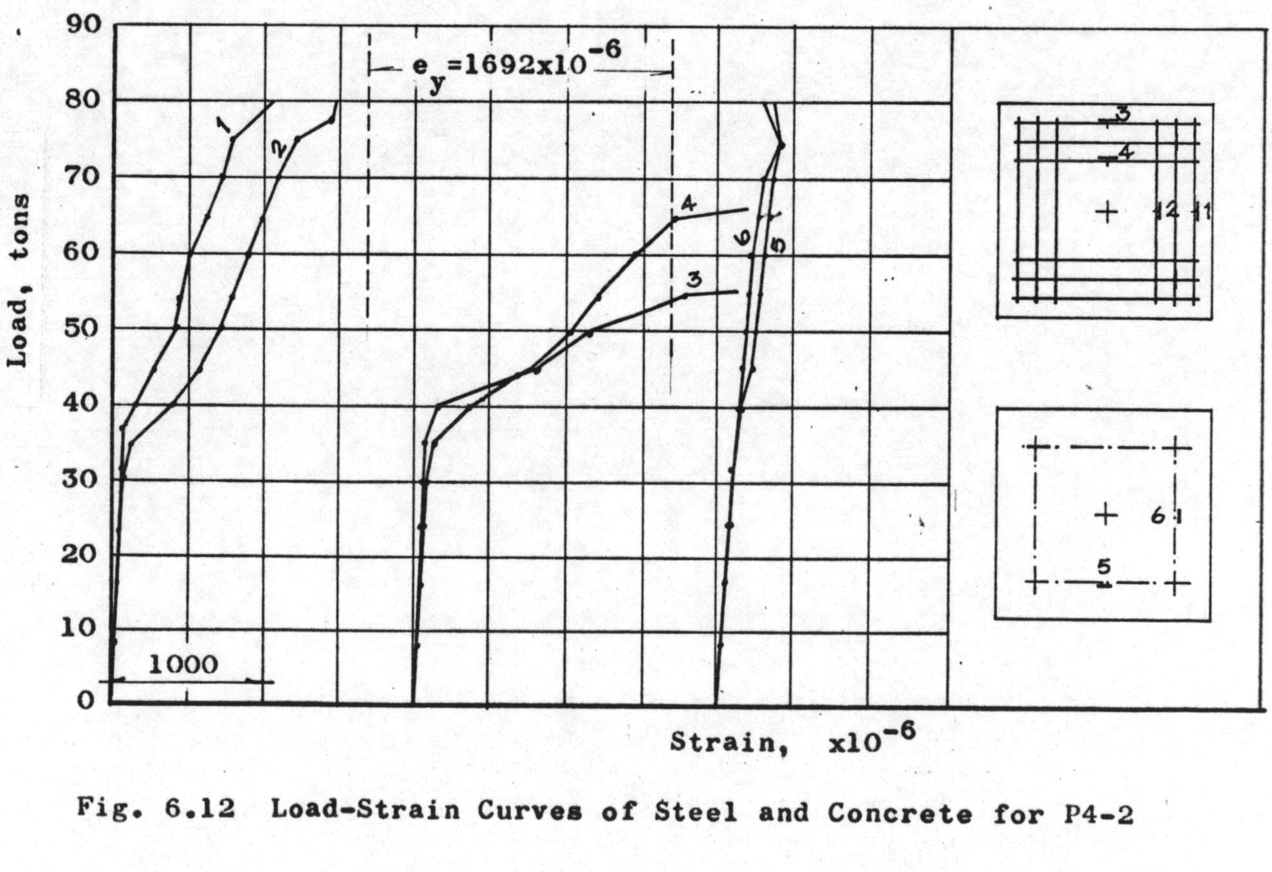


Fig. 6.12 Load-Strain Curves of Steel and Concrete for P4-2

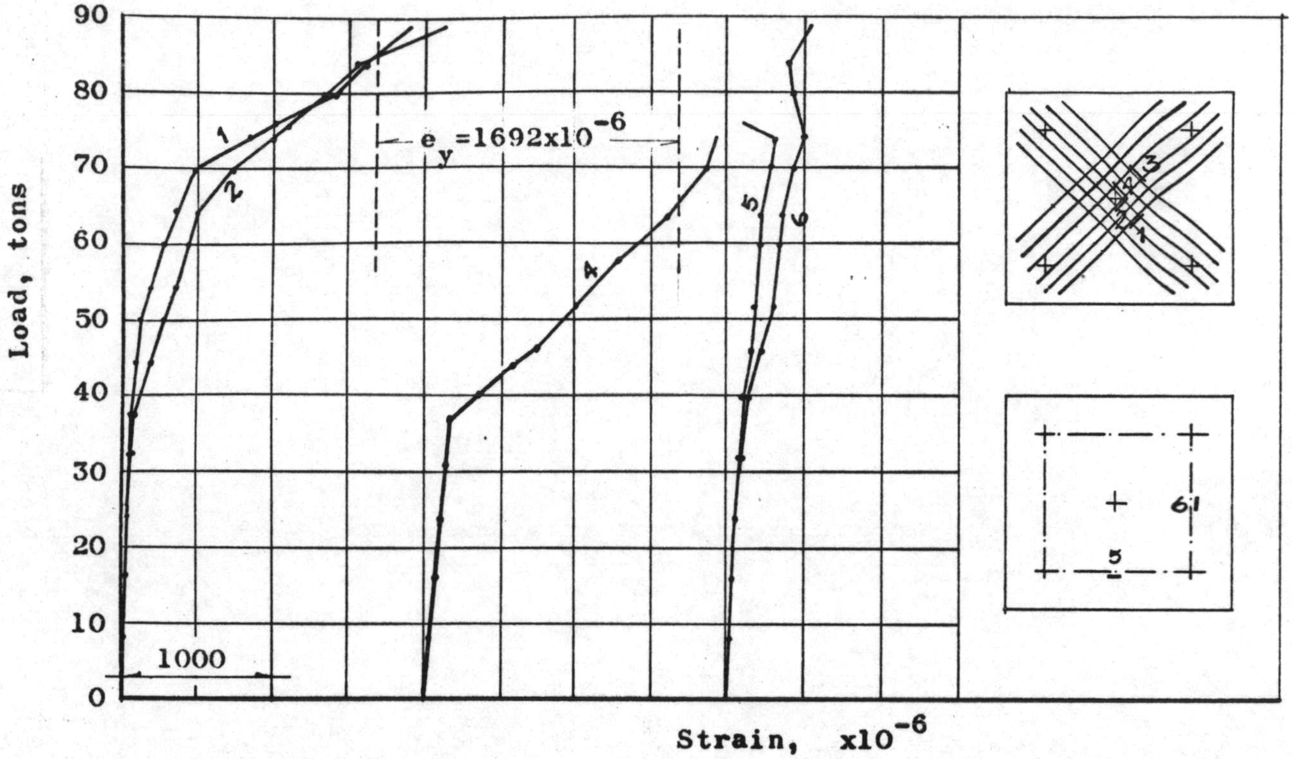


Fig. 6.13 Load-Strain Curves of Steel and Concrete for P4-3

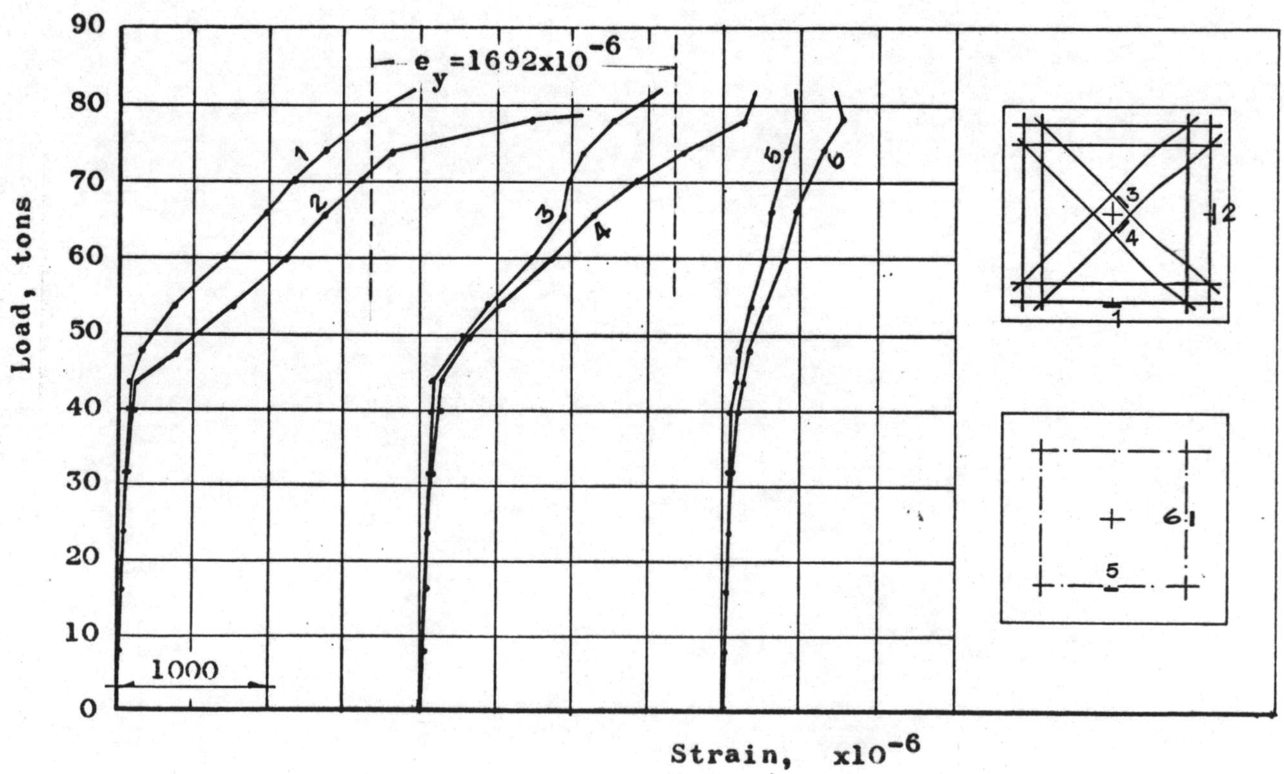


Fig. 6.14 Load-Strain Curves of Steel and Concrete for P4-4

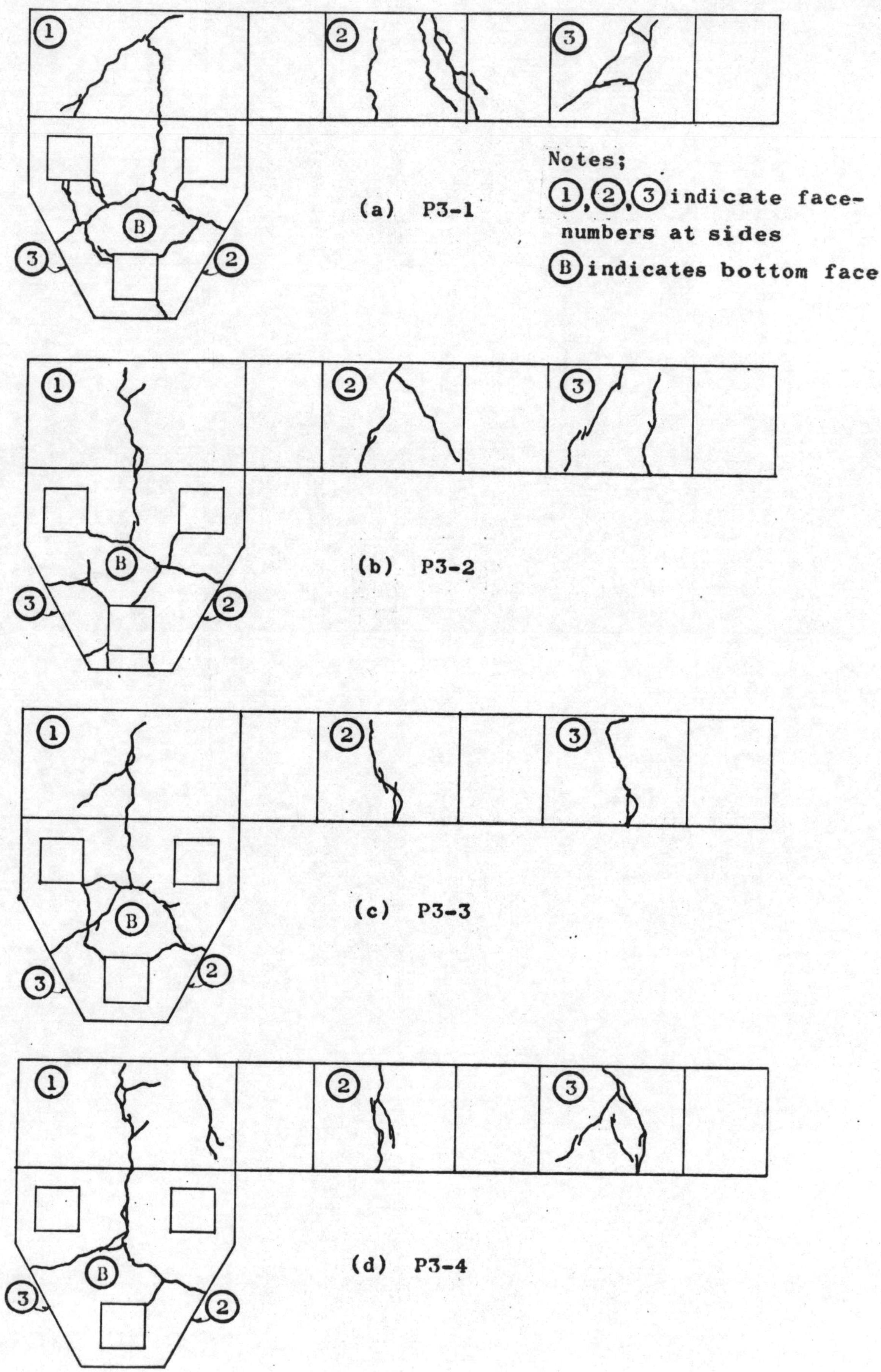
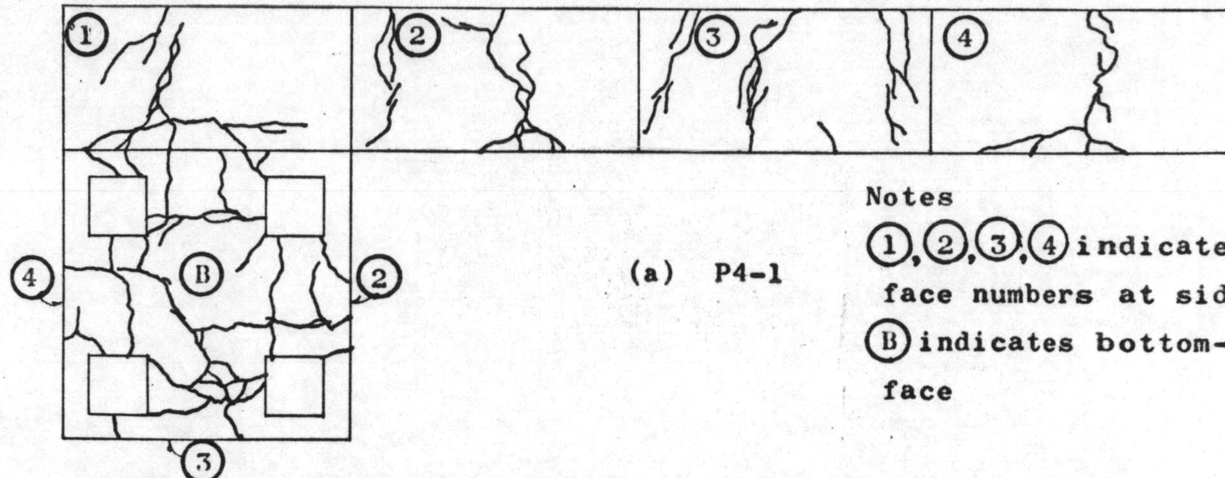


Fig. 6.15 Crack Patterns in Three-Pile Cap Models

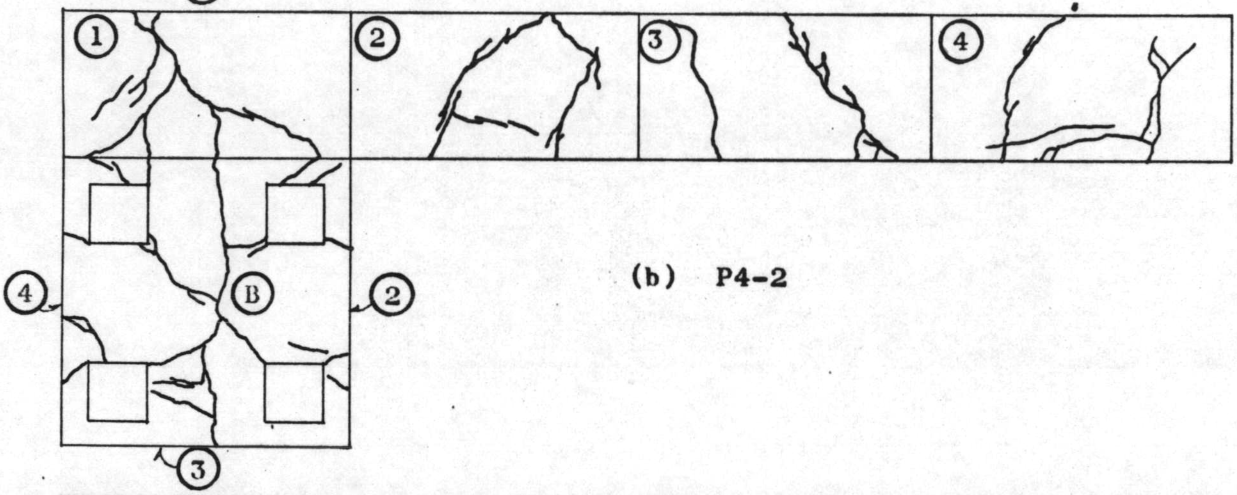


(a) P4-1

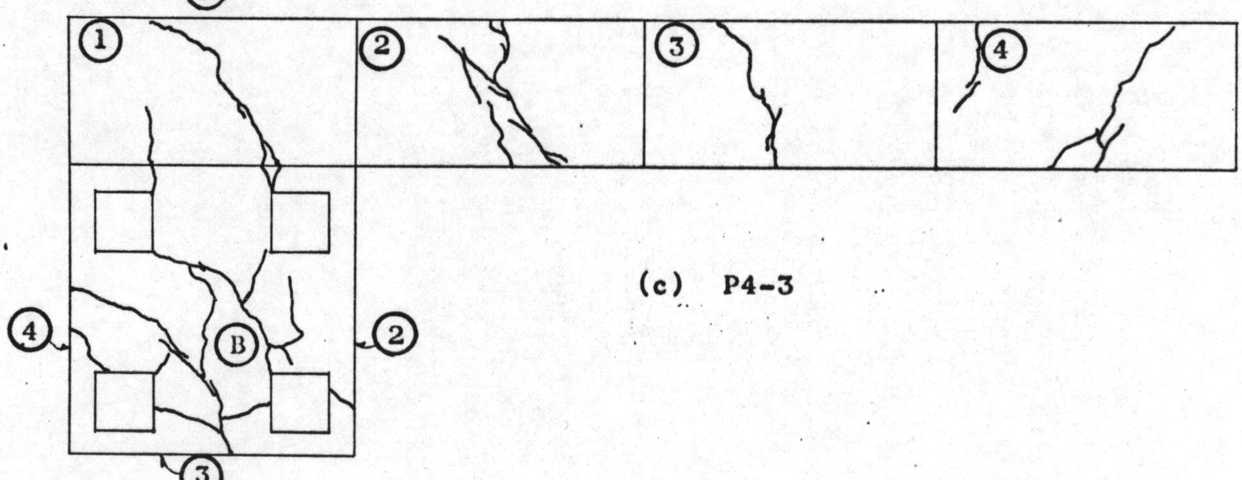
Notes

1, 2, 3, 4 indicate-face numbers at sides

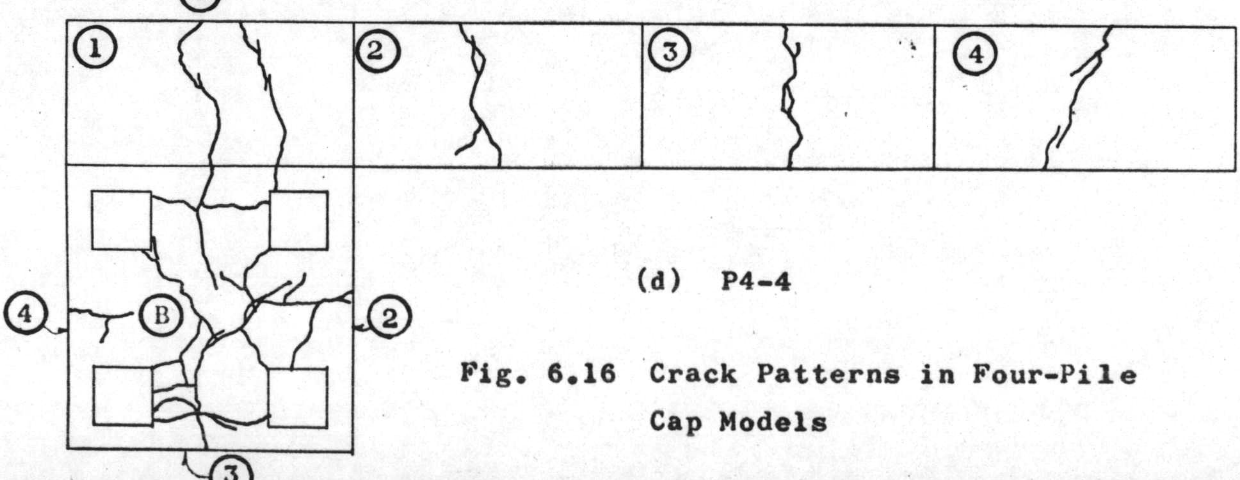
B indicates bottom-face



(b) P4-2



(c) P4-3

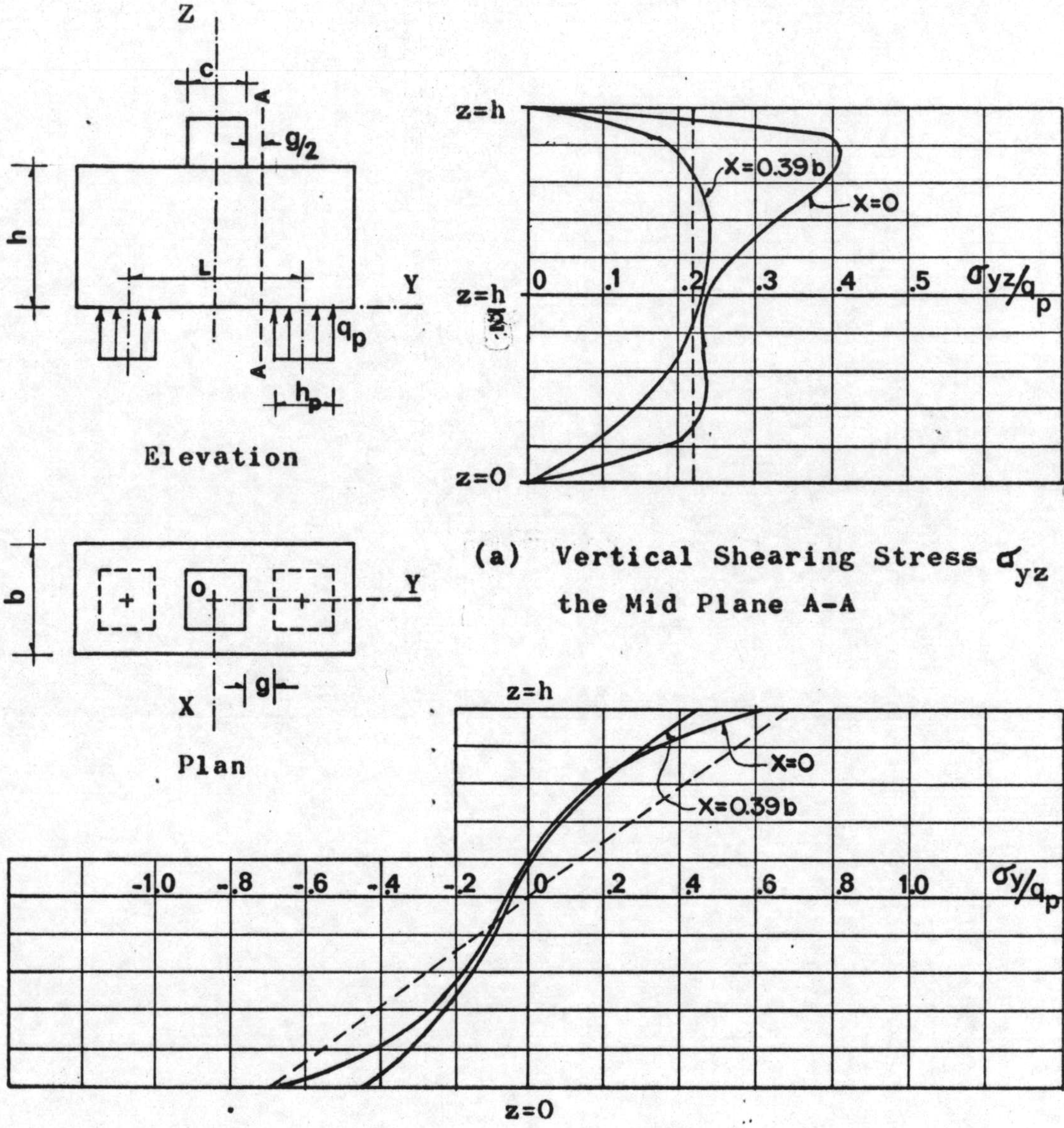


(d) P4-4

Fig. 6.16 Crack Patterns in Four-Pile Cap Models

APPENDIX A

Stress Distributions in Pile Caps Obtained by Finite Element Method

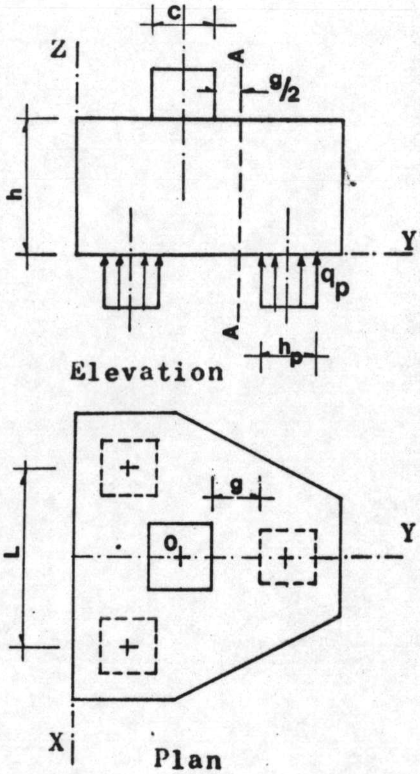


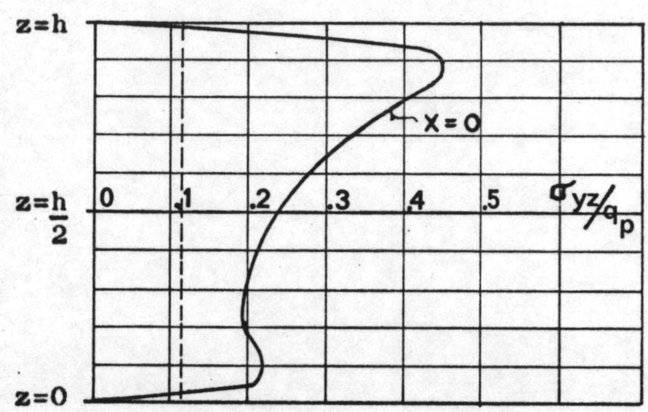
(a) Vertical Shearing Stress σ_{yz} on the Mid Plane A-A

(b) Horizontal Stress σ_y on the Center Line y=0

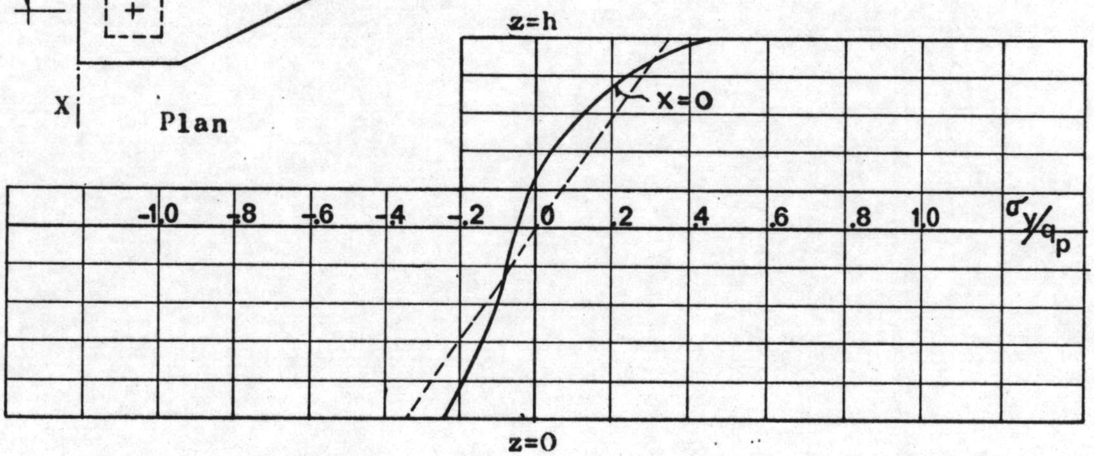
Note; ---- according to simple beam theory

Fig. A.1 Normalized Elastic Distribution of Horizontal Stress and Vertical Shearing Stress in Two-Pile Cap





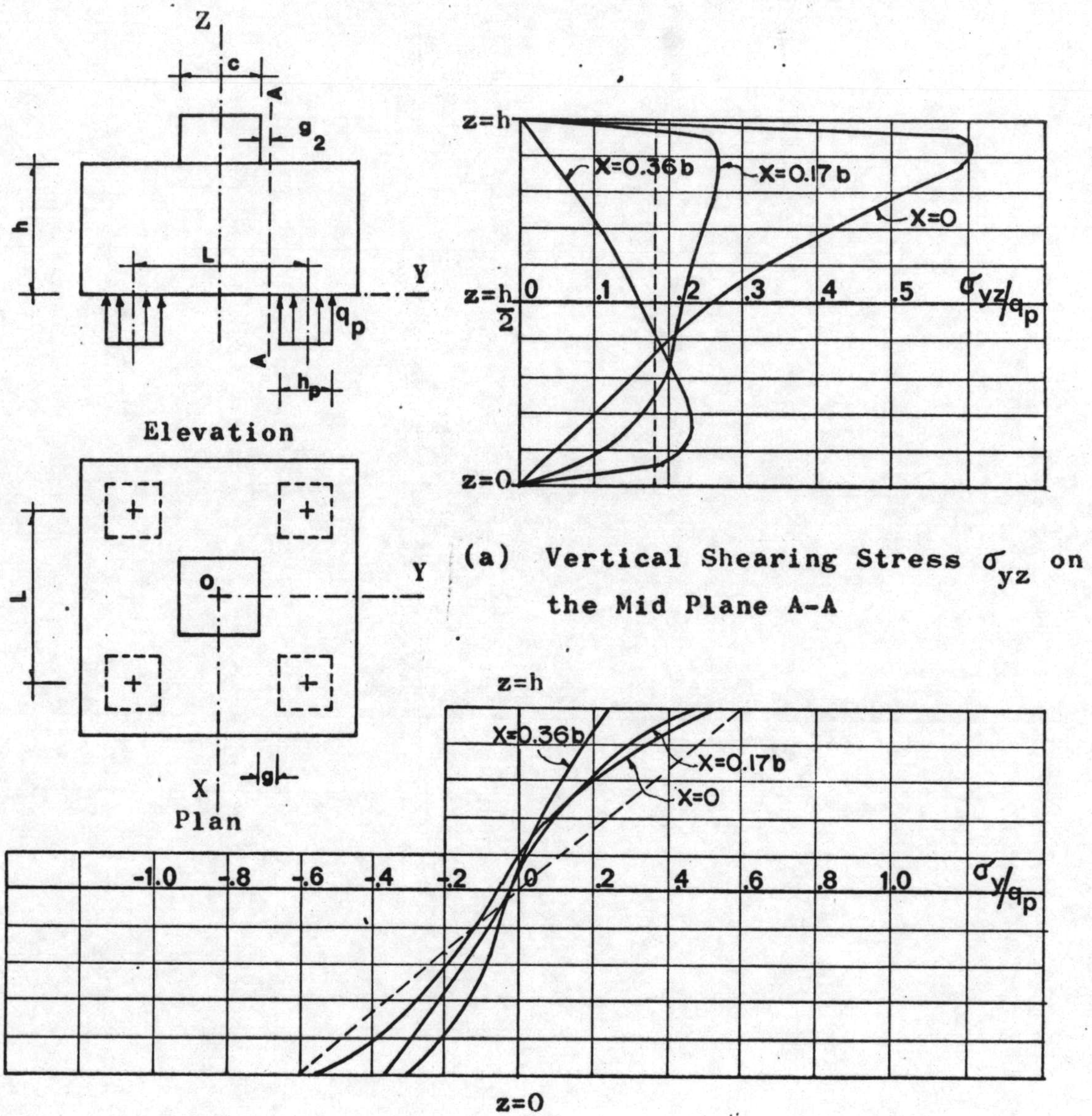
(a) Vertical Shearing Stress σ_{yz} on the Mid Plane A-A



(b) Horizontal Stress σ_y on the Center Line y=0

Note; ---- according to simple beam theory

Fig. A.2 Normalized Elastic Distribution of Horizontal Stress and Vertical Shearing Stress in Three-Pile Cap



(a) Vertical Shearing Stress σ_{yz} on the Mid Plane A-A

(b) Horizontal Stress σ_y on the Center Line y=0

Note; ---- according to simple beam theory

Fig. A.3 Normalized Elastic Distribution of Horizontal Stress and Vertical Shearing Stress in Four-Pile Cap

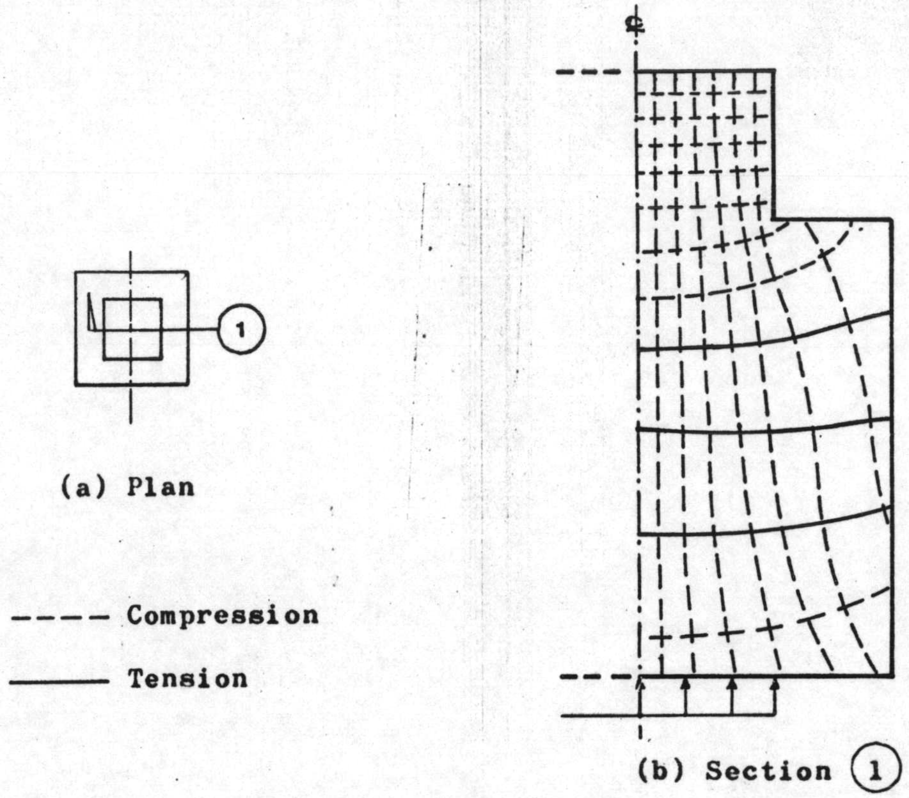


Fig. A.4 Principal Stress Trajectories in Single-Pile Cap

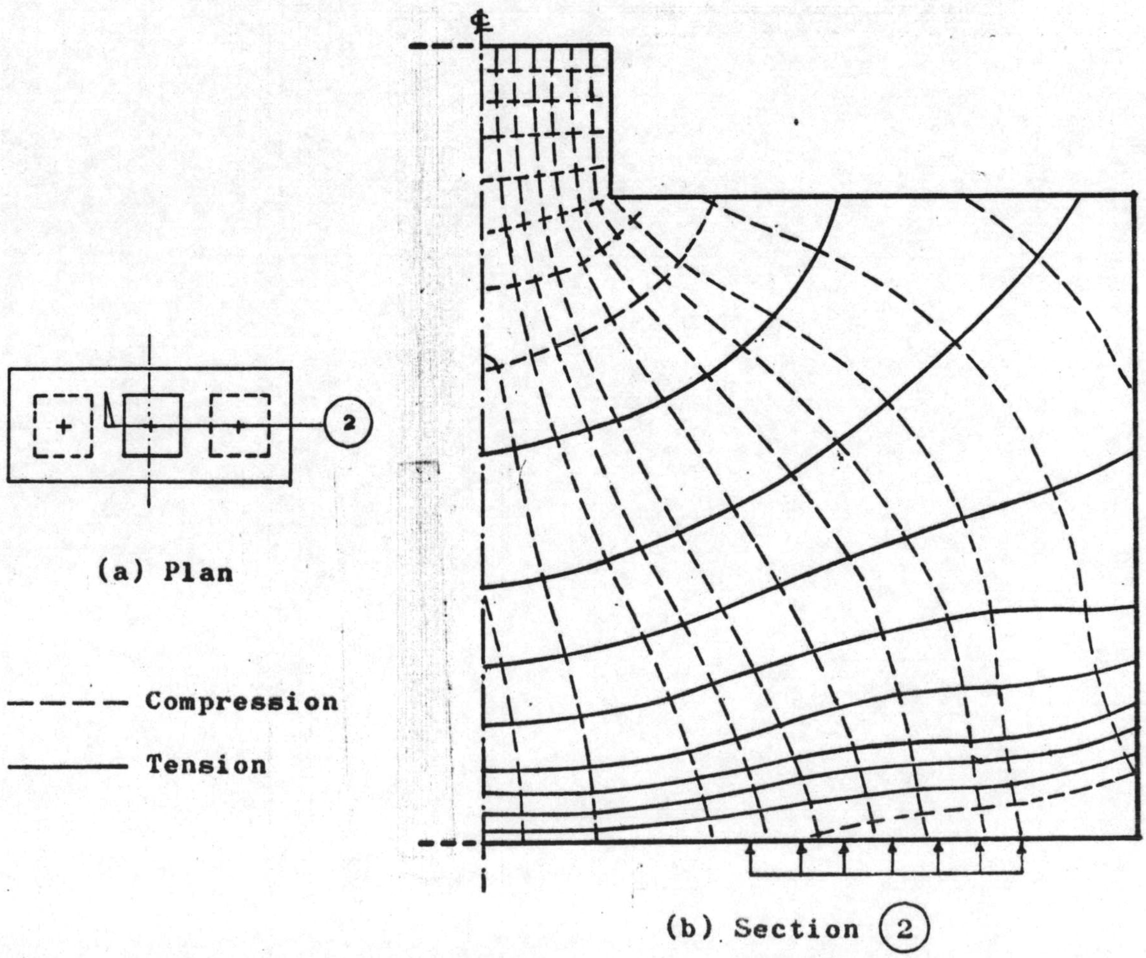


Fig. A.5 Principal Stress Trajectories in Two-Pile Cap

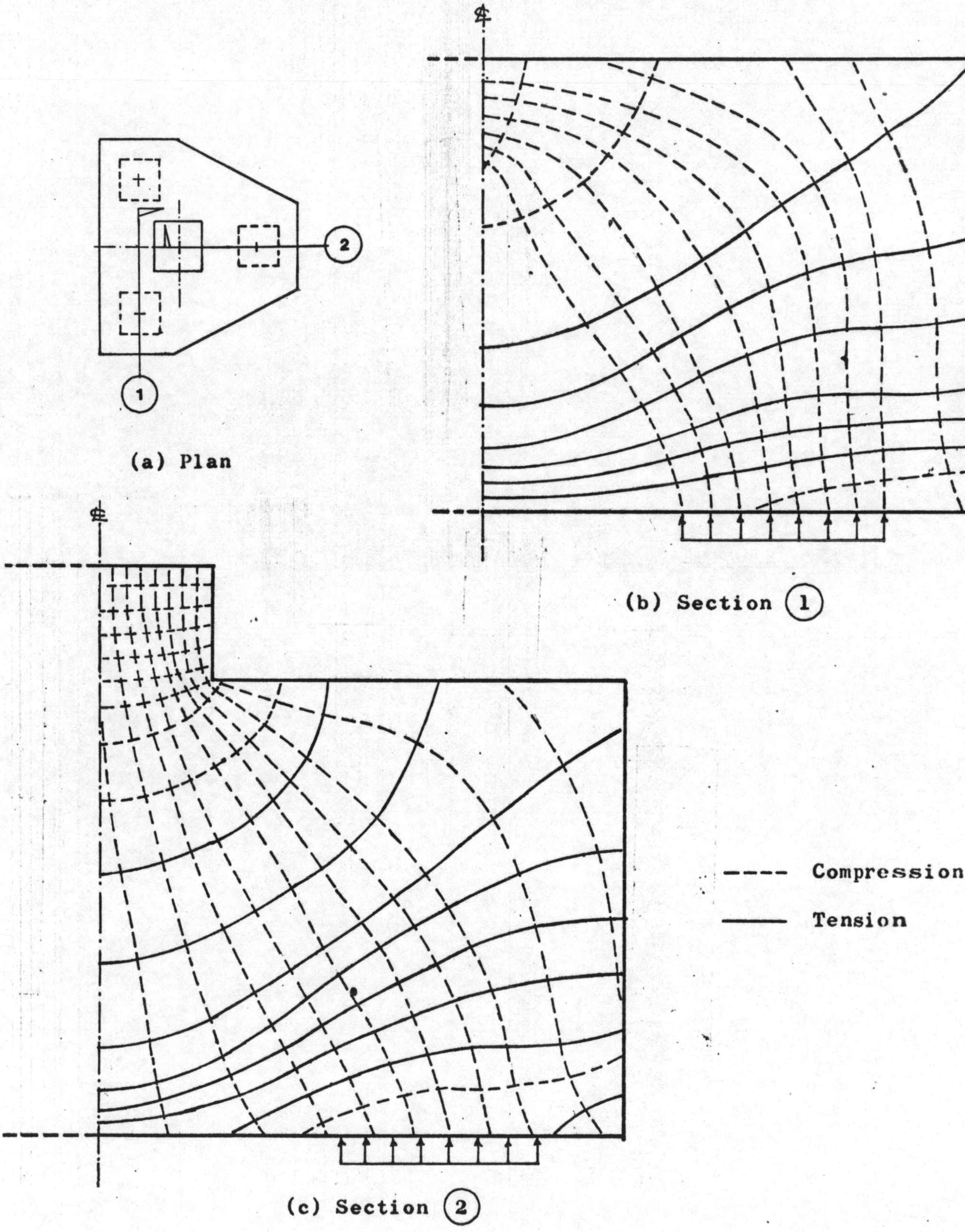


Fig. A.6 Principal Stress Trajectories in Three-Pile Cap

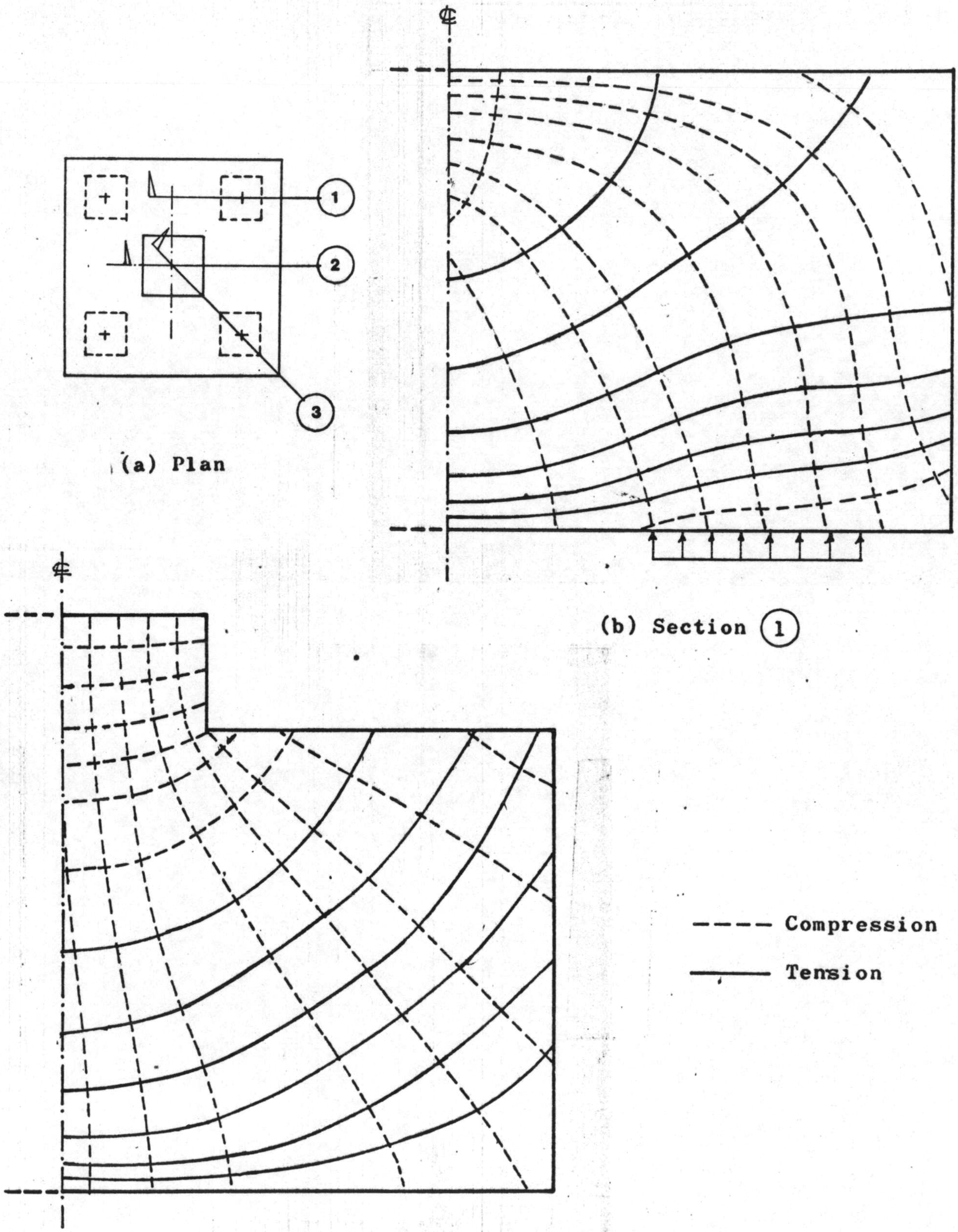
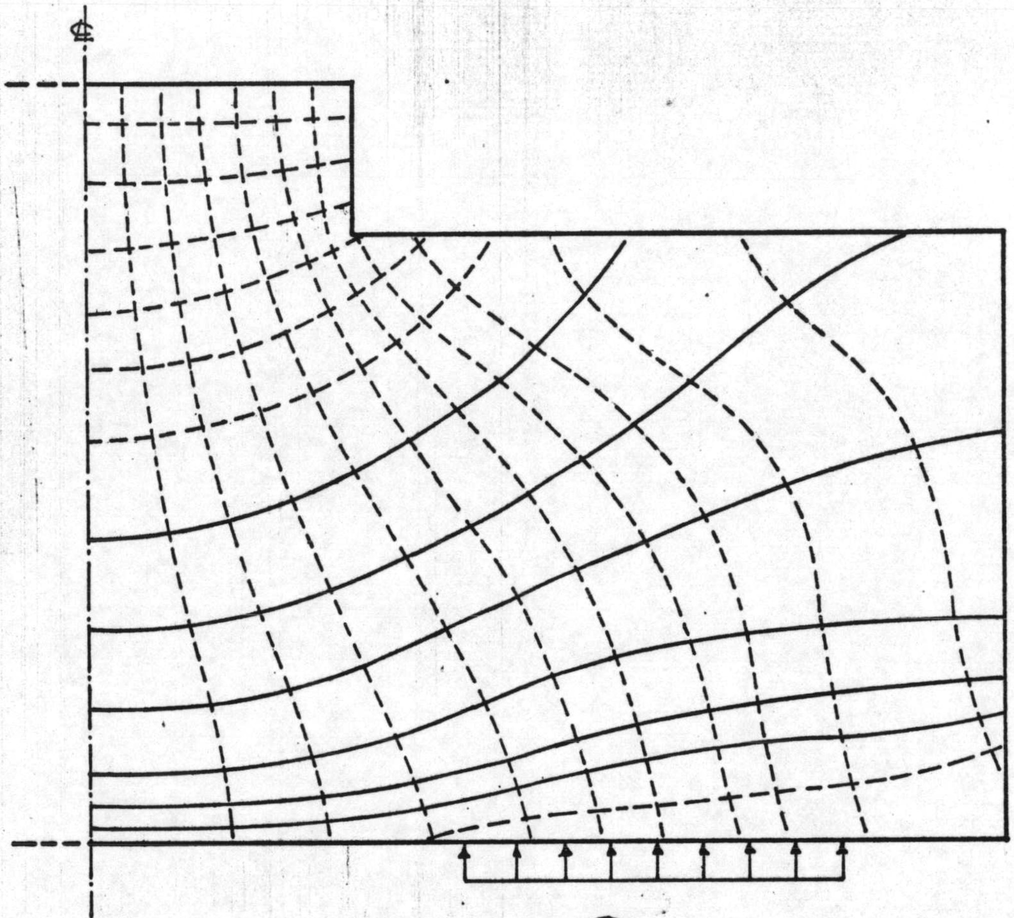


Fig. A.7 Principal Stress Trajectories in Four-Pile Cap



(c) Section (3)

Fig. A.7 Principal Stress Trajectories in Four-Pile Cap

APPENDIX B

Sample of Calculations

B.1 Flexural Strength

Fig. 3.9-3.10 illustrate the assumptions made in the analysis of flexural strength in pile cap at cracking and ultimate conditions. Two concepts of approach, beam analogy and truss analogy, are used in calculation for each form of reinforcement arrangement in pile cap. The mechanical properties of steel and concrete are summarized in Table 2-3.

a) Cracking Loads

Three-Pile Cap;

d = 25 cm. , h = 28.3 cm. , b = 47.3 cm. , L = 35 cm. ,

n = 9 , f_s = 1700 ksc. , f_y = 3400 ksc. , A_s = 1.909 cm^2.

P3-1;

$$M_{cr} = \frac{I_g f_r}{y_t} \qquad \text{(eq. 3.16)}$$

$$= \frac{47.3 \times 28.3^3 \times 31.93}{12 \times 14.15} = 201,596 \text{ kg-cm.}$$

$$P_{cr} = \frac{3M_{cr}}{12.7} = \underline{47,620 \text{ kg.}}$$

P3-2;

$$P_{cr} = \frac{18T_c L_c d_c}{(2L_c^2 - c^2)} + \frac{18T_s Ld}{(2L^2 - c^2)} \qquad \text{(eq. 3.20)}$$

where $T_c = (hc/2)(f_r/2) = \dfrac{28.3 \times 15 \times 32.73}{4} = 3,473$ kg.

$T_s = nf_r A_s = 9 \times 32.73 \times 1.909 = 562$ kg.

$L_c = \dfrac{3L}{4} = 26.25$ cm., $d_c = \dfrac{3h}{4} = 21.23$ cm.

thus,

$$P_{cr} = \frac{18 \times 3473 \times 26.25 \times 21.23}{(2 \times 26.25^2 - 15^2)} + \frac{18 \times 562 \times 35 \times 25}{(2 \times 35^2 - 15^2)}$$

$$= 30,205 + 3,980 = \underline{34,185 \text{ kg.}}$$

P3-3; $M_{cr} = \frac{I_g f_r}{y_t} = \frac{47.3 x 28.3^3 x 30.02}{12 x 14.15} = 189,536$ kg-cm.

$P_{cr} = \frac{3M_{cr}}{12.7} = $ 44,772 kg.

P3-4; $P_{cr} = \frac{18 T_c L_c d_c}{\sqrt{3}(2L_c^2 - c^2)} + \frac{18 T_s L d}{\sqrt{3}(2L^2 - c^2)}$ (eq. 3.21)

$T_c = (hc/2)(f_r/2) = \frac{28.3 x 15 x 31.75}{4} = 3,370$ kg.

$T_s = n f_r A_s = 9 x 31.75 x 1.909 = 545$ kg.

thus, $P_{cr} = \frac{18 x 3370 x 26.25 x 21.23}{\sqrt{3}(2 x 26.25^2 - 15^2)} + \frac{18 x 545 x 35 x 25}{\sqrt{3}(2 x 35^2 - 15^2)}$

$= $ 19,149 kg.

Four-Pile Cap ;

d = 25 cm. , h = 28.3 cm. , b = 56.6 cm. , L = 35 cm. ,

n = 9 , f_s = 1700 ksc. , f_y = 3400 ksc. , A_s = 3.817 cm^2.

P4-1; $M_{cr} = \frac{I_g f_r}{y_t} = 56.6 x 28.3 x 29.89 = 225,820$ kg-cm.

$P_{cr} = \frac{2M_{cr}}{10} = $ 45,164 kg.

P4-2; $P_{cr} = \frac{24 T_c L_c d_c}{(3L_c^2 - c^2)} + \frac{24 T_s L d}{(3L^2 - c^2)}$ (eq. 3.22)

where, $T_c = (hc/2)(f_r/2) = \frac{28.3 x 15 x 28.81}{4} = 3,058$ kg.

$T_s = n f_r A_s = 9 x 28.81 x 1.909 = 495$ kg.

$L_c = \frac{3L}{4} = 26.25$ cm. , $d_c = \frac{3h}{4} = 21.23$ cm.

thus, $P_{cr} = \frac{24 x 3058 x 26.25 x 21.23}{(3 x 26.25^2 - 15^2)} + \frac{24 x 495 x 35 x 25}{(3 x 35^2 - 15^2)}$

$= \underline{25,206 \text{ kg.}}$

P4-3; $P_{cr} = \dfrac{24T_cL_cd_c}{\sqrt{2}(3L_c^2-c^2)} + \dfrac{24T_sLd}{\sqrt{2}(3L^2-c^2)}$ (eq. 3.23)

$T_c = (hc/2)(f_r/2) = \dfrac{28.3x15x30.28}{4} = 3,214$ kg.

$T_s = nf_rA_s = 9x30.28x3.817 = 1,040$ kg.

thus, $P_{cr} = \dfrac{24x3214x26.25x21.23}{\sqrt{2}(3x26.25^2-15^2)} + \dfrac{24x1040x35x25}{\sqrt{2}(3x35^2-15^2)}$

$= \underline{20,976 \text{ kg.}}$

P4-4; $P_{cr} = \dfrac{24T_cL_cd_c}{(3L^2-c^2)} + \dfrac{24T_sLd}{(3L^2-c^2)}$ (eq. 3.22)

where $T_c = (hc/2)(f_r/2) = \dfrac{28.3x15x30.86}{4} = 3275$ kg.

$T_s = nf_rA_s = 9x30.86x1.272 = 353$ kg./ edge & diag.

thus, $P_{cr} = \dfrac{24x3275x26.25x21.23}{(3x26.25^2-15^2)} + \dfrac{24x353x35x25}{(3x35^2-15^2)}$

$+ \dfrac{24x353x35x25}{\sqrt{2}(3x35^2-15^2)} = \underline{27,446 \text{ kg.}}$

b) Ultimate Loads :

Three-Pile Cap;

d = 25 cm. , b = 47.3 cm. , L = 35 cm. , f_y = 3400 ksc.

A_s = 1.909 $cm.^2$

P3-1; $M_u = \emptyset A_sf_y(d-\dfrac{a}{2})$ (eq. 3.18)

$= 0.9x1.909x3400(25- \dfrac{1.909x3400}{0.85x258x47.3})$

$= 142,383$ kg-cm.

$P_u = \dfrac{3M_u}{12.7} = \underline{33,634 \text{ kg.}}$

P3-2; $P_u = \dfrac{18A_sf_yLd}{(2L^2-c^2)}$ (eq. 3.25)

$$= \frac{18x1.909x3400x35x25}{(2x35^2-15^2)} = \underline{45,945 \text{ kg.}}$$

<u>P3-3</u>; $M_u = \phi A_s f_y (d-\frac{a}{2})$

$$= 0.9x3.18x3400(25- \frac{3.18x3400}{0.85x228x47.3})$$

$$= 231,793 \text{ kg-cm.}$$

thus $P_u = \frac{3M_u}{12.7} = \underline{54,754 \text{ kg.}}$

<u>P3-4</u>; $P_u = \frac{18A_s f_y Ld}{\sqrt{3}(2L^2-c^2)}$ (eq. 3.26)

$$= \frac{18x1.909x3400x35x25}{\sqrt{3}(2x35^2-15^2)} = \underline{26,526 \text{ kg.}}$$

Four-Pile Cap ;

d = 25 cm. , b = 56.6 cm. , L = 35 cm. , f_y = 3400 ksc.

A_s = 3.817 cm^2.

<u>P4-1</u>; $M_u = \phi A_s f_y (d-\frac{a}{2})$

$$= 0.9x3.817x3400(25- \frac{3.817x3400}{0.85x226x56.6})$$

$$= 278,059 \text{ kg-cm.}$$

$P_u = \frac{2M_u}{10} = \underline{55,612 \text{ kg.}}$

<u>P4-2</u>; $P_u = \frac{24A_s f_y Ld}{(3L^2-c^2)}$ (eq. 3.27)

$$= \frac{24x1.909x3400x35x25}{(3x35^2-15^2)}$$

$$= \underline{39,508 \text{ kg.}}$$

<u>P4-3</u>; $P_u = \frac{24A_s f_y Ld}{\sqrt{2}(3L^2-c^2)}$ (eq. 3.28)

$$= \frac{24x3.817x3400x35x25}{\sqrt{2}(3x35^2-15^2)} = \underline{55,858 \text{ kg.}}$$

P4-4; $P_{cr} = \frac{24A_s f_y Ld}{(3L^2-c^2)} + \frac{24A_s f_y Ld}{\sqrt{2}(3L^2-c^2)}$ (eq. 3.27 & 3.28)

$= \frac{24x1.272x3400x35x25}{(3x35^2-15^2)} + \frac{24x1.272x3400x35x25}{\sqrt{2}(3x35^2-15^2)}$

$=$ 44,939 kg.

B.1 Shear Strength

a) Punching Shear: ACI[1]

$v = 1.06\sqrt{f'_c}$, $P_v = vb_o d$

Three-Pile Cap;

P3-1; $v = 1.06x0.85\sqrt{258} = 14.47$ ksc.

$P_v = 14.47x160x25 =$ 57,889 kg.

P3-2; $v = 1.06x0.85\sqrt{271} = 14.83$ ksc.

$P_v = 14.83x160x25 =$ 59,329 kg.

P3-3; $v = 1.06x0.85\sqrt{228} = 13.60$ ksc.

$P_v = 13.60x160x25 =$ 54,419 kg.

P3-4; $v = 1.06x0.85\sqrt{255} = 14.39$ ksc.

$P_v = 14.39x160x25 =$ 57,551 kg.

Four-Pile Cap;

P4-1; $v = 1.06x0.85\sqrt{226} = 13.55$ ksc.

$P_v = 13.55x160x25 =$ 54,180 kg.

P4-2; $v = 1.06x0.85\sqrt{210} = 13.06$ ksc.

$P_v = 13.06x160x25 =$ 52,227 kg.

P4-3; $v = 1.06 \times 0.85\sqrt{232} = 13.72$ ksc.

$P_v = 13.72 \times 160 \times 25 = \underline{54{,}894 \text{ kg.}}$

P4-4; $v = 1.06 \times 0.85\sqrt{241} = 13.99$ ksc.

$P_v = 13.99 \times 160 \times 25 = \underline{55{,}949 \text{ kg.}}$

b) Ultimate Shear Strength : Corbel Design[2]

$$v_u = 1.72(1-0.5a/d)(1+64\ )\sqrt{f'_c}$$

where, a = shear span

= steel ratio

Three-Pile Cap;

P3-1; $v_u = 1.72(1-.5 \times \frac{12.7}{25})(1+64 \times .00269)\sqrt{258} = 24.16$ ksc.

$P_{vu} = 3 \times 24.16 \times 47.3 \times 25 = \underline{85{,}697 \text{ kg.}}$

P3-2; $v_u = 1.72(1-.5 \times \frac{12.7}{25})(1+64 \times .00279)\sqrt{271} = 24.90$ ksc.

$P_{vu} = 3 \times 24.90 \times 47.3 \times 25 = \underline{88{,}336 \text{ kg.}}$

P3-3; $v_u = 1.72(1-.5 \times \frac{12.7}{25})(1+64 \times .00269)\sqrt{228} = 22.71$ ksc.

$P_{vu} = 3 \times 22.71 \times 47.3 \times 25 = \underline{80{,}561 \text{ kg.}}$

P3-4; $v_u = 1.72(1-.5 \times \frac{12.7}{25})(1+64 \times .00161)\sqrt{255} = 22.61$ ksc.

$P_{vu} = 3 \times 22.61 \times 47.3 \times 25 = \underline{80{,}194 \text{ kg.}}$

Four-Pile Cap;

P4-1; $v_u = 1.72(1-.5 \times \frac{10}{25})(1+64 \times .00270)\sqrt{226} = 24.26$ ksc.

$P_{vu} = 2 \times 24.26 \times 56.6 \times 25 = \underline{68{,}645 \text{ kg.}}$

P4-2; $v_u = 1.72(1-.5 \times \frac{10}{25})(1+64 \times .00270)\sqrt{210} = 23.38$ ksc.

$P_{vu} = 2 \times 23.38 \times 56.6 \times 25 = \underline{66{,}175 \text{ kg.}}$

P4-3; $v_u = 1.72(1-.5x\frac{10}{25})(1+64x.00381)\sqrt{232} = 26.07$ ksc.

$P_{vu} = 2x26.07x56.6x25 =$ 73,790 kg.

P4-4; $v_u = 1.72(1-.5x\frac{10}{25})(1+64x.00307)\sqrt{241} = 25.56$ ksc.

$P_{vu} = 2x25.56x56.6x25 =$ 72,327 kg.

VITA

Mr. Luck Siridanupath accquired Bachelor's Degree in Engineering from Chiengmai University in 1975. He joined the Engineering Institute of Thailand and the American Concrete Institute as a junior membership in 1976. He joined the firm of Metric Co.,Ltd, Consulting Engineers & Architects in 1978. Since then he has been concerned with aspects of reinforcement detailing in concrete structures and joint detailing in steel structures.