A METHOD FOR THE DYNAMIC ANALYSİS OF EMBEDDED STRUCTURES

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SUMMARY

In the dynamic analysis of embedded structures, non-reflecting boundaries are proposed to use along with transmitting and viscous boundaries. With this approach, a rigid base assumption at the base will be dispensed with.

1. INTRODUCTION

To analyse an embedded structure using the finite element method, the structure as well as the adjacent soil, should be discretized adequently. The larger the discretized zone is, the better representation of the mathematical model will be attained. This intention towards better modelling will obviously increase the number of equations which will eventually leads expensive solution. However, in order to minimise the finite element applied zone, viscous [1] and transmitting [3] boundaries have been widely used in this field.

Even though, these boundaries are employed for the mathematical modelling of the problem, it is assumed that the model has to be extended as far as a rigid base, or else a rigid base assumption has to be made at the base. To extend the mathematical model to reach the rigid base will automatically increase the number of elements, particularly in the existing of deep soil deposits. In this case, the cost of the solution will be much pronounced due to the limitations on the element size [2] depending upon the foundation materials.

2. PROPOSED MODEL

In this study, a mathematical model which does not require a rigid base assumption is employed. Such that so called 'non-reflecting boundaries'are introduced at the base. The employed model has three features : a) It has transmittng boundaries to include the dynamic effect of both left and right layered zone, b) Wave propogation due to the soil-structure interaction effect is included by the use of viscous boundaries on the planer surfaces, c) Non-reflecting boundaries are used along the base to dispense with the rigid base assumption, as shown in Fig 1.

The proporties of latter boundaries may be summarized into three groups. a) Displacements at these boundaries are equal to the total displacements of the free field at the same depth, b) There will be viscous dampers to absorbe the incomming energy.

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c) At non-reflecting boundaries, forces acting on the discretized zone, due to wave propogation will be calculated only from the incident wave components of vertically travelling shear waves.

3. EQUATION OF MOTION

In order to provide the requirement of non-reflecting boundaries, the equation of motion needed to be written in terms of total displacements rather than relative displacements. In addition it will also necessitate utilising a force time history as an input motion. These forces, by definition, should be composed of only incident wave components of vertically travelling shear waves.

In an half space, acceleration and shear stresses occur due to shear waves can be expressed as follow [5].

$$\ddot{u}(y,t) = -\omega^2 (Ee^{iky}+Fe^{-iky})e^{i\omega t} \qquad (1)$$

$$\tau(y,t) = -ikG^* (Ee^{iky}-Fe^{-iky})e^{i\omega t} \qquad (2)$$

The right hand side of Eq.1 is the known given acceleration time history. Similarly, that of Eq.2 can be obtained simply by using the equation of motion of a unit-cross sectional soil-column to a given ground acceleration. This equation may be written in a matrix form as,

$$[M]\{\ddot{u}\}^r+[K]^* \{u\}^r = - \{m\} \ddot{u}(t) \qquad (3)$$

where, $[M],[K]^*,\{u\}^r$, $\ddot{u}(t)$ are mass, complex stiffness matrix including damping effect, relative displacement vector and acceleration, respectively. $-\{m\}$ is the product of mass matrix and direction cosines vector. Once, relative displacements are obtained from Eq.3, then total displacements can be obtained by adding relative displacements to the base displacements. Forces can be worked out in terms of stiffness matrix and total displacement vector,

$$\{p\} = [K] \{u\} \qquad (4)$$

The coplex amplitude of the total force acting on the unit area at the base of the soil-column (where ground acceleration is applied), may be calculated in terms of total displacements of the column element connected to the base. Such that,

$$W_s = ([K]^*_{n+1} - \omega^2 [M]_{n+1}) \left| \begin{matrix} U_{fn} \\ U_{fn+1} \end{matrix} \right| \qquad (5)$$

in this equation n, indicates the n^{th} row of the matrices involed. U_{fn} and U_{fn+1} are complex amplitudes of total displacements of the last column element. Using equations 1 to 5 the coefficient E in Eq. 1 and 2 related to the incident wave component, can be worked out as,

$$E = \frac{1}{2} \left(- \frac{\ddot{U}}{\omega_s^2} - \frac{W_s}{iGk} \right) \qquad (6)$$

Once, the value of E is substitute in Eq. 2 and omitting the reflecting wave component, then, the complex amplitude of non-reflecting boundary forces in the frequency domain may be expressed with the following expression,

$$W_{si}=\frac{1}{2}(W_s+\frac{iG^*k\ddot{U}}{\omega_s^2}) \qquad (7)$$

where, G*,k,Ü and i are complex shear modulus, wave number, complex amplitute of ground acceleration in the frequency domain and unit complex number, respectively.

The equation of motion of the defined mathematical model may then be expressed in terms of total displacements, non-reflecting and other viscous and transmitting boundary forces. This equation is similar to that used by Lysmer et al [4] as,

$$[M]\{\ddot{u}\}+[D]\{\dot{u}\}+[K]^*\{u\} = \{W\}-\{V\}+\{F\}-\{T\} \qquad (8)$$

Additional terms in this equation are the second and fourth terms which define damping and boundary forces at the mobile base, defined as non-reflecting boundaries. This equation was solved in the frequency domain for harmonic acceleration with unit amplitude. Results are demonstrated in Fig. 1.

Through the analysis of the presented results, it is seen that the variation of ground motion along the elevation is a factor of soil-structure interaction phenomenon.

4. CONCLUSIONS

In the dynamic analysis of an embedded structures, non-reflecting boundaries may be satisfactorily employed along with transmitting and viscous boundaries. They will also help to choose a mathematical model which dispense with the rigid base assumption. To this end, it is no need to require that the region where finite elements are applied should be extented as far as the rigid base.

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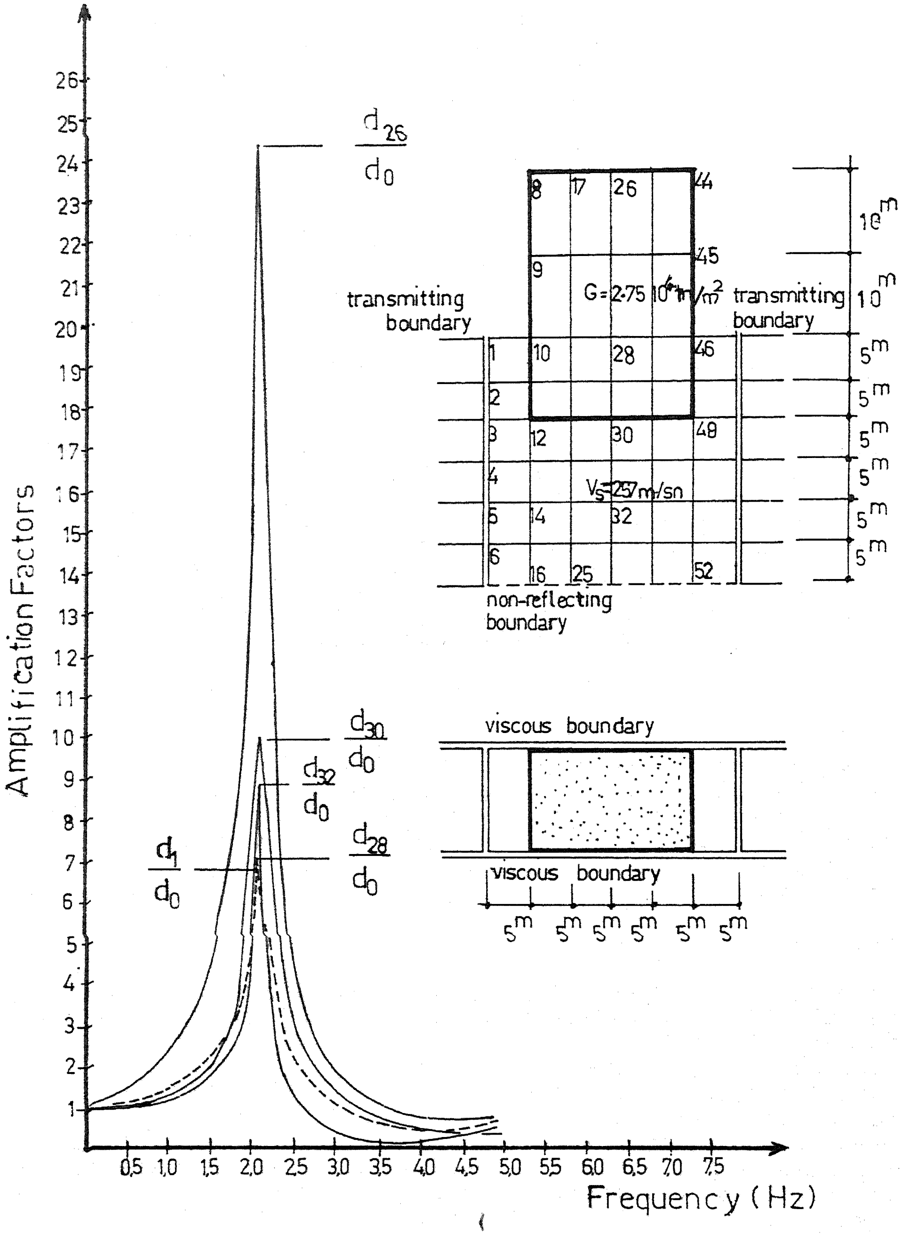

Fig.1 Amplification Factors of Nodal Points 26,28,30,32