CHAPTER I

INTRODUCTION

Background

Investigation of soil-structure interaction problems due to external disturbances like earthquake excitation or machine vibration is a complicated task. Many researchers have conducted their works in this field in order to predict the soil-structure interaction behaviour in a logical and practical manner. Lysmer (1975) concluded the main objectives and requirements of an acceptably analytical method as :

1. ability to consider the variation of soil properties at different depths
2. ability to consider the nonlinearity and energy absorption of the soil medium
3. ability to consider the variation of soil displacements at different depths in case of embedded structure
4. ability to consider three-dimensional behaviour
5. ability to consider effects due to adjacent structures.

The above list contains the desirable features of an analytical method which will successfully model the behavior of the three-dimensional continuum. One quickly finds that the three-dimensional finite element modeling for the near field with special elements incorporated at the far field boundaries to absorb the reflecting waves is one of the best solutions.

However, the full three-dimensional finite element modeling results in an extremely large system of simultaneous algebraic equations which is time consuming to solve. A large mainframe computer is also usually required for such a large system. Furthermore, tremendous work is needed in data preparation, which is error prone due to the large amount of data involved. To reduce the amount of data and computation efforts, many researchers solve soil-structure interaction problems by using axisymmetric models. The obvious disadvantage of such an approach is the difficulty in discretizing of the effects caused by embedded piles which are often non-axisymmetric.

Lysmer et al. (1974) introduced another approach in which a two-dimensional plane strain finite element model is used to discretize the soil medium. The major advantages of this model are that the number of unknown variables are considerably reduced and that the effects of the adjacent structures can be considered; however, this approach cannot predict the real three-dimensional phenomenon. Hwang et al. (1975) improved this two-dimensional plane strain model by attaching dashpots on both sides of the plane strain slice to absorb waves propagating perpendicular to the plane. It should be noted that only earthquake excitation was considered. This model is called the simplified-three-dimensional model. The comparision of the results of the simplified model with that from a more refined axisymmetric modeling (as in Berger (1975)) yielded the conclusion that the simplified three-dimensional model can be used for practical problems of seismic analyses of structures.

The simplified three-dimensional model is interesting because of its simplicity and low cost. The model can be well applied in the case of non-axisymmetric structures and when accounting for the effects of the adjacent structures. However, no study has been done on the case of point loads directly applied on the foundation.

Soil-structure interaction problems become even more complicated when piles are present. Penzien (1970) introduced an approximate method for soil-pile-structure interaction analyses using lumped springs, dashpots and masses. However, it is difficult to appropriately determine such parameters due to the complexity of the real nature of the continuum. Novak (1974) applied analytical solutions of horizontal plane strain medium to evaluate the stiffness and damping of a single pile. Novak's solutions have been widely referred to in most of the later works. The same concept had been further examined in Nogami and Novak (1976), Novak and Nogami (1977), and others. For a pile group, it is very difficult to apply Novak's method due to the presence of pile-soil-pile interaction.

Blaney et al. (1976) utilized the axisymmetric finite element model developed by his predecessors, Kausel et al. (1975), to analyse single pile problems. The solutions agree with Novak's results.

Wolf and von Arx (1978) proposed an effective method for solving pile group problems. Using an axisymmetric finite element in conjunction with a Fourier expansion of loads, the complex stiffness of the soil medium without pile can be determined by inverting the complex flexibility matrix relating to all unit interaction forces at the nodes of each pile concerned. The soil-pile interaction forces acting on any pile node can then be written as a product of the complex stiffness matrix and the unknown nodal displacements, and the equations of motion for the piles can be easily obtained.

A paper presented by Aubry and Postel (1985) inspired the writer's idea to conduct a simple approach for the soil-pile-structure problems. Beginning with Navier equations in the frequency domain, Aubry and Postel formulated the element stiffness and mass matrices of soil including embedded piles within the volume of the soil mass, resulting in the matrices of the homogeneized soil-pile element.

Objectives

The main objectives of the present study are: (i) to investigate validity of Hwang's model in case of point loads acting on the foundations, (ii) to propose a new approach to modify the plane strain model for equivalent results with those of the three-dimensional model, and (iii) to introduce a simple soil-pile element and study effects of piles in seismic analyses.

Scope of Study

The soil-structure considered in this study is treated as an elastic system undergoing small displacements. Piles are idealized as one dimensional beam elements, perfectly bonded with the surrounding soil.

For footings on elastic half space the effects of vertical and horizontal concentrated loads as well as earthquake excitations are investigated. However, for pile-foundations only seismic loadings are considered since the equivalent plane strain model is not suitable in such cases.

Results obtained from linear elastic analyses should be acceptable for most practical cases due to the fact that only small displacements are usually tolerated in vibration problems. Furthermore, plastic deformations, if existent, would reduce responses of structures. Thus a linear elastic solution would be conservative for practical purposes.