CHAPTER V

PILE EFFECTS IN EARTHQUAKE ANALYSES

Soil-Pile Modeling for Earthquake Analyses

For an elastic half space under earthquake excitations, the whole soil medium in each cross section is commonly assumed to undergo the same ground motion. Consequently, the state of plane strain approximately prevails as far as the soil foundation is concerned. Since the fundamental frequencies of soil medium resting on rigid bed rock determined by one-dimensional wave equation or two-dimensional plane strain model or three-dimensional model are almost the same as shown by Berger et al. (1975), the ordinary two-dimensional plane strain model should be adopted rather than the equivalent plane strain model in which the addition of side spring and the mass reduction schemes are incorporated.

Moreover, Berger et al. (1975) and Hwang et al. (1975) made some comparisons between the results by using the ordinary plane strain model and the axisymmetric model. The most valuable conclusion is that even though responses of the top of the super-structure differ somewhat for the two models, the surface ground motions are almost the same.

Example Problems

Since there is no previous research work concerning pile effects in the plane strain model, the pile foundation investigated by Wolf and von Arx (1978) is taken as an example problem. The foundation consists of the homogeneous soil medium of 30 m depth resting on rigid bed rock. The shear modulus G and mass density ρ of the soil are 60 MN/m^2 and 1.5 Mg/m^3, respectively, resulting in a shear wave velocity V_s of 200 m/sec. Poisson's ratio ν of the soil is taken to be 0.4. Piles are made of concrete with the following properties : modulus of elasticity E = 30 GN/m^2, mass density = 2.5 Mg/m^3, ratio of hysteretic damping = 0. The radius of each pile is 0.75 m and the piles are spaced 4.5 m in both directions. Single pile (1×1) and 2×2 pile configurations were considered herein.

While the axisymmetric model used by Wolf and von Arx accurately represents the problem considered, so long as there exists no adjacent building, the plane strain model would be quite acceptable for practical purposes. The reason is that in reality in urban areas, buildings are constructed not too far apart alongside the streets so that rows of piles extend for a large distance from the one considered.

The difference in pile configurations in the axisymmetric model and in the plane strain model are illustrated in Fig.5.1. For example, single pile in the axisymmetric model denotes that there exists only one pile in the half space but in the plane strain model it is implied that piles are arranged with equal spacing perpendicular to the slice of the plane strain model.

To check the validity of the proposed model and to study the effects of pile to resist earthquake, transfer functions stated in Chapter 2, are considered.

To study the effectiveness of the soil-pile element proposed, two model groups representating the finer and the coarser finite element meshes were constructed. In the finer models, the widths of the plane strain host elements in which the piles were occupied were set equal to the pile diameter. Fig.5.2 shows the finer finite element mesh layout for model group A. Three cases were considered which corresponded to plane half space (without pile), single pile and 2×2 pile configurations. These are labeled as models $A-0$, $A-1$ and $A-2$, respectively. To test the mesh size effects, a coarser finite element mesh B in which the plane strain host element widths were much larger than the inserted pile diameter as shown in Fig. 5.3 was adopted. As in model group A, model B − 0, B − 1 and B − 2 represent no pile, single pile and 2×2 pile configurations, respectively.

Transfer Functions

Results of analyses for the acceleration transfer functions, for 5% hysteretic damping obtained from the finer models (model A − 0, model A − 1 and model A − 2) and of coarser models (model B − 0, model B − 1 and model B − 2) are shown in Fig. 5.4a and Fig. 5.4b, respectively.

In case of free field problem (i.e. without pile), the transfer functions determined using both finer and coarser models are almost identical. The maximum transfer function at fundamental frequency is about thirty-five percents greater than that of Wolf and von Arx, due to the nature of plane strain which is more flexible than that of axisymmetric model.

The transfer functions resulting from model A − 1 (with single line piles) are very close to the transfer function for the free field condition indicating that the contribution of a single pile is negligibly small compared with the whole half space. However, in case of two-lines piles, the transfer function at fundamental frequency is somewhat reduced, by about 20%.

In contrast to the present findings, the transfer functions given by Wolf and von Arx for the free field and the 2×2 pile models are almost the same. The major cause of discrepancies is the differences in pile configurations of the axisymmetric model and the plane strain model as noted in the previous section.

Except for the free field problem, the coarser models yield unsatifactory results when piles are present. The transfer functions at fundamental frequency are much smaller than those of the finer models, indicating that the coarser models with piles are stiffer than the real conditions.