*Structural Eng. / Earthquake Eng. Vol. 4. No. 1, 233s-236s. April 1987 / Technical Note.*
*Japan Society of Civil Engineers (Proc. of JSCE No. 380 / I-7)*

# DAMPING COEFFICIENT OF STRUCTURAL FOUNDATION ANALYZED BY 3-D FEM WITH NON-REFLECTING BOUNDARY

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The Dynamic FEM is frequently used for analyzing wave propagation problems. In case of infinite or semi-infinite media, the artificial boundaries reflect the waves. The present authors could solve the problem by applying Smith-Cundall's method. It superimposes two types of waves reflected from Dirichlet's and Neumann's boundaries. In this study, the radiation damping of structure models has been analyzed using this Finite Element Method.
*Keywords* : *FEM, non-reflecting boundary, radiation damping.*

## 1. INTRODUCTION

Suzuki and Hakuno (1984)[1),2)] developed the FEM idea of Smith[3)], Cundall and Kunar[4)] to a three dimensional one with non-reflecting boundaries. This three dimensional FEM does not generate the reflecting waves at boundaries.

The numerical free vibration of the structure model foundation in the ground, was obtained by using the 3D-FEM. The radiation damping of the structure, obtained from the free vibration, has been analyzed.

## 2. RADIATION DAMPING OF A STRUCTURE WITH VARIOUS FOUNDATION DEPTHS

Structure's model is shown in **Fig.** 1 (b). The cross-sectional areas for all models are 10 m×20 m. Structure's height and the depth of the foundation are given in Table 1. The total element's number used for the analysis is 5 880. The size of each is 5 m×5 m×5 m.

The region of boundary depth, where the reflecting wave is eliminated, consists of four elements. The free vibration of the structure is calculated step by step with time interval $\Delta t=0.01$ sec by applying an impulsive force, as shown in **Fig.** 1 (a), on the top of the structure. Structure's materials and the ground are considered to be of linear elastic characters. The internal damping of the system has not been taken into account, therefore, all the damping effect found in the free vibration could be caused by those waves transmitted from the foundation into the ground.

**Fig.** 2 shows each model, the wave form of the input force and the displacement response of the model. The shaded portion indicates the comparatively hard material. The height of the superstructure of models

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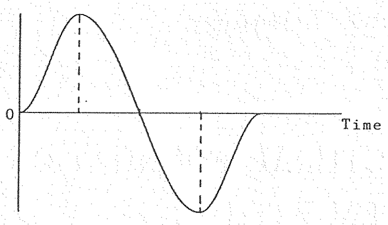



Fig. 1 (a) Wave form of applied force, half period of Sine plus 1/4 of Cosine.

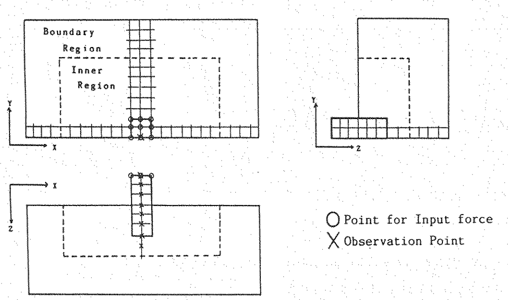



Fig. 1 (b) FEM model (corresponding to model No. 1 in Table 1).

Table 1 Model cases for 3-D FEM simulation.

| Model No. | Superstructure and Foundation | | | | Ground Condition | |
|---|---|---|---|---|---|---|
| | Height of Super-structure(m) | Depth of Foundation (m) | Vs(m/s) | ν | Vs(m/s) | ν |
| 1) | 15 | 15 | 200 | 0.3 | 100 | 0.4 |
| 2) | 15 | 5 | 200 | 0.3 | 100 | 0.4 |
| 3) | 15 | 0 | 200 | 0.3 | 100 | 0.4 |
| 4) | 15 | - | 100 | 0.4 | 100 | 0.4 |
| 5) | 15 | - | 200 | 0.3 | 200 | 0.3 |
| 6) | 15 | 15 | 200 | 0.3 | 100 | 0.4 |
| 7) | 15 | 5 | 200 | 0.3 | 100 | 0.4 |
| 8) | 15 | 0 | 100 | 0.4 | 200 | 0.3 |
| 9) | 5 | 15 | 200 | 0.3 | 100 | 0.4 |
| 10) | 5 | 5 | 200 | 0.3 | 100 | 0.4 |
| 11) | 5 | 0 | 200 | 0.3 | 100 | 0.4 |
| 12) | 5 | - | 100 | 0.4 | 100 | 0.4 |
| 13) | 5 | 15 | 200 | 0.3 | 100 | 0.4 |
| 14) | 5 | 5 | 200 | 0.3 | 100 | 0.4 |
| 15) | - | - | - | - | 100 | 0.4 |
| 16) | 0 | 15 | 200 | 0.3 | 100 | 0.4 |

No. 1 to 8 is 15 meters. High-structure models (No. 1 to 8) continue to vibrate longer than low-structure models (No. 9 to 16.)

Examples of the vibration mode of models No. 1 to 8 are given in Fig. 3. These two modes were made by connecting deformation peaks, at A, B, ⋯ (Fig. 2), at beginning of the period and after a half period. The ground under the structure of model No. 8 didn't vibrate. This indicates the fact that softer superstructure detains the vibration energy and only a little amount of the energy is transmitted into the ground. Fig. 2 and 3 show that the free vibrations of the system are of first order. The damping coefficient value

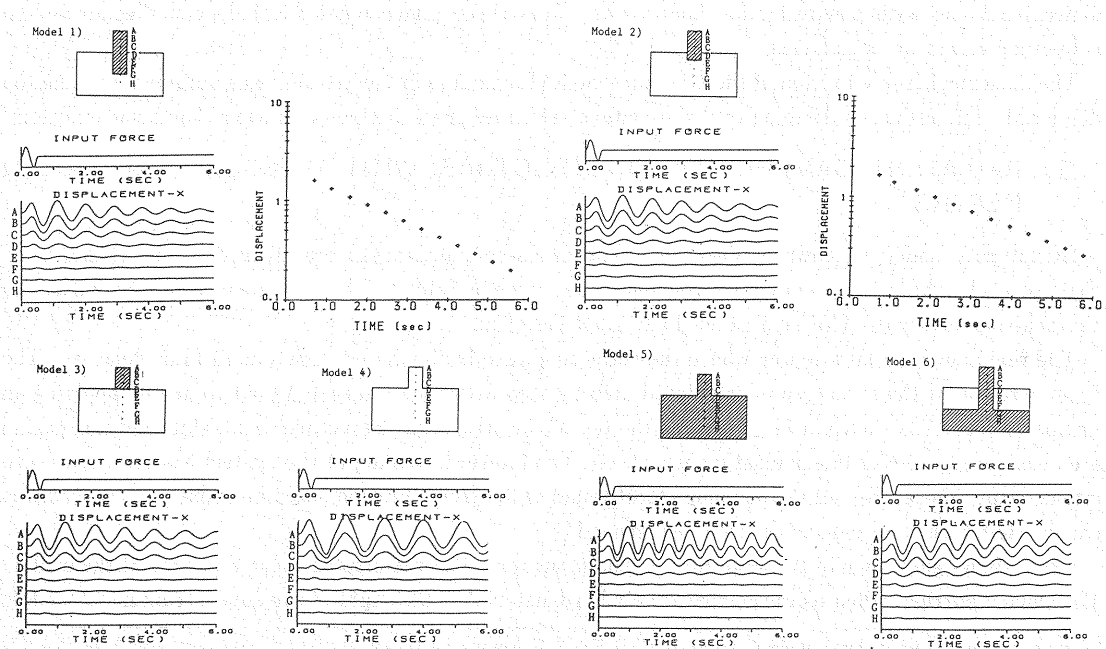
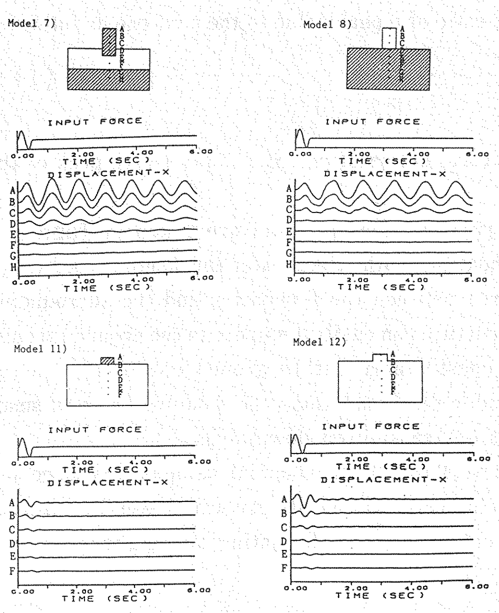



Fig. 2 Impulsive response of each structure model and foundation system (continued).



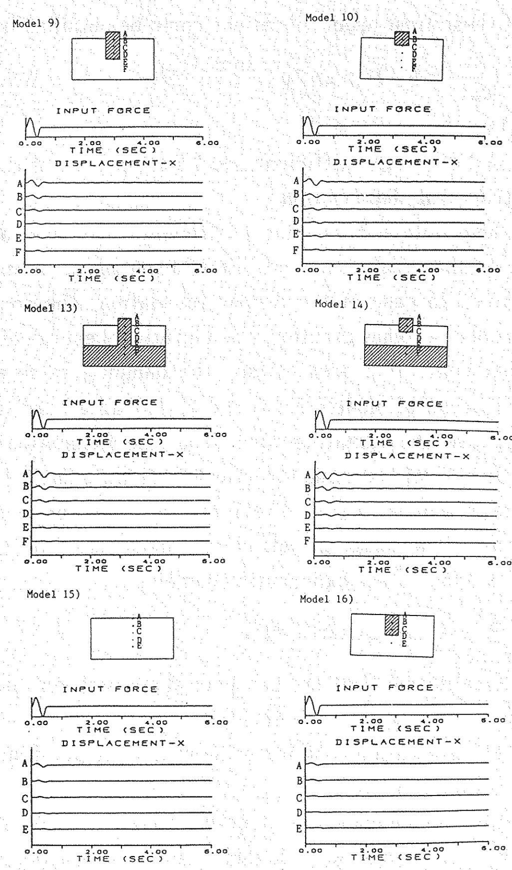




**Fig. 2** Impulsive response of each structure model and foundation system.

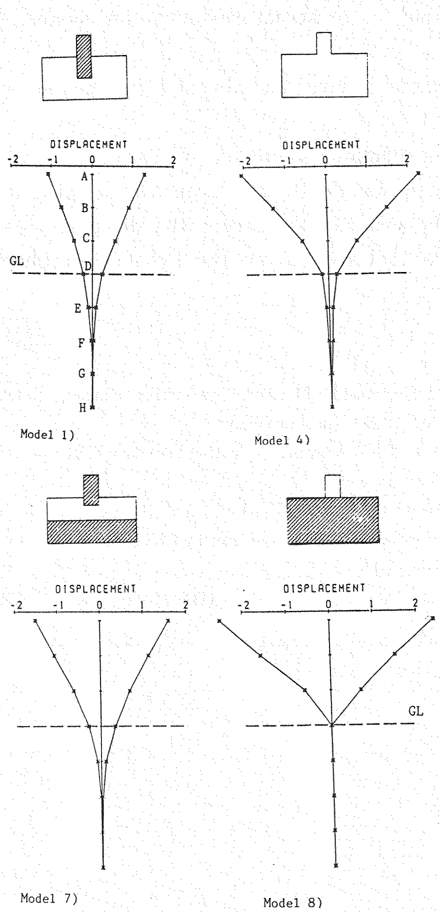
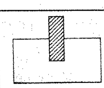
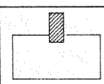
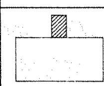
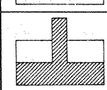
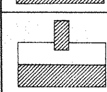
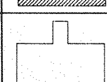
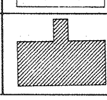



**Fig. 3** Vibration form of the models.

**Table 2** Predominant periods and damping Coefficients of the models.

| Model No. | Model condition | Predominant period(sec) | Damping coefficients h |
|---|---|---|---|
| 1) |  | 0.89 | 0.060 |
| 2) |  | 0.92 | 0.052 |
| 3) |  | 0.95 | 0.045 |
| 6) |  | 0.87 | 0.022 |
| 7) |  | 0.90 | 0.019 |
| 4) |  | 1.25 | 0.018 |
| 5) |  | 0.67 | 0.014 |

of these first order vibrations could be obtained from the ratio of a peak value to the next one as follows,

$$\frac{x_m}{x_{m+1}}=EXP(2\pi h/\sqrt{1-h^2}) \quad (1)$$

where,

$h$ : damping coefficient, $x_m$ : $(m)$th peak of the structural deformation, $x_{m+1}$ : $(m+1)$th peak of the structural deformation.

The obtained damping coefficients and predominant periods of each model are listed in Table 2.

As those values indicate : the larger the structural foundation depth, the greater the damping coefficient value. In case of the deeper foundation, the contact area between the foundation and the surrounding ground becomes greater. The vibrational energy of the structure can easily dissipate to the ground through that contacting area. Also, the damping value varies considerably due to ground condition.

In case of models No. 6 and 7, having a hard layer under the foundation, the damping value is small because the radiating wave from the foundation cannot be transmitted downwards.

In case of low or no structures over the ground (models No. 9 to 16), the damping value is very large and nearly equals to 1.0. Therfore, the free vibration of the structure is hardly generated even by external shock. The damping coefficient of model No. 9 to 16 could not be achieved. Radiating damping of the system is a kind of an exponential damping.

## 3. CONCLUSIONS

Qualitative analysis has been done with only several examples of structure-foundation system. The present study reveals the following points :

a) Radiation damping value of a structure-foundation system is large and almost 1.0, when structure height is very low.
b) The higher the structure, the smaller the radiation damping value.
c) In case of equal height structures, the deeper the foundation depth, the larger the damping value.
d) The stiffer structural foundation and the softer the ground, the larger the damping value.

The FEM with non-reflecting boundary is an effective tool to analyse the dynamic problems in semi-infinite medium.

### REFERENCES

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(Received May 23 1986)