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FIGURES

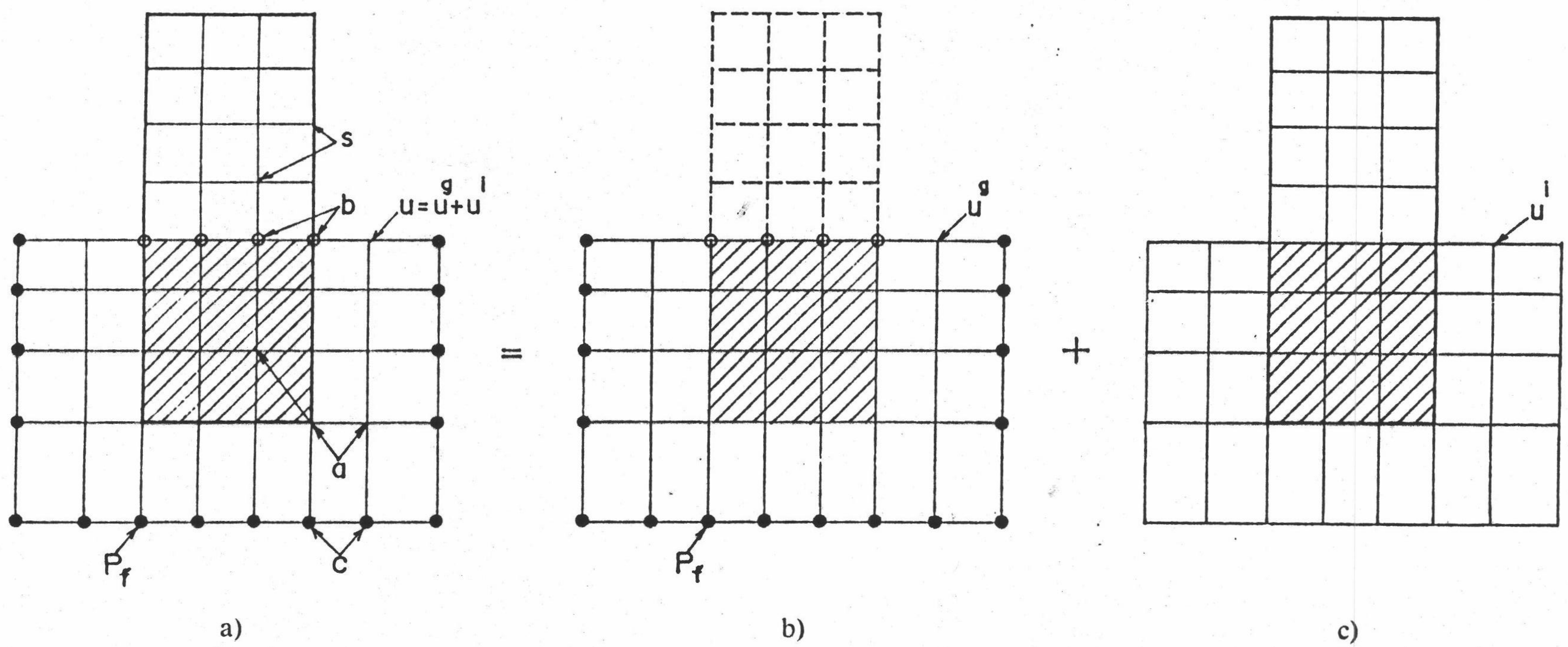
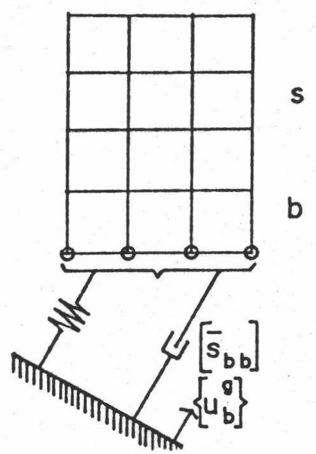
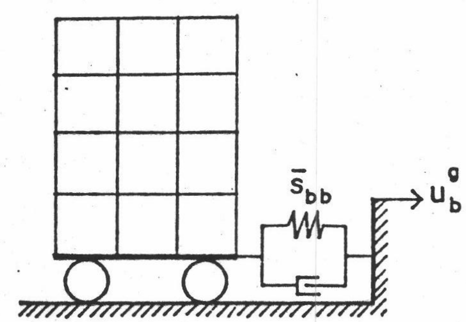


FIGURE 2.1 Displacement superposition schematic representation of soil-structure interaction substructuring a) complete model b) model of foundation without super-structure c) interaction model

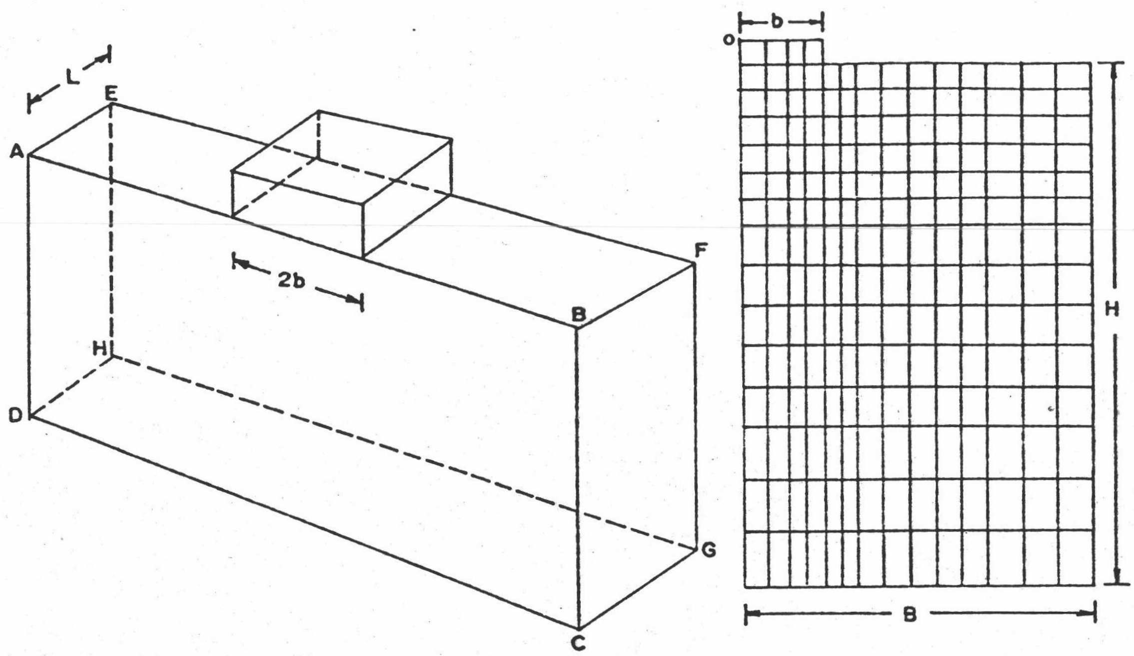


a)



b)

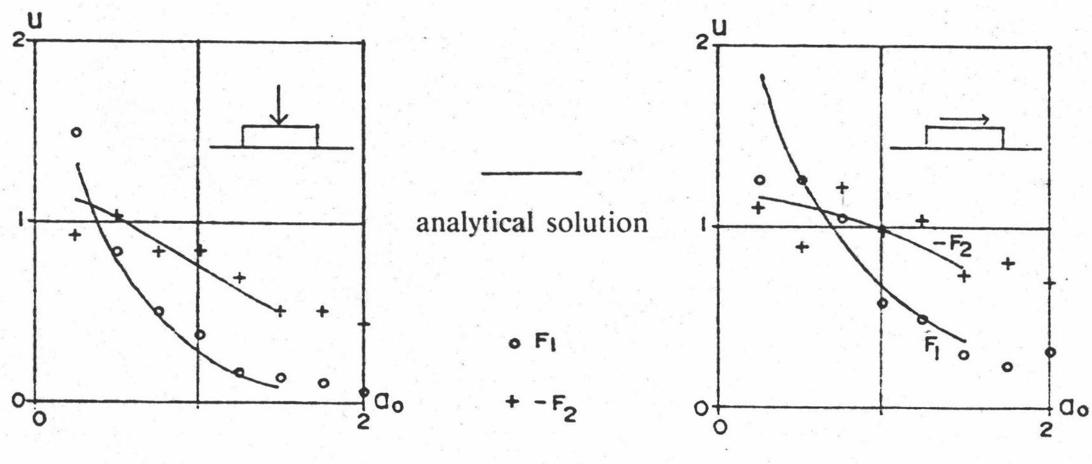
FIGURE 2.2 Physical interpretation of soil-structure interaction analysis using substructure



a) b)

FIGURE 3.1 a) Soil-structure model

b) Finite element discretization B/b = 4.3, H/B = 1.5, ν = 0.25



a) b)

FIGURE 3.2 Non-dimensional displacement functions comparing the plane strain finite element and analytical solutions

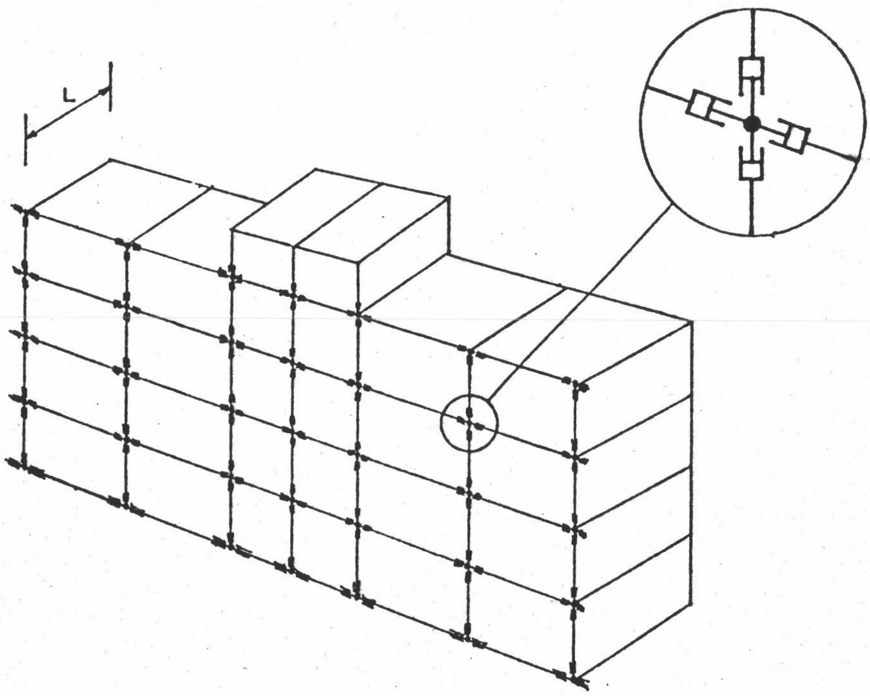


FIGURE 3.3 Simplified three-dimensional model using dashpots

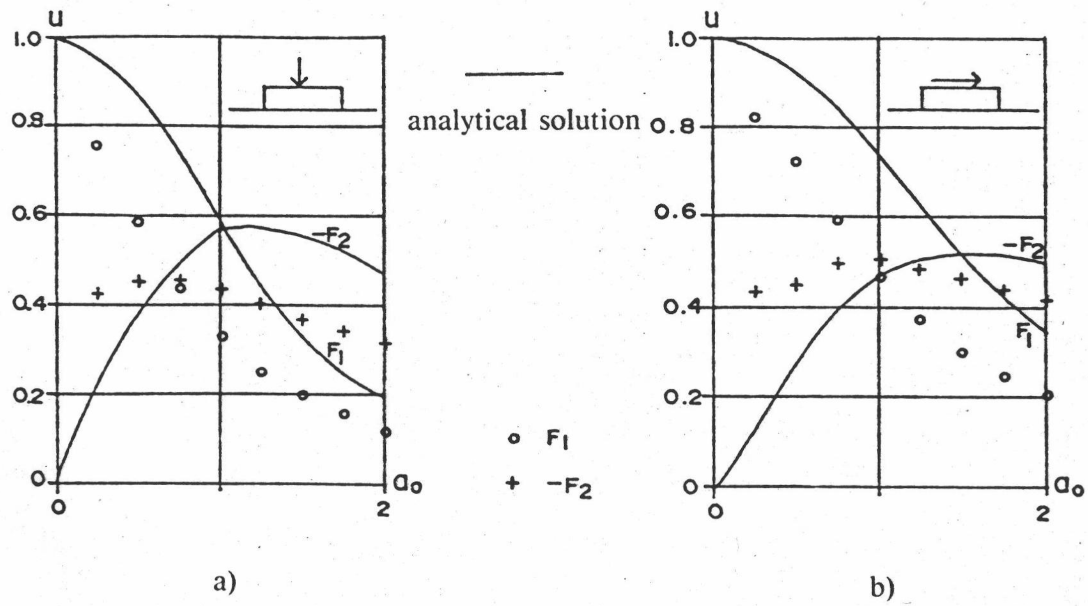


FIGURE 3.4 Non-dimensional displacement functions of circular footing on elastic half space comparing the Hwang's simplified three-dimensional model and analytical solutions

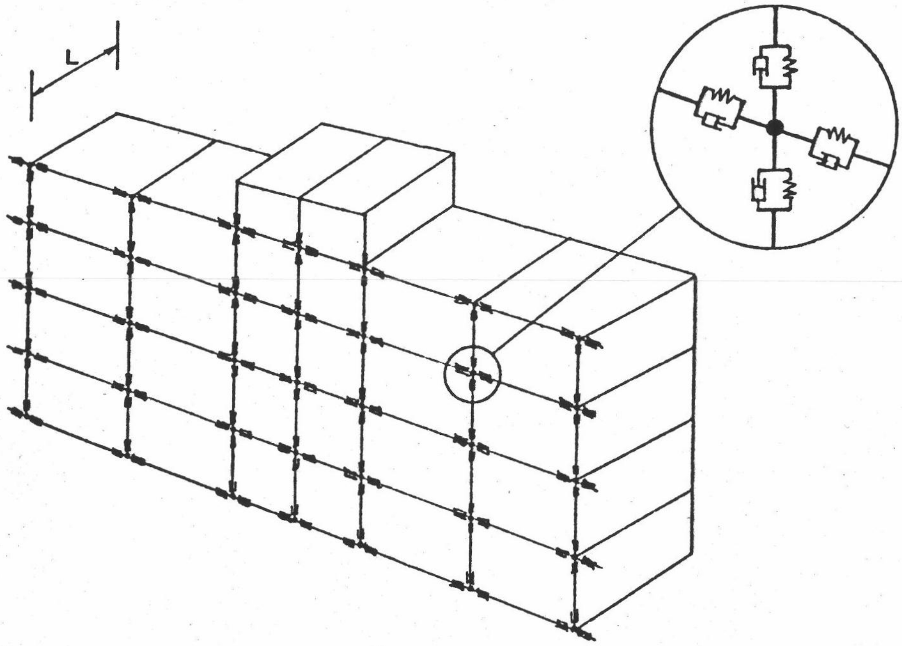


FIGURE 3.5 Equivalent plane strain model using dashpots together with side springs

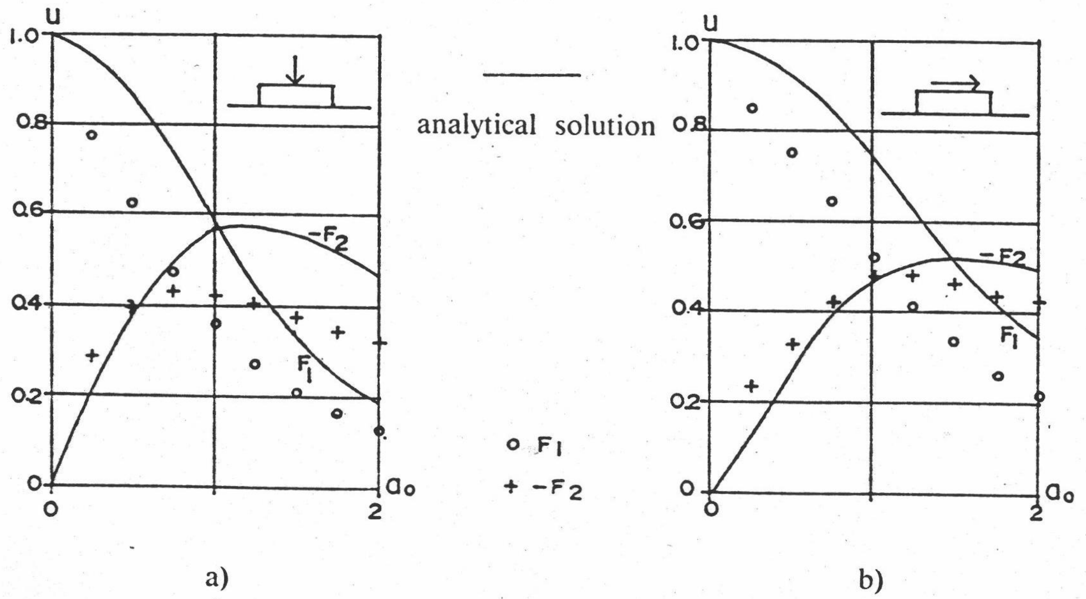
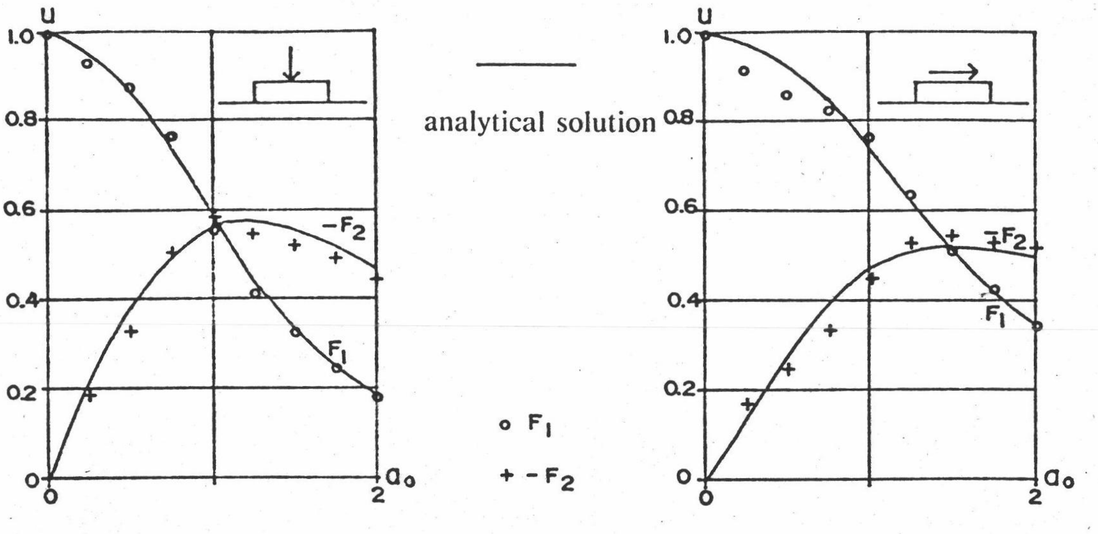


FIGURE 3.6 Non-dimensional displacement functions of circular footing on elastic half space comparing the proposed model using Hwang's parameters and analytical solutions

a) $C_m = 1.0$, $C_d = 1.0$ and $C_s = 0.0259$

b) $C_m = 1.0$, $C_d = 1.0$ and $C_s = 0.0449$

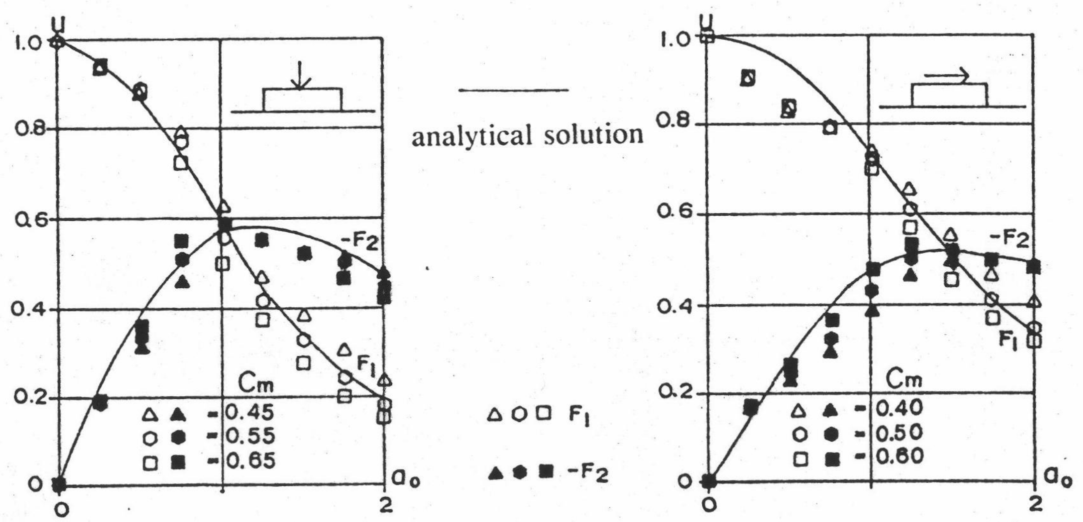


a) b)

FIGURE 3.7 Non-dimensional displacement functions of circular footing on elastic half space comparing the proposed model after adjustment of parameters C_m and C_d and analytical solutions

a) $C_m = 0.55$, $C_d = 0.35$ and $C_s = 0.0259$

b) $C_m = 0.50$, $C_d = 0.50$ and $C_s = 0.0449$



a) b)

FIGURE 3.8 Parametric study on the variations of C_m while keeping C_d and C_s constant

a) $C_d = 0.35$, $C_s = 0.026$

b) $C_d = 0.50$, $C_s = 0.042$

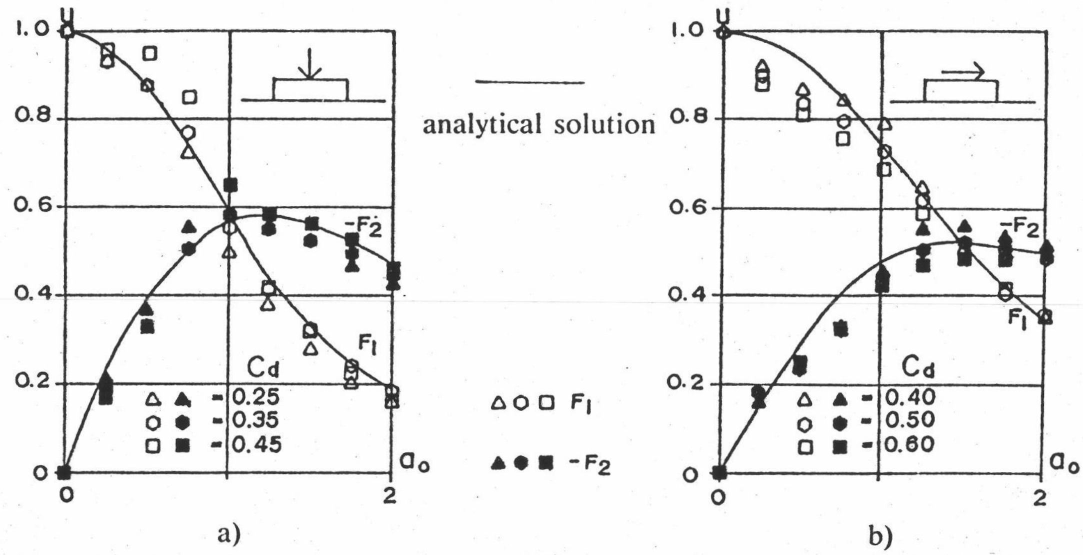


FIGURE 3.9 Parametric study on the variations of C_d while keeping C_m and C_s constant

a) $C_m = 0.55$, $C_s = 0.026$

b) $C_m = 0.50$, $C_s = 0.042$

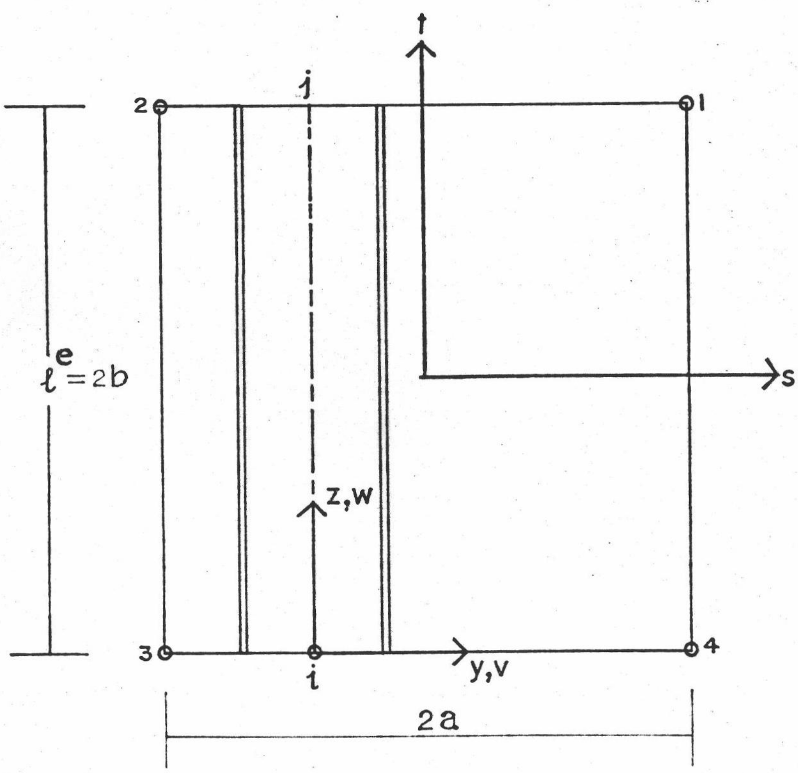


FIGURE 4.1 Typical soil-pile element

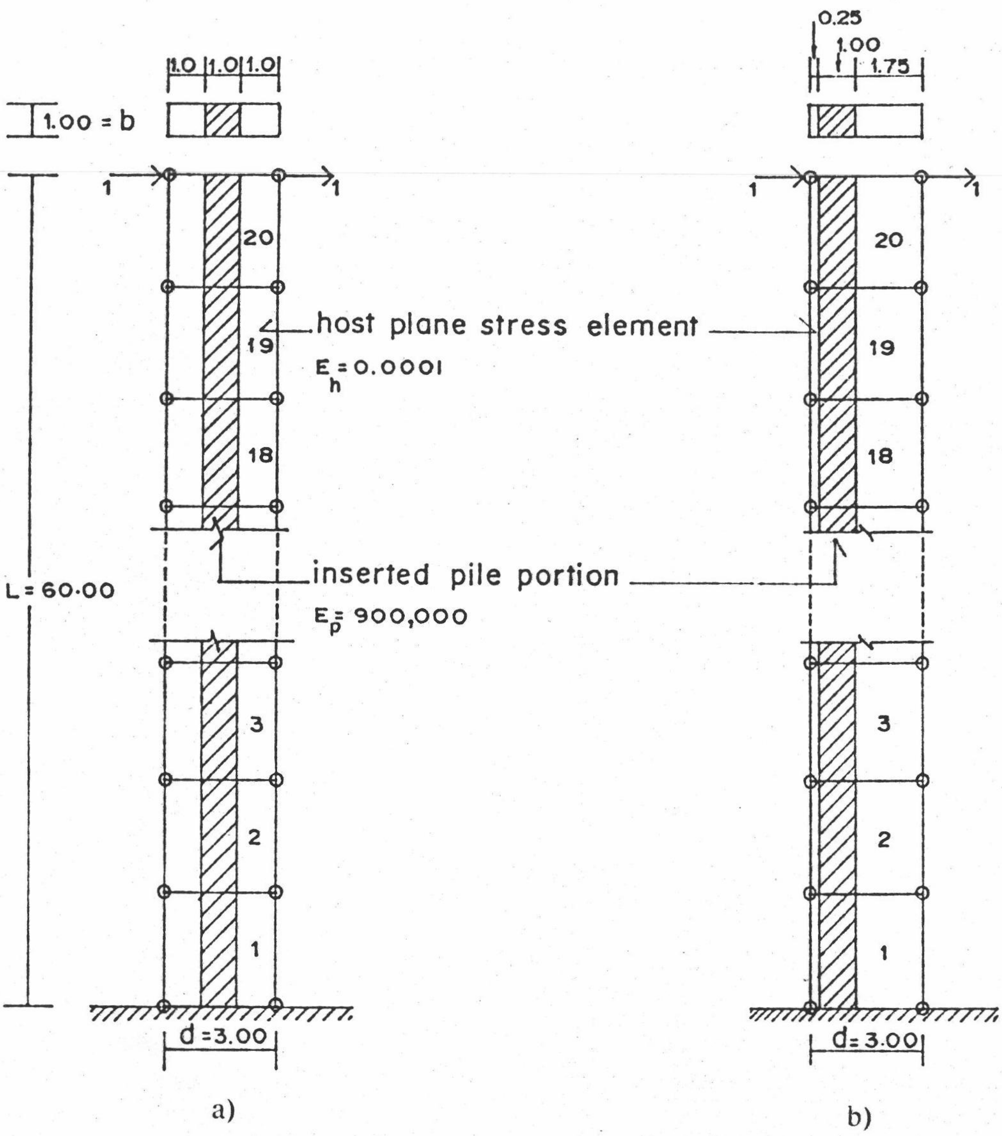


FIGURE 4.2 Cantilever beams using plane stress finite element model with inserted piles.

a) concentric pile b) eccentric pile

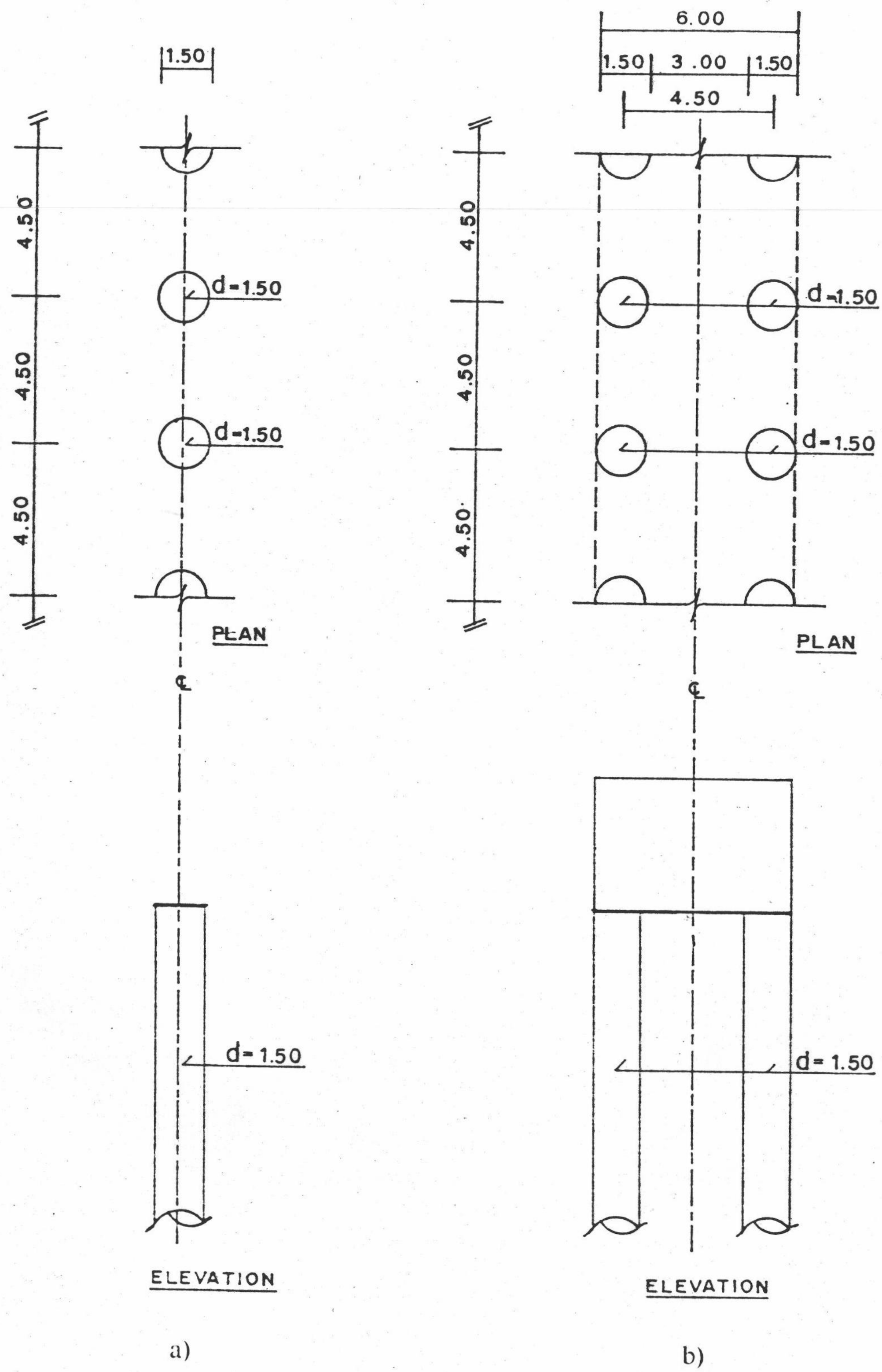


FIGURE 5.1 Pile configurations in the plane strain model

a) single-line piles b) two-line piles

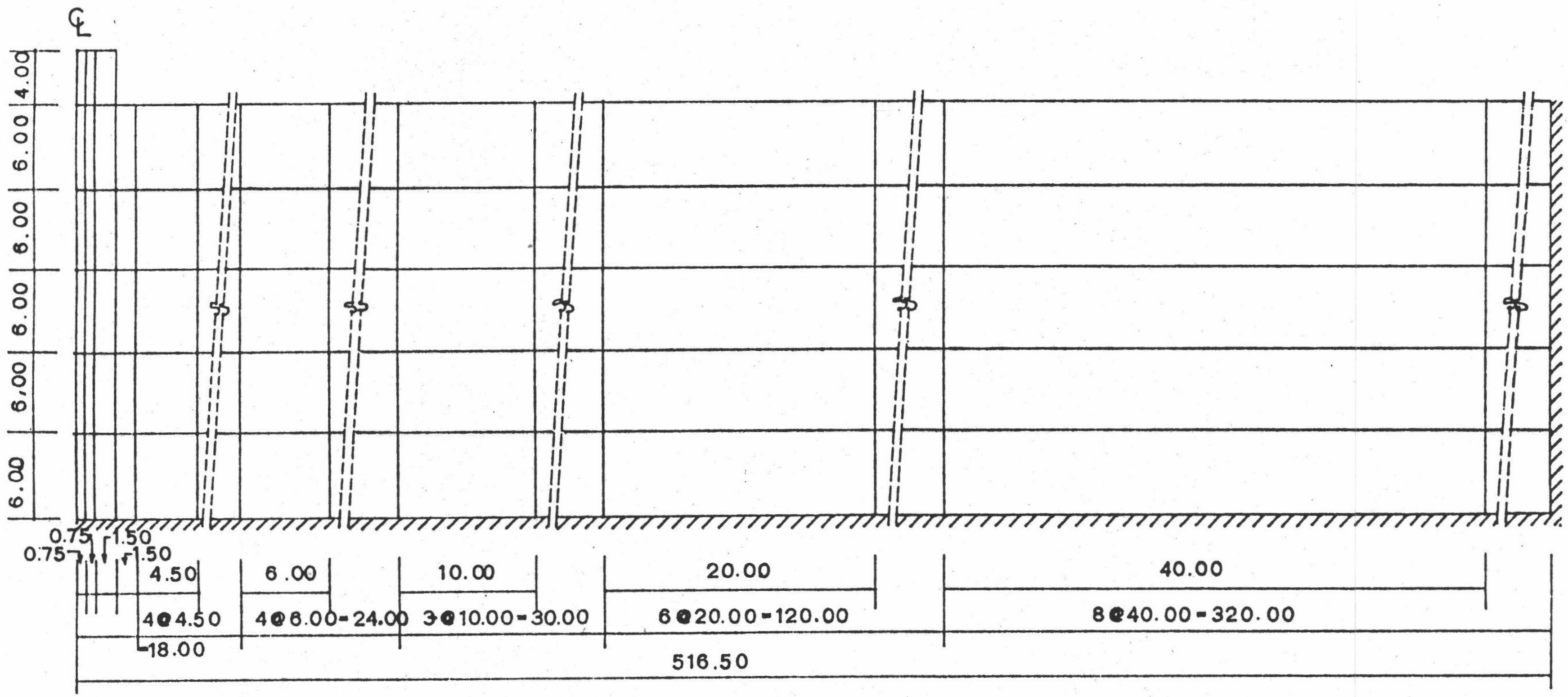


FIGURE 5.2 Finer model of finite element mesh

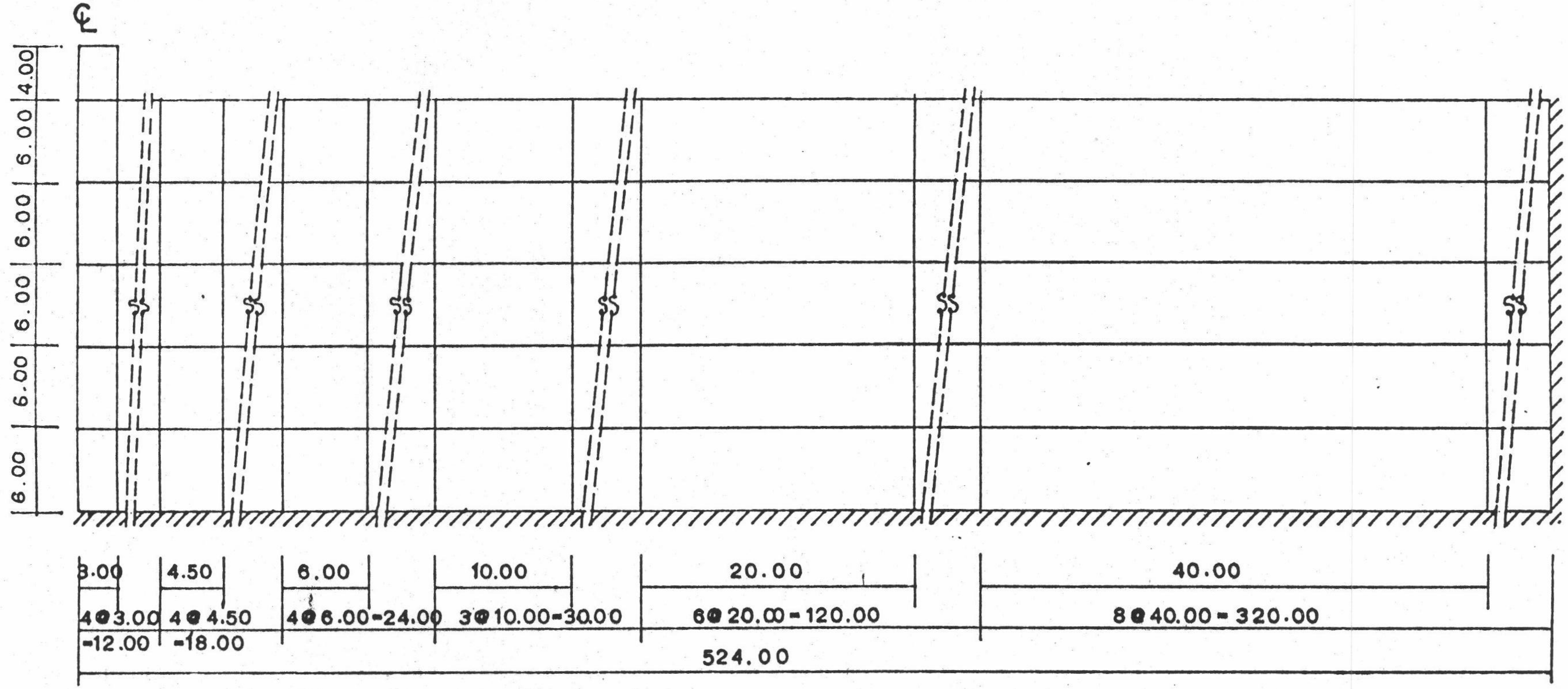
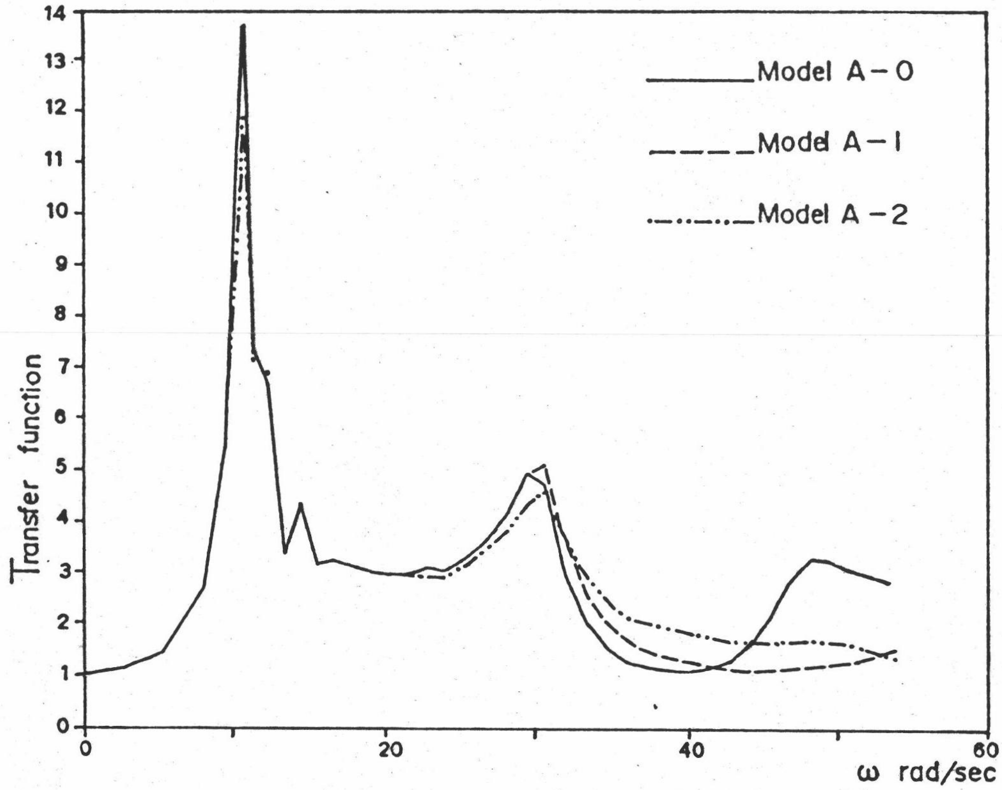
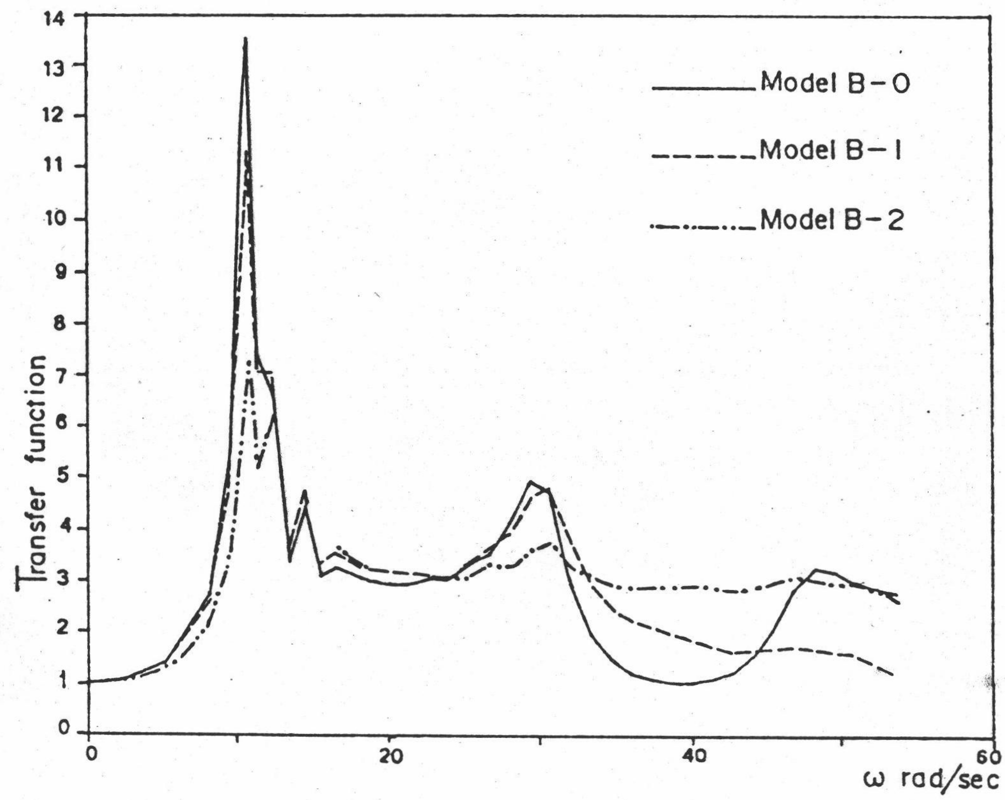


FIGURE 5.3 Coarser model of finite element mesh



a)



b)

FIGURE 5.4 Acceleration transfer functions a) finer models b) coarser models

APPENDIX

APPENDIX

Element Stiffness of Two-dimensional Plane Strain Element

As described in the introductory chapter, the two-dimensional plane strain model is used as the host soil element for the soil-pile element. Derivation of the plane strain element stiffness is simple and normally appears as an example in most finite element text books. The following presentation on plane strain element stiffness is to review the basic concept and to use the pertinent quantities as the basis in derivation of the soil-pile element stiffness.

Since the soil mass is a large medium and only the global effect on the super-structure due to soil is required, modeling of the soil element in the shape of simple rectangular with four corner nodes as shown in Fig. 4.1 is adequate and widely adopted.

For isoparametric elements, both the spatial coordinates and the displacement fields of any point within the element can be expressed by the same interpolation functions; thus we have

$$y\,(s, t) = \sum_{i=1}^{4} N_i^e\,(s, t) \cdot y_i \qquad \text{(A.1a)}$$

$$z\,(s, t) = \sum_{i=1}^{4} N_i^e\,(s, t) \cdot z_i \qquad \text{(A.1b)}$$

and

$$v\,(s, t) = \sum_{i=1}^{4} N_i^e\,(s, t) \cdot v_i \qquad \text{(A.2a)}$$

$$w\,(s, t) = \sum_{i=1}^{4} N_i^e\,(s, t) \cdot w_i \qquad \text{(A.2b)}$$

The local shape functions of the four-node two-dimensional rectangular element are in the form

$$N_1^e(s, t) = \frac{1}{4}(1+s)(1+t) \tag{A.3a}$$

$$N_2^e(s, t) = \frac{1}{4}(1-s)(1+t) \tag{A.3b}$$

$$N_3^e(s, t) = \frac{1}{4}(1-s)(1-t) \tag{A.3c}$$

$$N_4^e(s, t) = \frac{1}{4}(1+s)(1-t) \tag{A.3d}$$

The strain energy U_s, already derived in Chapter 2 and appears as the first term on the right hand side of Eq. (2.17), is

$$U_s = \sum_e \frac{1}{2} \int_{\Omega^e} \{q\}^T [B^e]^T [D^e][B^e]\{q\} \, d\Omega^e \tag{A.4}$$

in which $\{q\}$, the vector of generalized displacement defined by Eq. (2.10), is taken as the nodal point displacements :

$$\begin{Bmatrix} v \\ w \end{Bmatrix} = \sum_{i=1}^{4} \begin{bmatrix} N_i^e & 0 \\ 0 & N_i^e \end{bmatrix} \begin{Bmatrix} v_i \\ w_i \end{Bmatrix} = [N^e]\{q\} \; ; \tag{A.5}$$

$$[B^e] = [\, B_1^e, \; B_2^e, \; B_3^e, \; B_4^e \,] \tag{A.6}$$

in which

$$[B_i^e] = \begin{bmatrix} \dfrac{\partial N_i^e}{\partial y} & 0 \\ 0 & \dfrac{\partial N_i^e}{\partial z} \\ \dfrac{\partial N_i^e}{\partial z} & \dfrac{\partial N_i^e}{\partial y} \end{bmatrix} \tag{A.7}$$

and

$$[D^e] = \frac{E(1-\nu)}{(1+\nu)\,(1-2\nu)} \begin{bmatrix} 1 & \frac{\nu}{1-\nu} & 0 \\ \frac{\nu}{1-\nu} & 1 & 0 \\ 0 & 0 & \frac{1-2\nu}{2(1-\nu)} \end{bmatrix} \qquad (A.8)$$

where E is the modulus of elasticity and ν is the Poisson's ratio.

Formulation of element stiffness matrix follows as described in Chapter 2. In view of Eq. (2.22), we have

$$[K^e] = \int_{\Omega^e} [B^e]^T [D^e][B^e]\, d\Omega^e \qquad (A.9)$$

To find the shape function derivatives appearing in Eq.(A.7), we begin with the basic mathematical concepts. Since the transformation from the global x, y to the local s, t is assumed to be one-to-one mapping, any shape function, N_i, can be expressed in terms of both coordinates. We can write, using the chain rule, the shape function derivatives as

$$\begin{Bmatrix} \frac{\partial N_i}{\partial s} \\ \frac{\partial N_i}{\partial t} \end{Bmatrix} = \begin{bmatrix} \frac{\partial y}{\partial s} & \frac{\partial z}{\partial s} \\ \frac{\partial y}{\partial t} & \frac{\partial z}{\partial t} \end{bmatrix} \begin{Bmatrix} \frac{\partial N_i}{\partial y} \\ \frac{\partial N_i}{\partial z} \end{Bmatrix} \qquad (A.10)$$

where $\begin{bmatrix} \frac{\partial y}{\partial s} & \frac{\partial z}{\partial s} \\ \frac{\partial y}{\partial t} & \frac{\partial z}{\partial t} \end{bmatrix}$ is called the Jacobian matrix $[J]$.

Each term in the Jacobian matrix can be evaluated by differentiating Eqs. (A.1); $\frac{\partial N_i}{\partial s}$ and $\frac{\partial N_i}{\partial t}$ are obtained by differentiation of Eqs. (A.3). Then $\frac{\partial N_i}{\partial y}$ and $\frac{\partial N_i}{\partial z}$ can be solved by matrix inversion of Eq. (A.10). Integration of element stiffness in Eq. (A.9) can be performed on the local coordinate domain by using the relation from elementary calculus :

$$d\Omega^e = \det[J]\, t\, ds\, dt \qquad \text{(A.11)}$$

where det[J] is the determinant of the Jacobian matrix; t is the thickness of the two-dimensional element in the direction perpendicular to the y−z plane. Substituting $d\Omega^e$ from Eq. (A.11) into Eq. (A.9) yields

$$[K^e] = \int_{-1}^{1}\int_{-1}^{1} [B^e]^T[D^e][B^e] \det[J]\, t\, ds\, dt \qquad \text{(A.12)}$$

An appropriate numerical procedure can be adopted in the evaluation of $[K^e]$ in Eq. (A.12).

VITA

Mr.Suriya Thusneeyanont was born on January 17, 1952 in Rajburi. He graduated from Suankularb College in 1970. He entered Chulalongkorn University and received B.Eng. and M.Eng. in Civil Engineering from Chulalongkorn University in 1975 and 1981, respectively. After four years of teaching at Nakhonsawan Technical College, Department of Vocational Education, he enrolled in a D.Eng. program at Chulalongkorn University.