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Table 4.1 Suggested ranges of values of Poisson's ratio of soil

| Soil type | Value of $\nu_s$ |
|---|---|
| <u>Undrained condition</u> | |
| Clays | 0.50 |
| <u>Drained condition</u> | |
| Stiff over consolidated clays | 0.10-0.20 (0.15) |
| Medium clays | 0.20-0.35 (0.30) |
| Soft normally consolidated clays | 0.35-0.45 (0.40) |
| Sand | 0.25-0.35 (0.30) |

Suggested average values are shown in brackets

Table 4.2 Suggested ranges of average values of soil modulus for driven pile in sand

| Sand density | Range of relative density, $D_r$ | Range of $E_s$ ($t/m^2$) |
|---|---|---|
| Loose | $< 0.4$ | 2750 - 5500 |
| Medium | 0.4 - 0.6 | 5500 - 7000 |
| Dense | $> 0.6$ | 7000 - 11000 |

Table 4.3 Summary of parameters for the analysis of the settlement behavior of pile groups

(a) Pile

| Pile description | Length (m) | $E_p$ ($t/m^2$) | $\nu_p$ |
|---|---|---|---|
| Prestressed concrete solid pile 0.4x0.4 m | 20.0 | $2.97x10^6$ | 0.15 |

(b) Soil

| Layer | Soil description | Depth (m) | $E_s$ ($t/m^2$) | $\nu_s$ |
|---|---|---|---|---|
| 1 | Soft clay | 0-14 | 3000* | 0.49 |
| 2 | Stiff clay | 14-20 | | |
| 3 | Sand | 20-30 | 3000 | 0.30 |
| 4 | Very stiff clay | 30-50 | 2500 | 0.49 |
| 5 | Sand | 50-60 | 5000 | 0.30 |

* The value of $E_s$ in founding layer (layer 1 and 2) is assumed to be the value which backfigured from pile load test

Table 4.4 Summary of average settlement of pile groups

| Pile group | s/d | $\rho_1$ (mm) | | $\frac{\rho_1 (1)}{\rho_1 (2)}$ |
|---|---|---|---|---|
| | | Proposed method(1) | Poulos's method (2) | |
| 2x2 | 2 | 7.10 | 9.49 | 0.75 |
| | 3 | 6.63 | 8.88 | 0.75 |
| | 4 | 6.25 | 8.55 | 0.73 |
| | 5 | 5.92 | 8.27 | 0.72 |
| 3x3 | 2 | 12.72 | 17.56 | 0.72 |
| | 3 | 11.38 | 15.91 | 0.72 |
| | 4 | 10.30 | 15.17 | 0.68 |
| | 5 | 9.41 | 14.29 | 0.66 |
| 4x4 | 2 | 18.39 | 27.65 | 0.67 |
| | 3 | 15.67 | 24.86 | 0.63 |
| | 4 | 13.66 | 23.15 | 0.59 |
| | 5 | 12.17 | 21.82 | 0.56 |

The settlements of the single pile from both methods are

Proposed method (1) = 3.25 mm

Poulos's method (2) = 3.59 mm

Table 4.5 Immediate settlement and equivalent width $B_e$ of smaller pile groups

| Group No. | Number of pile | Group size (m x m) | $\rho_i$ (mm) | $B_e$ (m) |
|---|---|---|---|---|
| 1 | 5 x 6 = 30 | 5.20 x 6.40 | 12.3 | 4.58* |
| 2 | 6 x 8 = 48 | 6.40 x 8.80 | 16.6 | 6.09* |
| 3 | 7 x 8 = 56 | 7.60 x 8.80 | 18.3 | 6.64* |

* Values of $B_e$ are interpolated form Figure 4.13

Table 4.6 Summary of parameters for the analysis of the settlement of Tower C Building

(a) Pile

| Pile description | Length (m) | $E_p$ $(t/m^2)$ | $\nu_p$ |
|---|---|---|---|
| Prestressed concrete I-section 0.4x0.4 m | 25.0 | $2.40 \times 10^6$ | 0.15 |

(b) Soil

| Layer | Soil description | Depth (m) | $1/m_v$ | $E_u$ $(t/m^2)$ | $\nu_u$ | $E_s'$ $(t/m^2)$ | $\nu_s'$ |
|---|---|---|---|---|---|---|---|
| 1 | Soft clay | 0-13.5 | - | 2900* | 0.49 | 2513 | 0.30 |
| 2 | Stiff clay | 13.5-29.0 | - | | | | |
| 3 | Sand | 29.0-39.0 | 3886 | - | - | 2887 | 0.30 |
| 4 | Very stiff clay | 39.0-46.5 | 2006 | 2478 | 0.49 | 1900 | 0.15 |
| 5 | Sand | 46.5-53.5 | 6878 | - | - | 5110 | 0.30 |
| 6 | Very stiff clay | 53.5-62.0 | 2427 | 2997 | 0.49 | 2298 | 0.15 |

* Backfigured from pile load test, see reference (19)

Values of $E_u$ and $E_s'$ are calculated using equation (4.3),(4.4)

For clay with $\nu_s'$ = 0.30 : $E_s' = 0.867 \times E_u$

For clay with $\nu_s'$ = 0.15 : $E_u = 1.235 \times 1/m_v$

$E_s' = 0.767 \times E_u$

For sand with $\nu_s'$ = 0.30 : $E_s' = 0.743 \times 1/m_v$

Table 4.7 Comparisons of the settlements of Tower C Building

| Method of analysis | $\rho_i$ (mm) | $\rho_f$ (mm) |
|---|---|---|
| Observed data (1) | 37 - 44* | 66 - 72* |
| Proposed method (2) | 28.2 - 35.7 | 40.6 - 51.1 |
| Poulos's method (3) | 38 - 40* | 65 - 71.6* |
| Proposed method (2) / Observed data (1) | 0.76 - 0.81 | 0.62 - 0.71 |
| Poulos's method (3) / Observed data (1) | 1.03 - 0.91 | 0.98 - 0.99 |
| Proposed method (2) / Poulos's method (3) | 0.74 - 0.90 | 0.62 - 0.71 |

* Settlement values of observed data (1) and Poulos's method (3) are from reference (19)

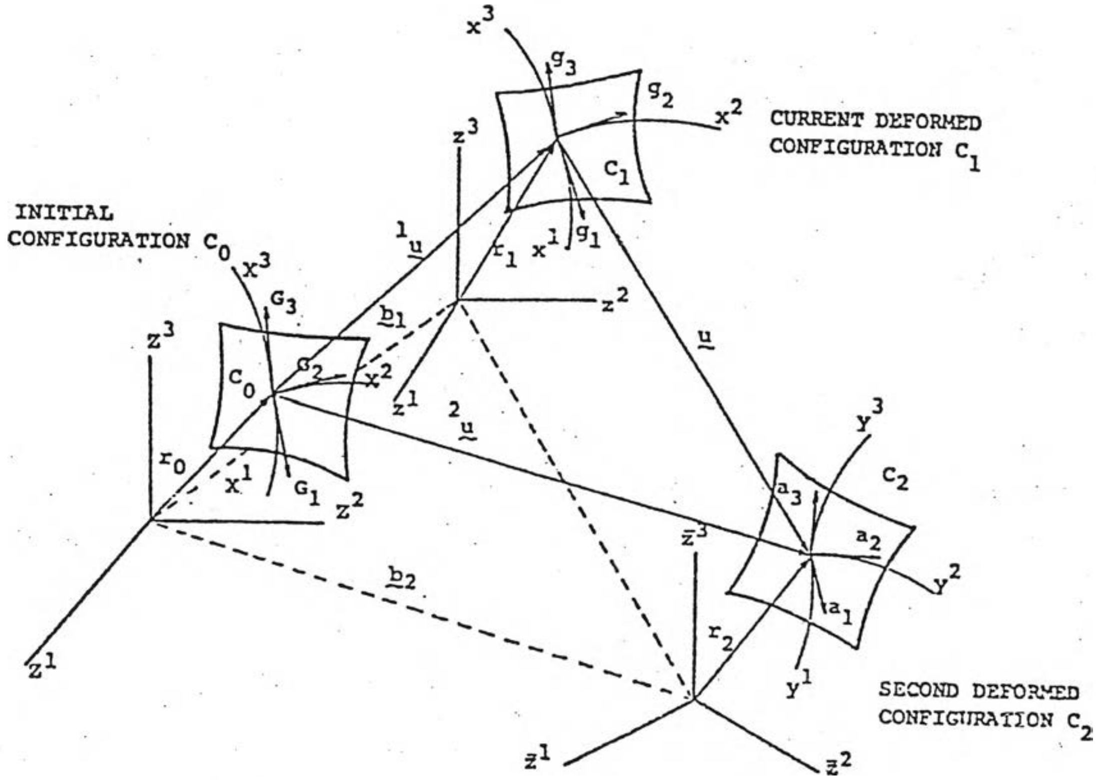



Figure 2.1 Deformation path of a body.

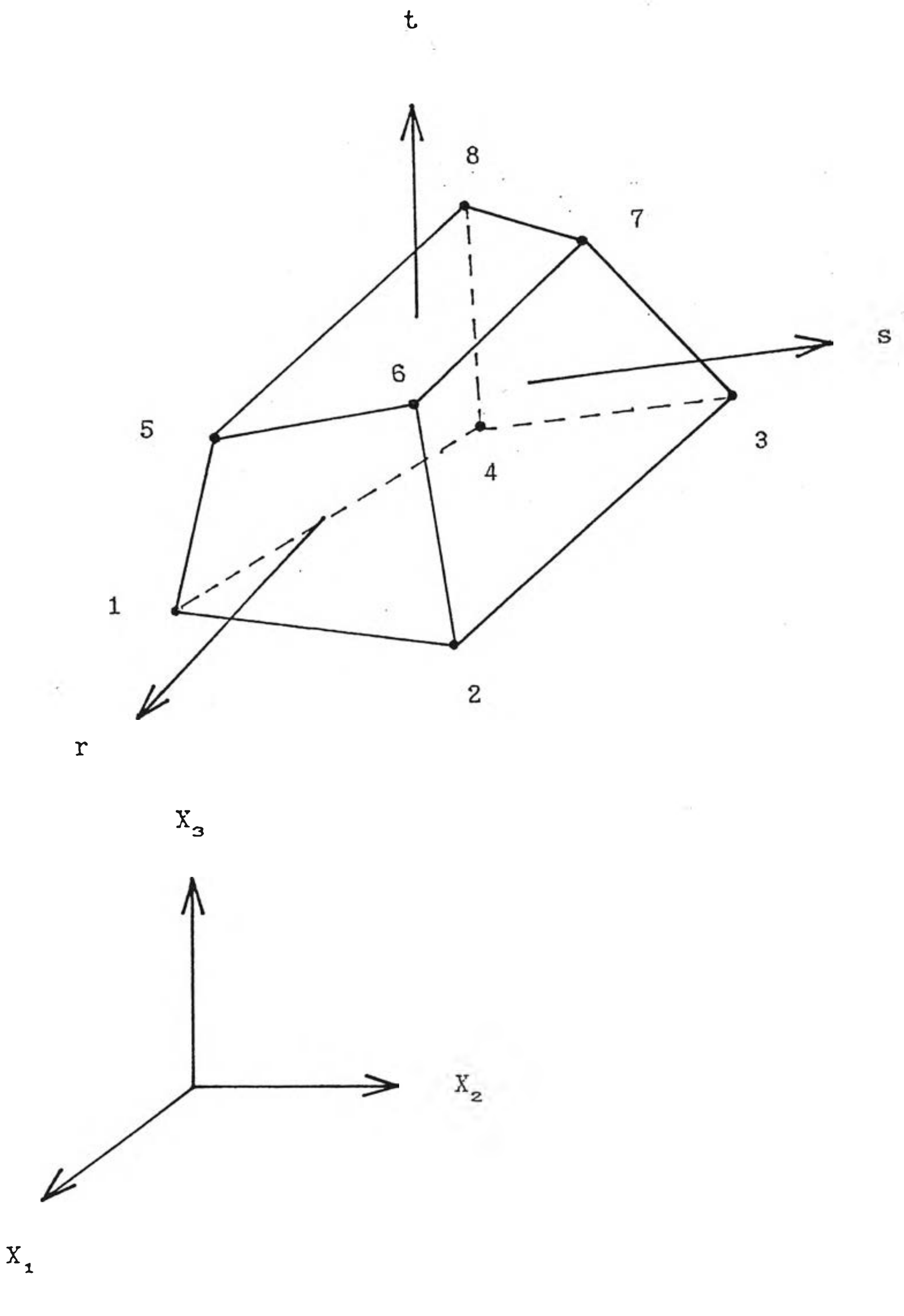



Figure 2.2 Three dimensional isoparametric hexahedral element.

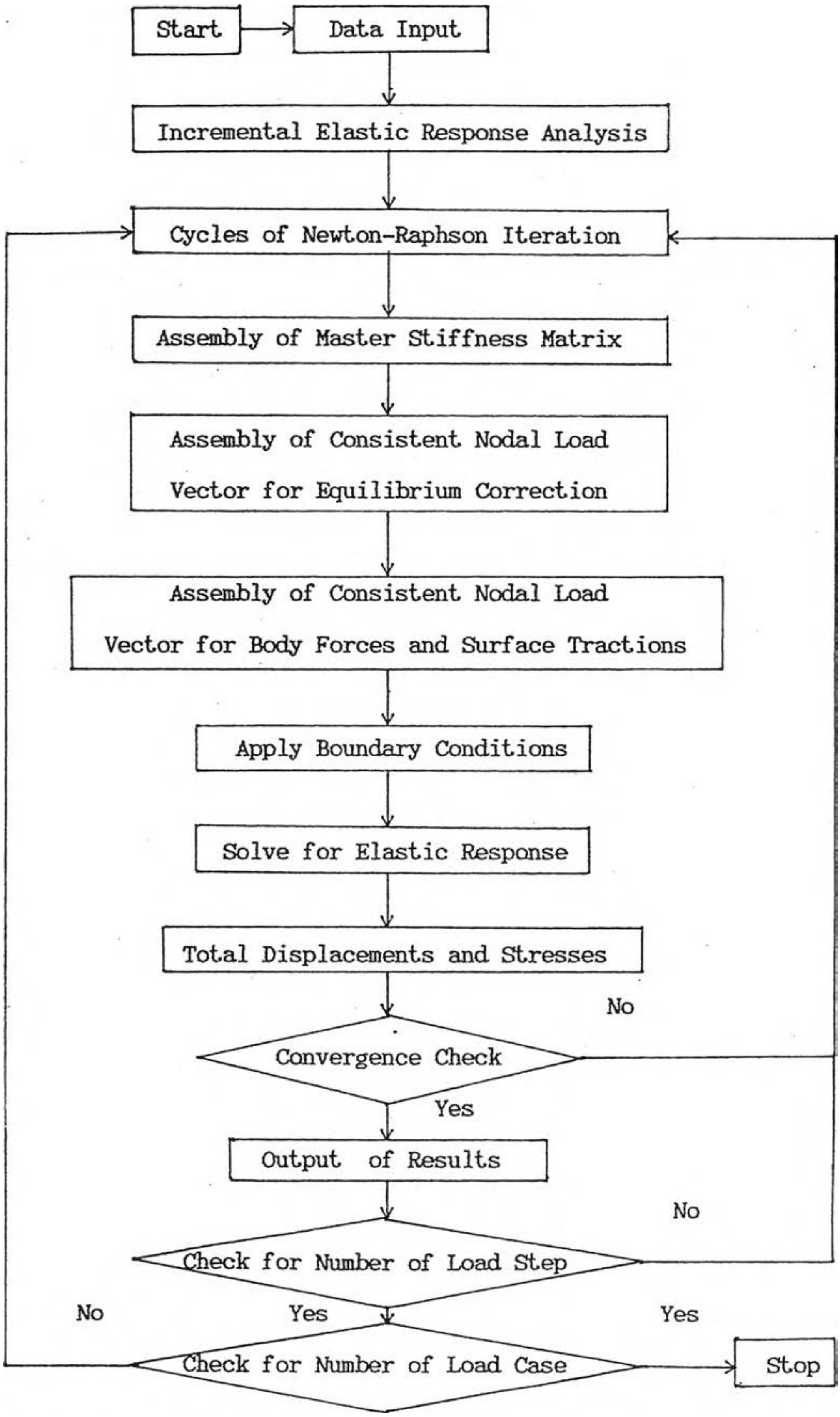
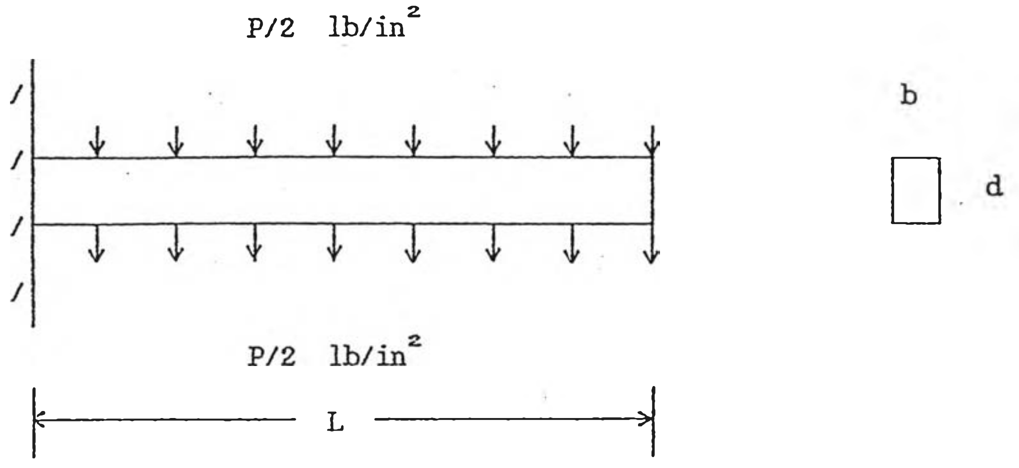



FIGURE 3.1 Flow chart for the computational procedure of the nonlinear elastic static finite element analysis.




$E = 12000$ psi

$\nu = 0.2$

$\rho = 10^{-6}$ lb-sec$^2$/in$^4$

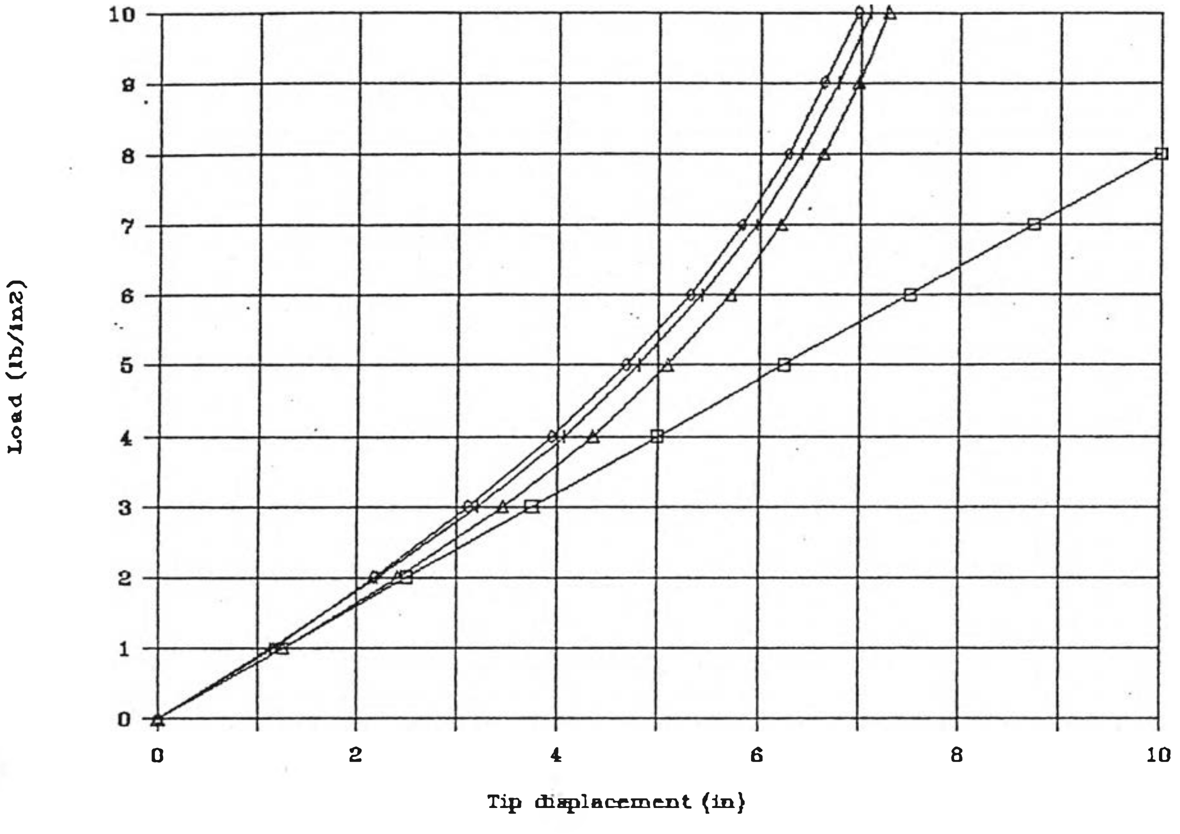
$b = 1$ inch

$d = 1$ inch

$L = 10$ inch

$P = 10$ lb/in$^2$

Figure 3.2 Elastic cantiliver beam under unformly distributed load.



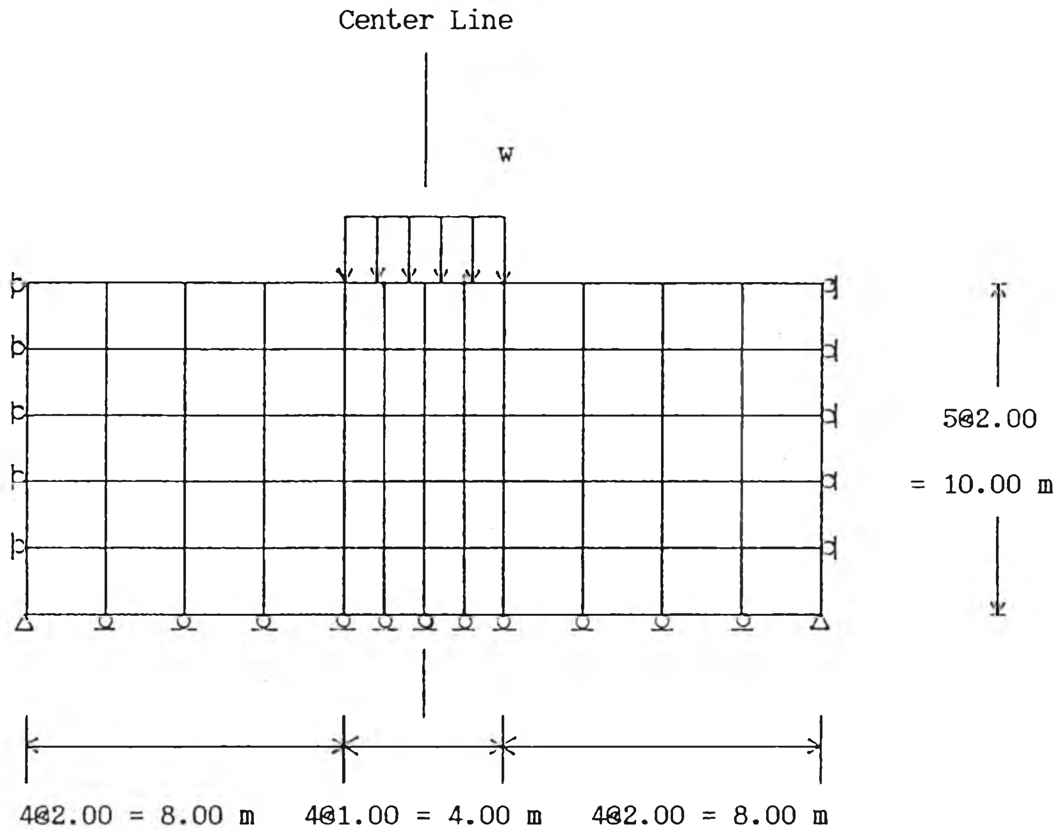

□ Linear analysis

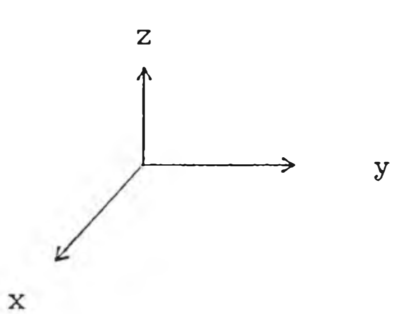
+ NONSAP program

◇ Proposed program

△ Monkar (10)

Figure 3.3 The relation between load and tip displacement.




w = 50 $t/m^2$

E = 300 $t/m^2$

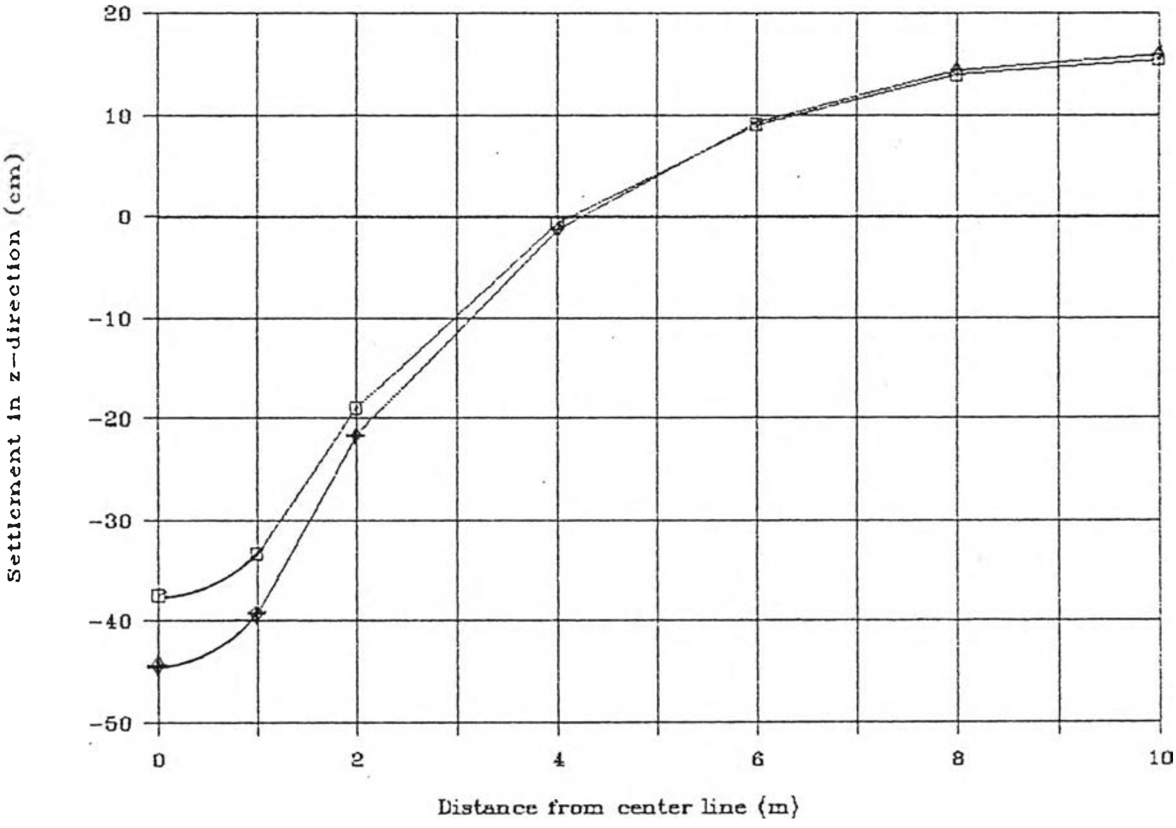
$\nu$ = 0.49

o| No translation in y direction

o No translation in z direction

△ No translation in y and z direction

Figure 3.4 Cross section of model of uniform soil mass under strip loading.

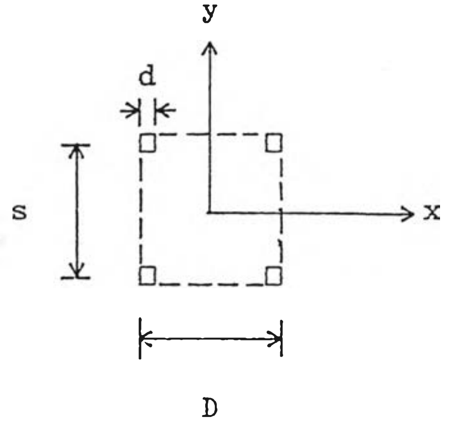



□ Linear analysis

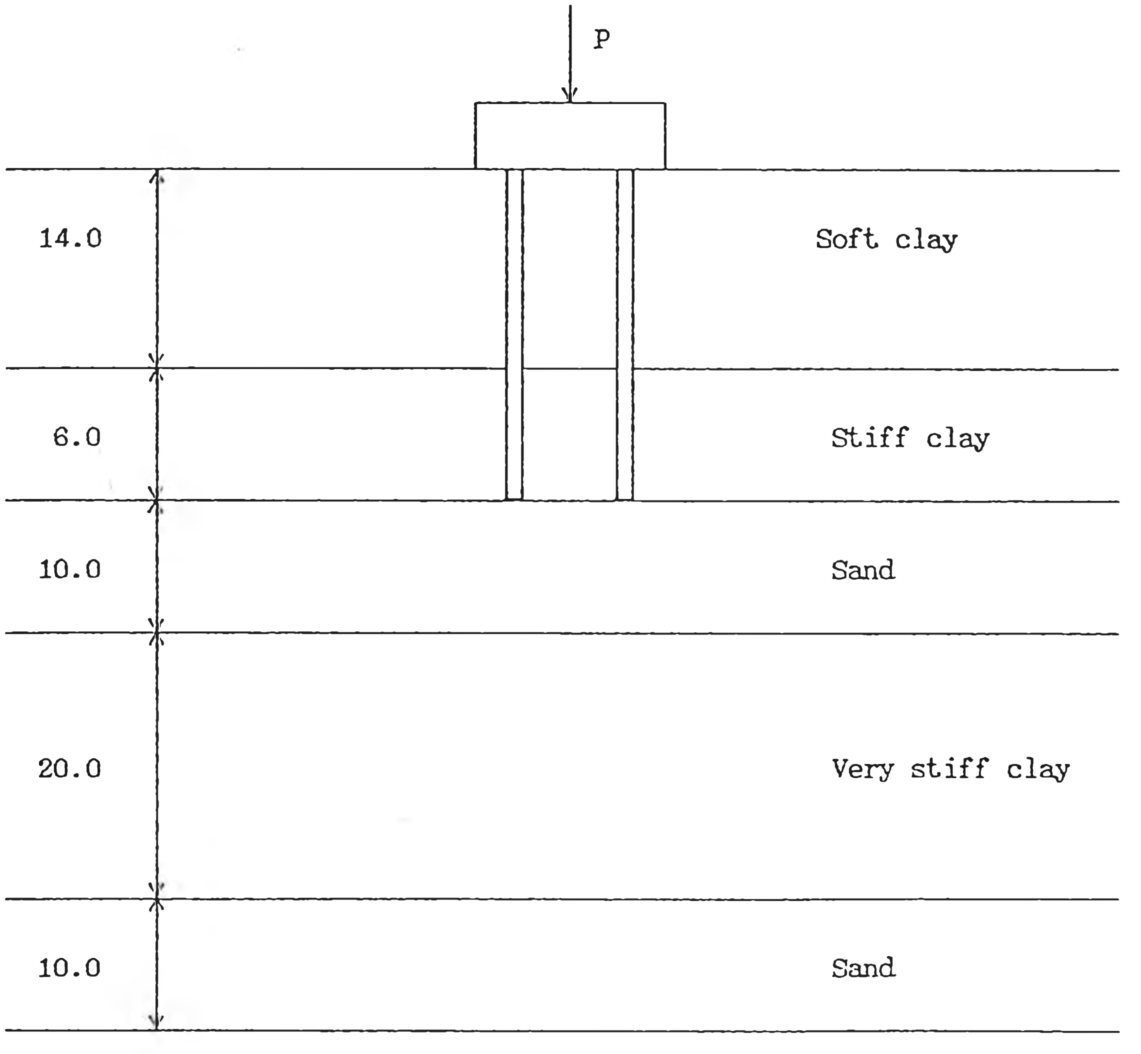
\+ NONSAP program

◇ Proposed program

Figure 3.5 The settlement profile of soil surface.




(a) Plan




(b) Elevation

Figure 4.1 Plan and elevation of 2x2 pile group.

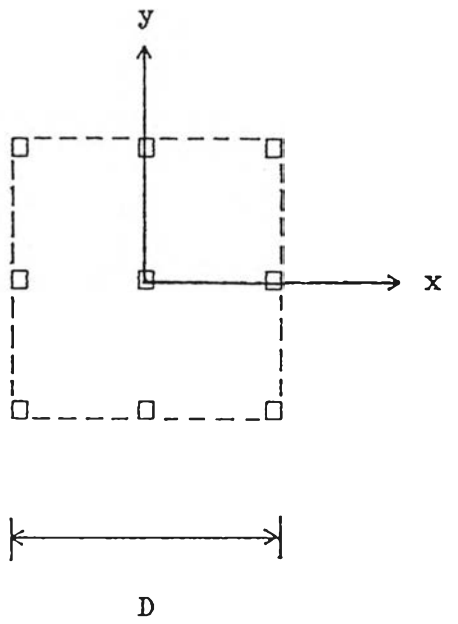



Figure 4.2 Plan of 3x3 pile group.

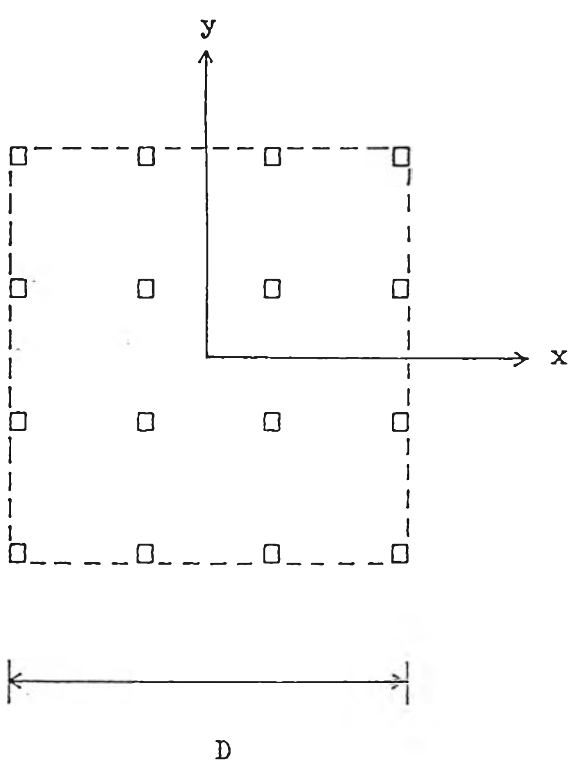



Figure 4.3 Plan of 4x4 pile group.

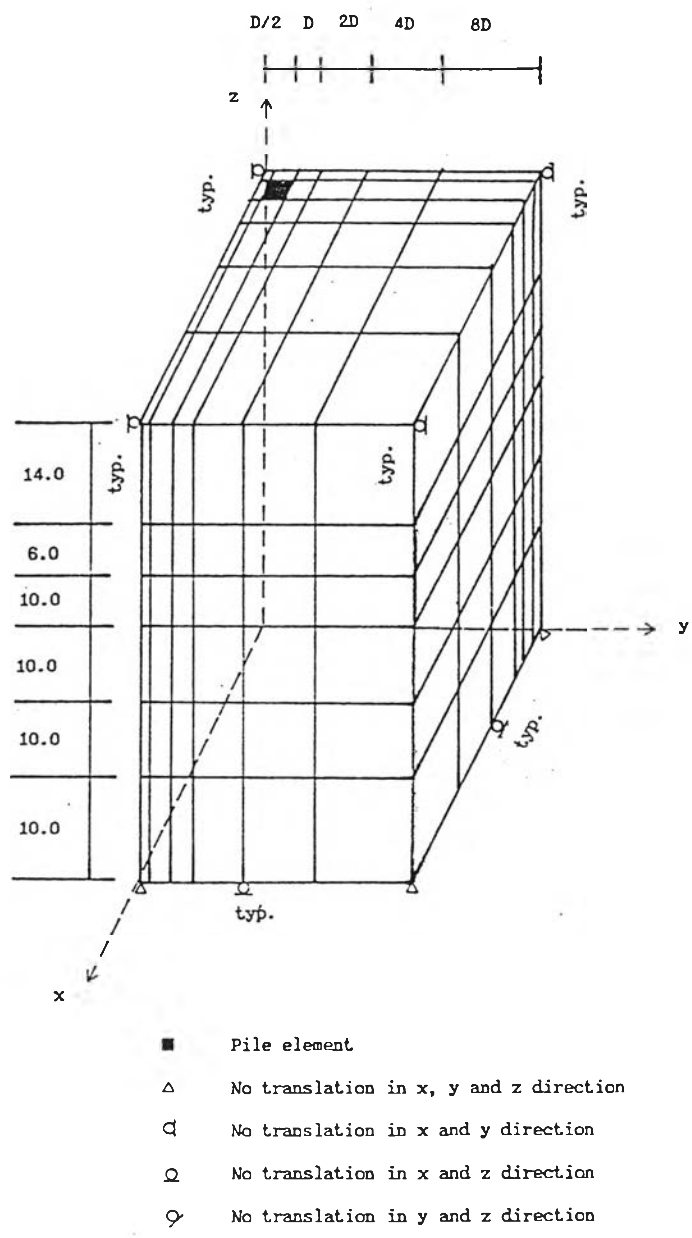



Figure 4.4 Finite element model for 2x2 pile group.

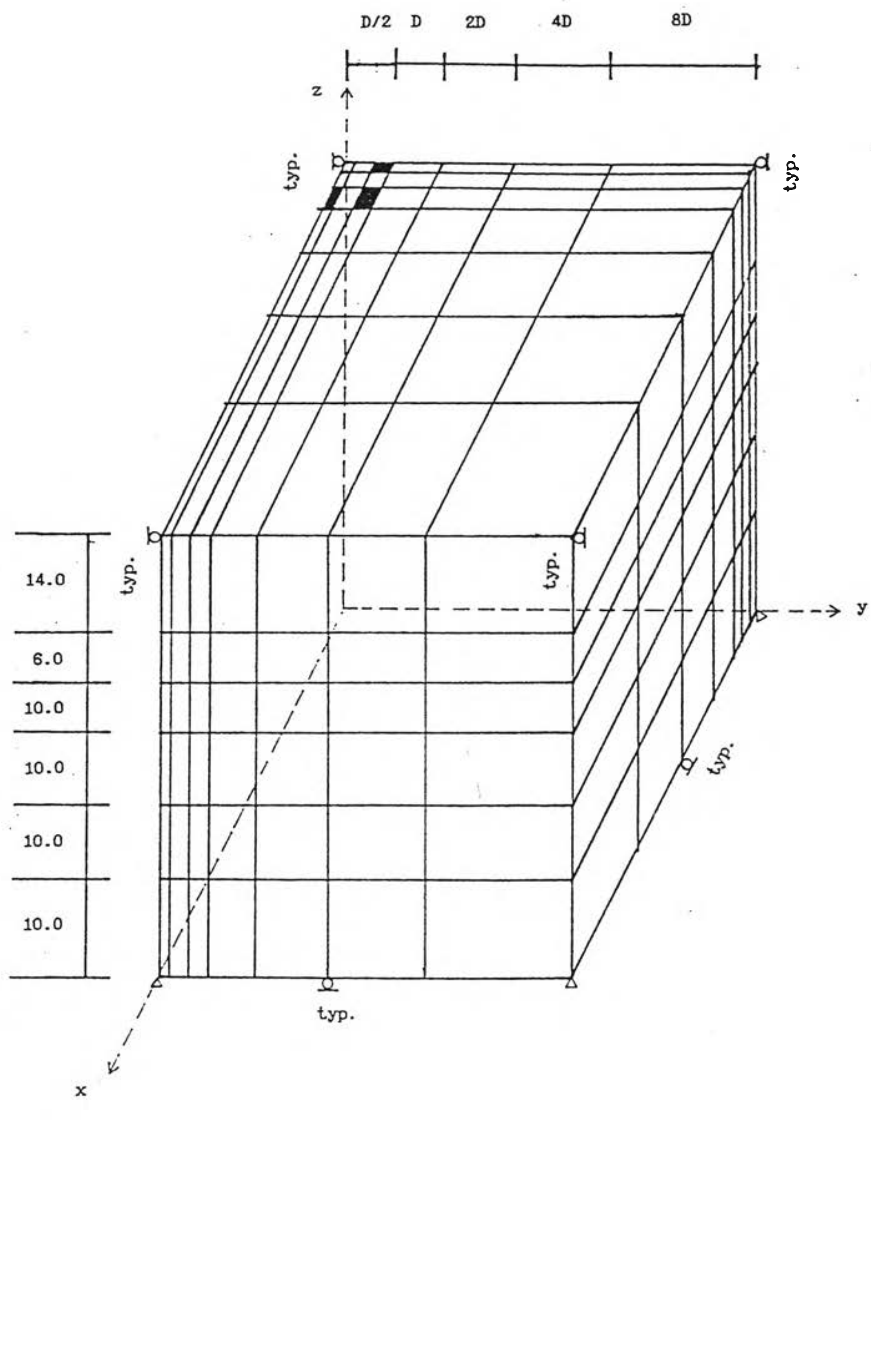



Figure 4.5 Finite element model for 3x3 pile group.

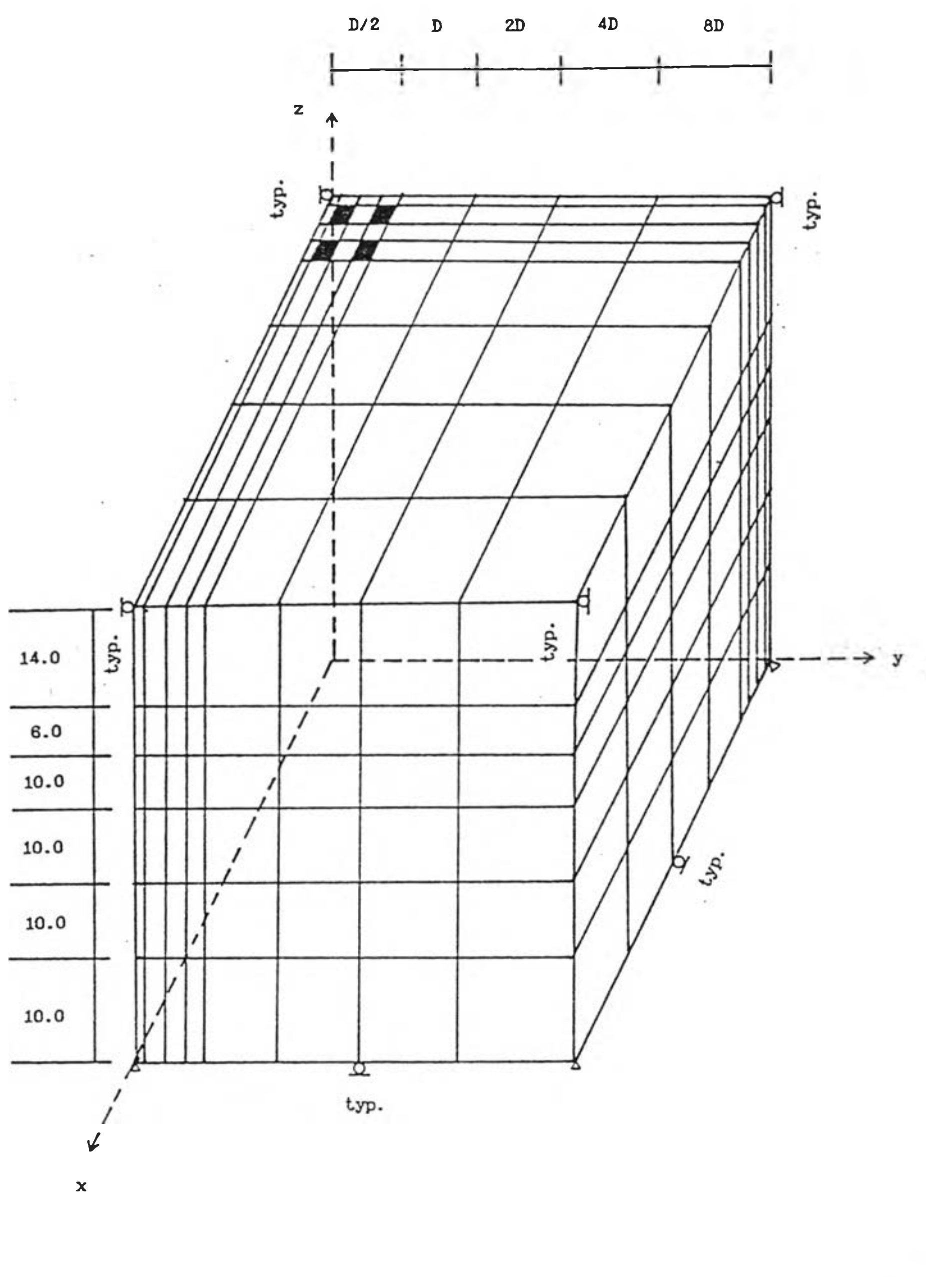
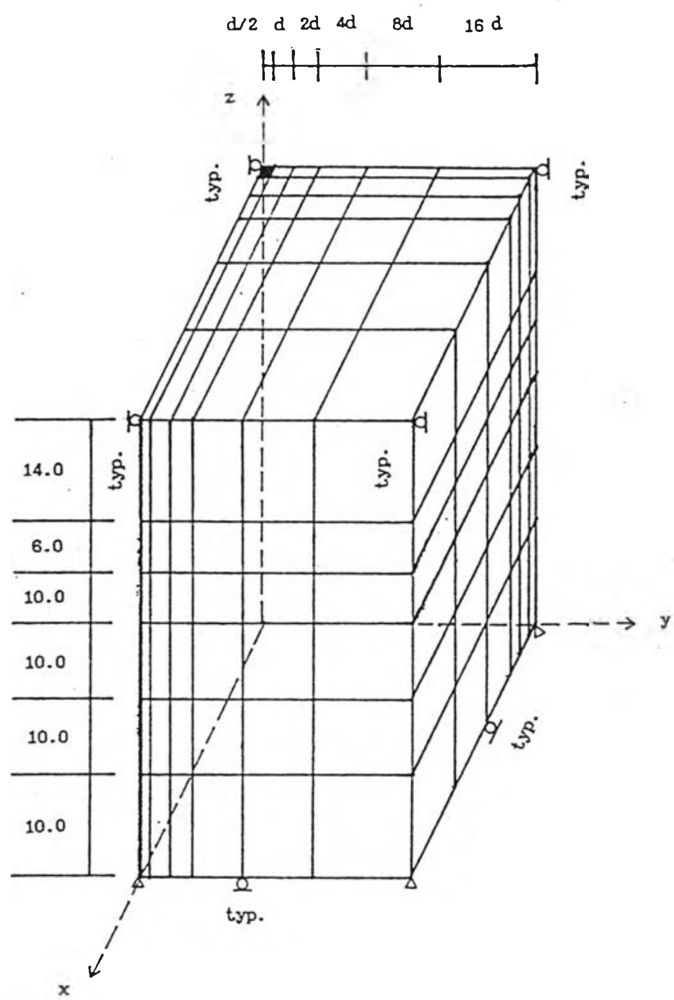



Figure 4.6 Finite element model for 4x4 pile group.




■ Pile element

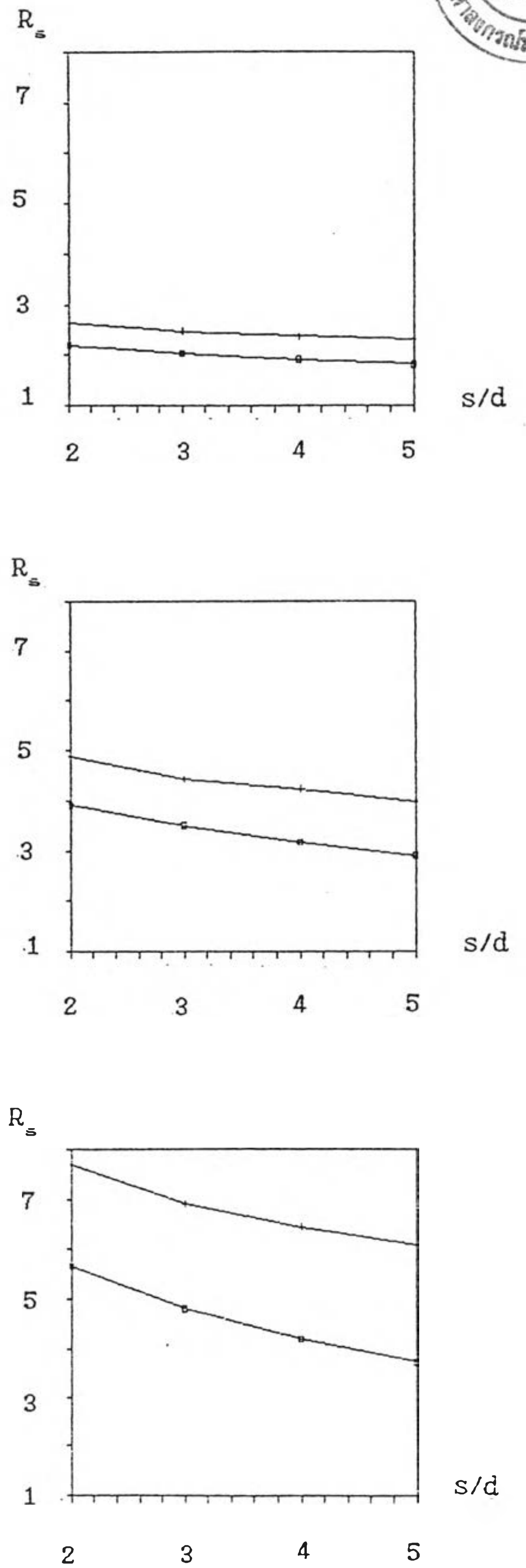
△ No translation in x, y and z direction

ᑫ No translation in x and y direction

ᑭ No translation in x and z direction

ᑴ No translation in y and z direction

Figure 4.7 Finite element model for single pile.




a) 2x2 pile group

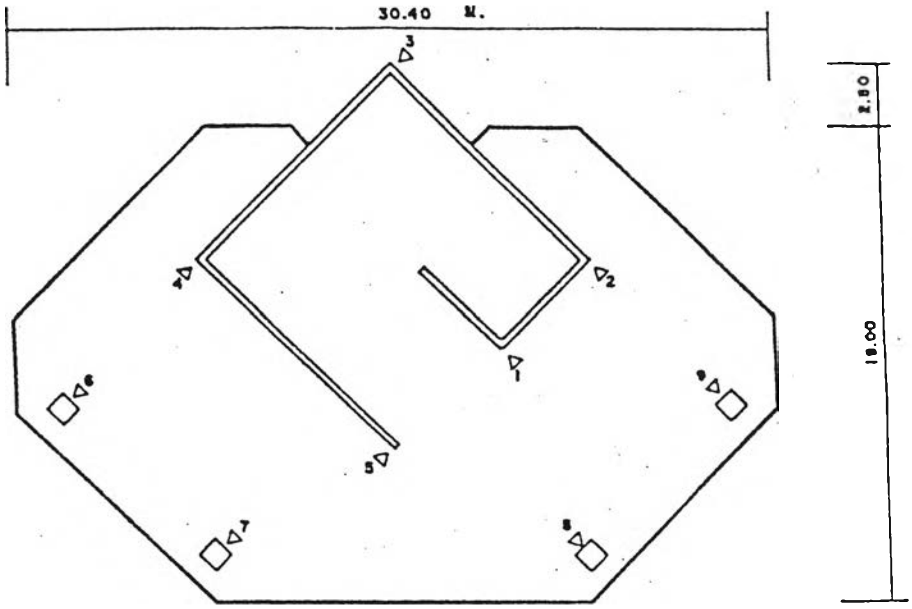
b) 3x3 pile group

c) 4x4 pile group

+ Poulos's method

▫ Proposed method

Figure 4.8 Relation between settlement ratio $R_s$ and pile spacing s/d.




Δ Observed point

Figure 4.9 The floor plan of Tower C Building with observed points.

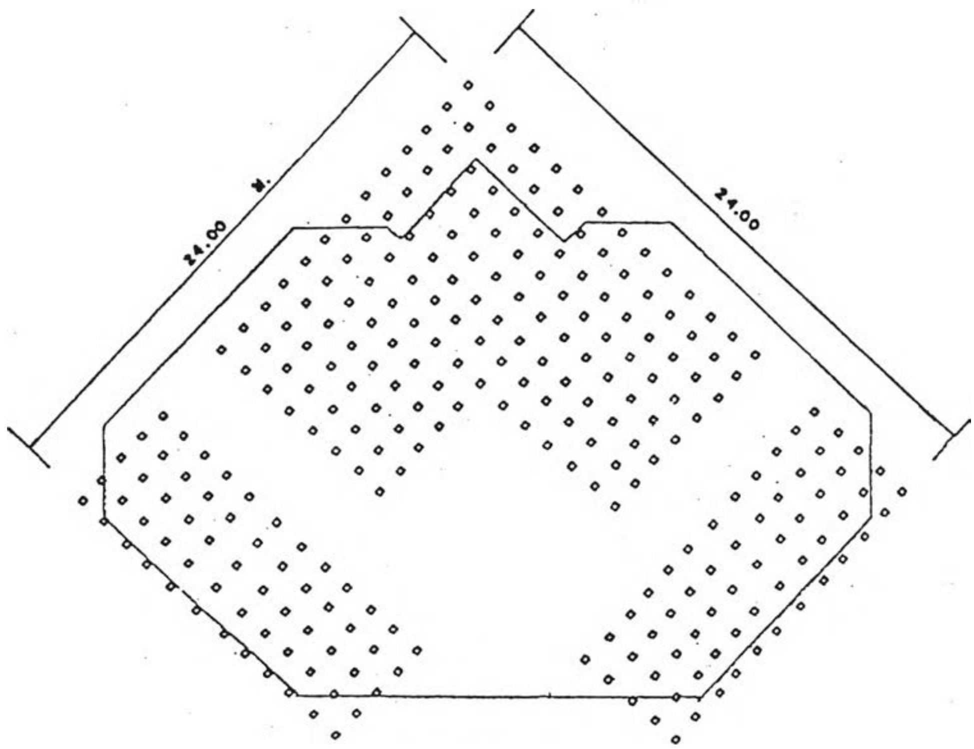
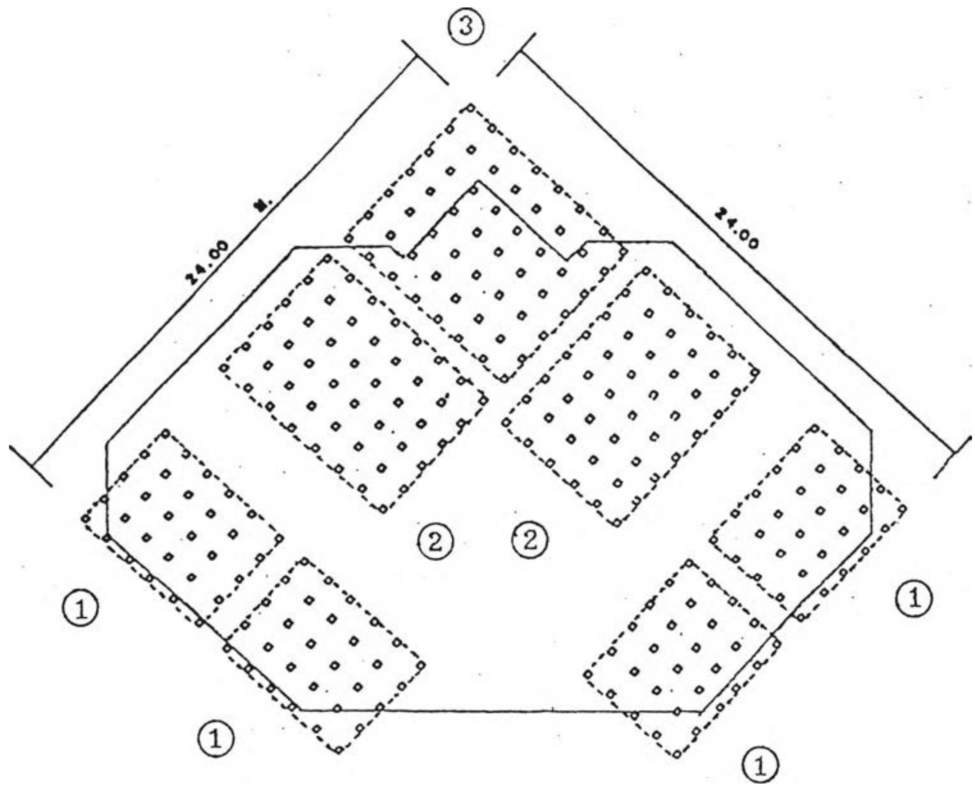



Figure 4.10 The plan of pile arrangement.

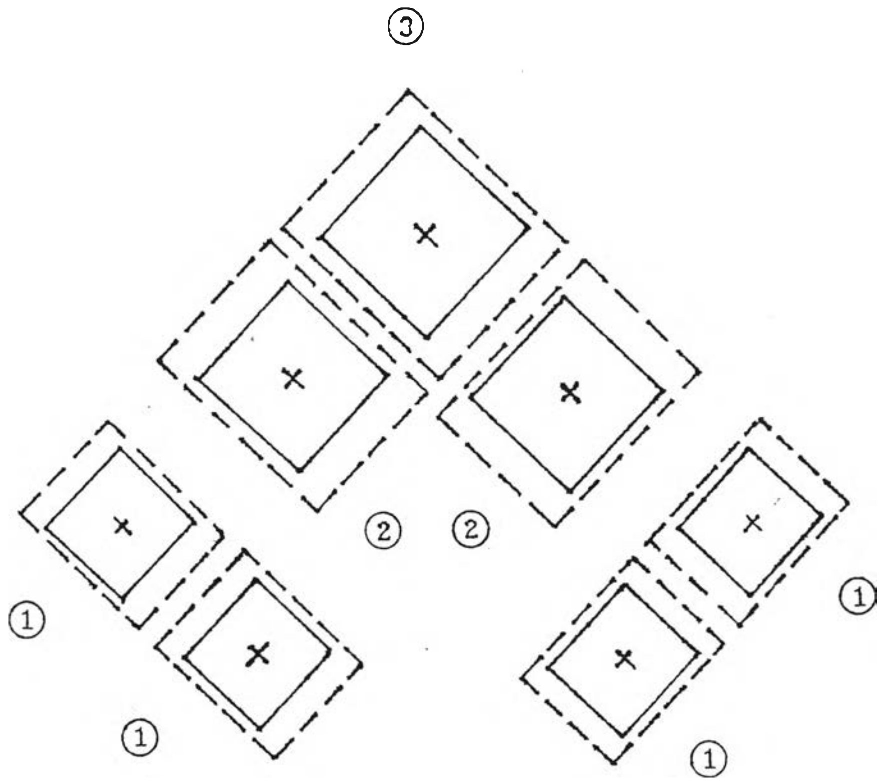



① 5x6 pile group

② 6x8 pile group

③ 7x8 pile group

Figure 4.11 The plan of the smaller pile groups.




- - - - Original pile group

——— Equivalent pile group

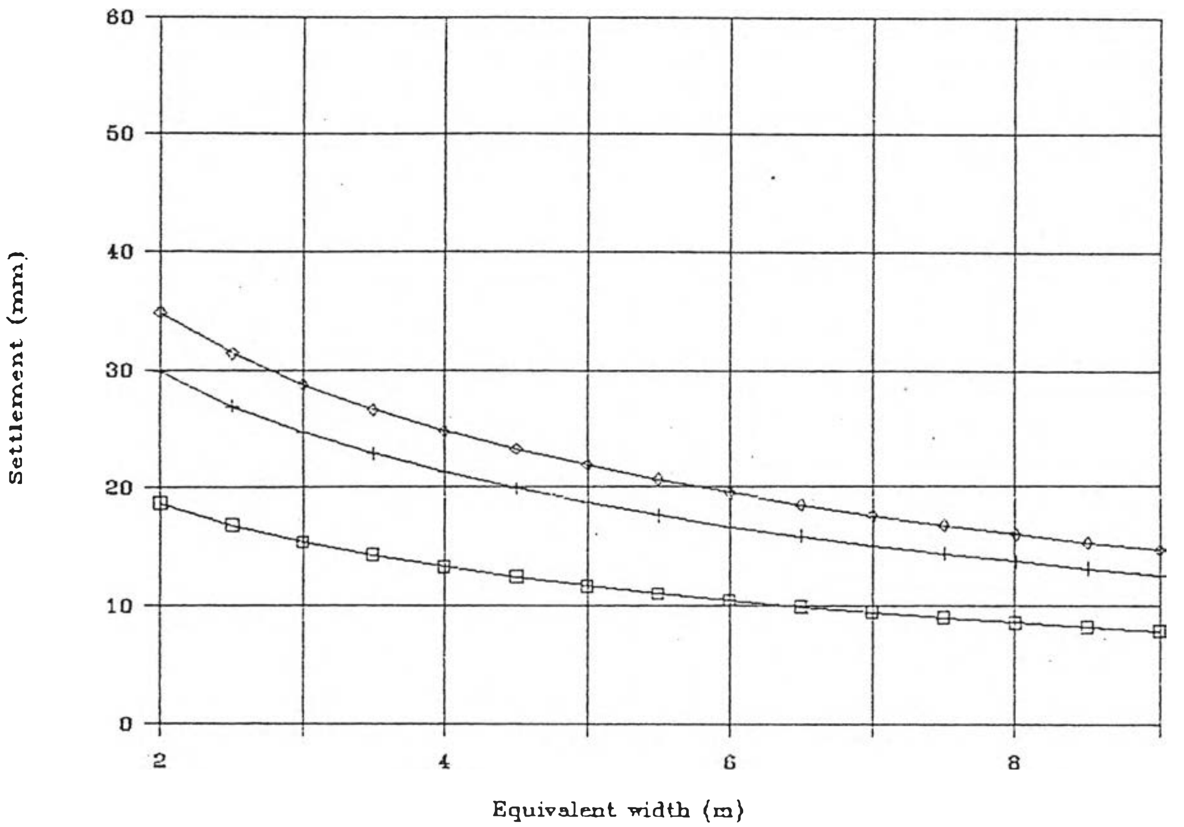
\+ Center of pile group

① Equivalent single pier for 5x6 pile group

② Equivalent single pier for 6x8 pile group

③ Equivalent single pier for 7x8 pile group

Figure 4.12 The plan of the equivalent pile groups.

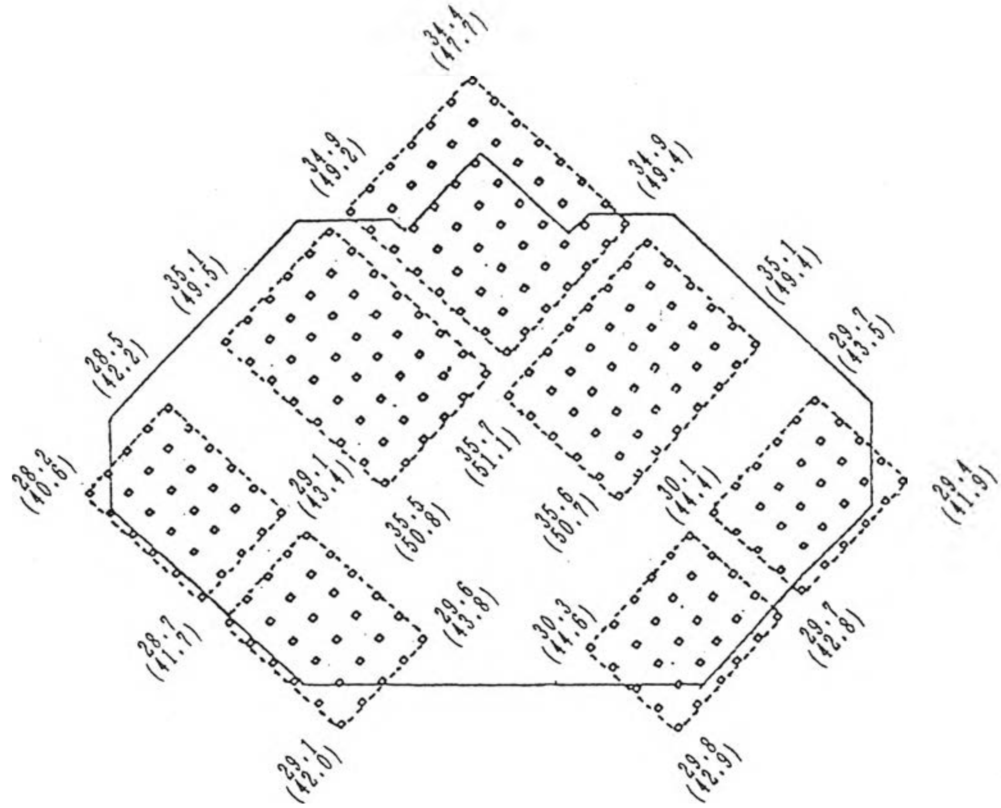



□ 5x6 pile group

\+ 6x8 pile group

◇ 7x8 pile group

Figure 4.13 The relation between the settlement and the equivalent width $B_e$ of pile groups.




Immediate settlement (mm)

( ) Final settlement (mm)

Figure 4.14 The settlement values predicted by the proposed method.

# VITA

Mr. Rutsapong Tweesaengsakulthai was born on August 27, 1964 in Khonkaen and graduated B.Eng. in Civil Engineering from Chulalongkorn University in 1985.