EFFECTS OF THE GROUND CONDITION
ON DYNAMIC CHARACTERISTICS OF STRUCTURES

by
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SYNOPSIS

The ambient and man-excited vibration tests of the apartment buildings on different kinds of ground were carried out. In these tests very significant results were obtained through investigating the effects of the ground condition on the natural period and the damping coefficient of actual buildings. The measured values were compared with the theoretical ones for the rocking vibration of continuous body on an elastic half-space.

INTRODUCTION

The purpose of this study is to investigate the effects of the ground condition on the dynamic characteristics of actual buildings. About 200 apartment buildings on different kinds of ground in Osaka Prefecture were selected. In order to obtain the natural period, the ambient vibration tests were carried out. On six of these buildings were carried out man-excited vibration tests in order to obtain the natural period and the damping coefficient. These six buildings were chosen because they were of the same plan type, height and structure.

BUILDINGS, GROUND AND MEASUREMENTS

The buildings investigated are of similar plan type and of reinforced concrete or steel reinforced concrete structure of 3 to 14 stories. The typical plan and section are shown in Figure 1. The structural system of buildings are of bearing wall structure of 3 to 5 stories and of rigid frame structure with bearing wall of 7 to 14 stories. All buildings more than 7 stories are supported on pile foundation. However, the pile length and the surrounding soil differ largely at sites.

The relationship between N-value by standard penetration test and the value of the shear wave velocity Vs (m/sec) in the ground of Osaka Prefecture has been obtained experimentally, as shown in Figure 2. Vs is related to N by the following equation:

$$V_s = 81\, N^{0.304} \qquad \text{———} \quad (1)$$

The ambient vibration tests were carried out at the top or on the roof floor in both principal directions of building. The block diagram of the measuring and analysing instruments are shown in Figure 3. The transducers used to detect horizontal displacement are velocity vibrograph of moving coil type. The man-excited vibration tests were carried out as follows: pushing the penthouse repeatedly 10 times by about 20 men with a resonant frequency of the building. In order to observe the phenomenon of wave propagation, the transducers were located on the floor of the building and on the ground, as shown in Figure 6.

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EXPERIMENTAL RESULTS

The natural period for the transverse direction obtained from the ambient tests are represented as a function of the height in Figure 4. The relationship between the natural period T (sec) and the height H (m) of the building is represented as the following equation:

$$T = 0.012H + 0.055 \qquad (2)$$

The natural period is influenced considerably by the ground condition in addition to the height of the building. For estimating the stiffness properties of the ground, the mean N-value in the extent of 10 m under the ground surface was considered. Considering the mean N-value and applying the multiple regression analysis, the following equation was obtained:

$$T = 0.011H + 0.143 - 0.062 \log_{10}N \qquad (3)$$

The equation (2) and (3) are plotted in Figure 4. The measured natural period for the transverse direction are represented as a function of the mean N-value in Figure 5. In the Figure, the mean N-value is related to Vs by the equation (1) and the straight lines were obtained from the equation (3). The natural period shows an increasing tendency by decreasing of the mean N-value.

The man-excited vibration tests were carried out on six of 14 story buildings, which plan and section are shown in Figure 1. Typical records for the transverse direction are shown in Figure 7.1 for the hard ground, and in Figure 7.2 for the soft. From the records the damping coefficient was estimated by the logarithmic damping method. The natural period and the damping coefficient obtained from the man-excited vibration tests are represented as a function of the mean N-value in Figure 9,10. The straight line of Figure 9 was obtained from the equation (3). The natural period and the damping coefficient show an increasing tendency by decreasing of the mean N-value, and the tendency of the latter is more remarkable. Curves of Figure 9,10 show the theoretically computed results as described later.

THEORETICAL RESULTS

The dynamic characteristics of 14 story building on which the man-excited vibration test was carried out were theoretically computed for the transverse direction. In the mathematical model, shown in Figure 8, the structure was assumed to be a continuous body and the ground a semi-infinite elastic medium. The shear wave velocity sVs which represents the stiffness properties of this continuous body was assumed 600 m/sec, 800 m/sec and 1000 m/sec. The dynamic response of structure, which was excited by harmonically varying load acting in a horizontal direction within the half-space, were computed. The natural period and the damping coefficient for the first mode can be obtained from the frequency response curves.

Figure 9 shows the relationship between the natural period T of the structure and the shear wave velocity Vs in the ground. The natural period has an increasing tendency by decreasing of the shear wave velocity in the ground, especially under 300 m/sec. The curves of the damping coefficient h as a function of the shear wave velocity Vs in the ground are shown in Figure 10. The Figure shows that the damping coefficient takes smaller value as the ratio of sVs to Vs decreases.

CONCLUSIONS

The dynamic characteristics of the reinforced concrete or steel reinforced concrete structure, which is relatively rigid, are influenced significantly by the ground condition.

The natural period of such structures shows an increasing tendency by decreasing of the soil rigidity. The strong correlation has been observed between the measured natural period and the mean N-value.

In the case of the soft ground, the damping coefficient increases about 4 times as large as in the case of the hard ground. It is proved that the damping characteristics are influenced greatly by the radiation damping of soil-structure interaction.

The natural period and the damping coefficient obtained from the computer analysis differ significantly from the measured ones in the case of the soft ground.This fact suggests that the existing of piles, especially in the soft ground, has considerable effects on the dynamic characteristics.

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REFERENCES

1. S.Ohba, I.Toriumi,1975,"The Change in Dynamic Characteristics of Apartment Houses during Construction", Trans.AIJ,No.227,pp.39-46 (in Japanese).
2. S.Ohba,1978,"Dynamic Characteristics of Multi Story Apartment Buildings obtained from the Measurement of Microtremors", Proc.of the 5th Japan Earthquake Engineering Symposium,pp.1153-1160 (Japanese).
3. T.Kobori, R.Minai, T.Suzuki, K.Kusakabe,1967,"Dynamic Ground Compliance of Rectangular Foundation on a Semi-Infinite Elastic Medium (Part 1), Annuals,Disas.Prev.Res.Inst.,Kyoto Univ.,No.10,pp.1-32 (Japanese).

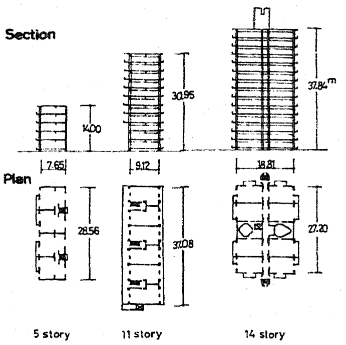


Fig.1 Outline of typical buildings

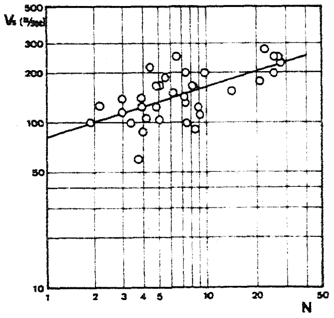


Fig.2 Relation between Vs and N

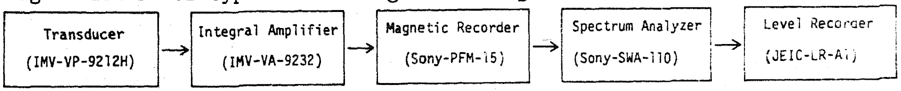


Fig.3 Block diagram of measuring and analysing instruments

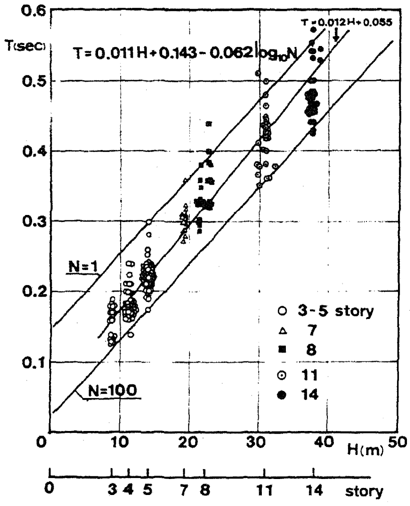


Fig.4 Relation between T and H

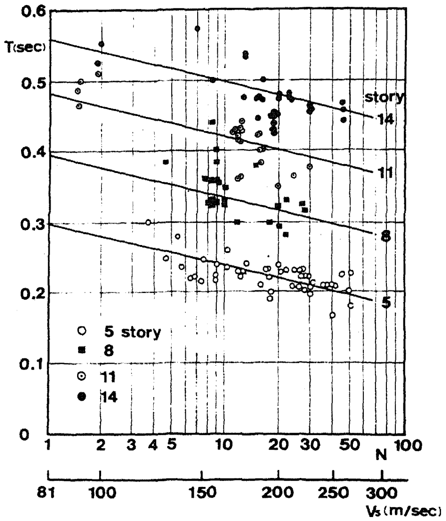


Fig.5 Relation between T and N

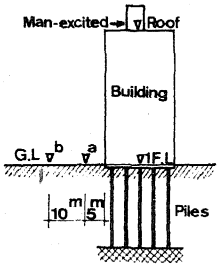
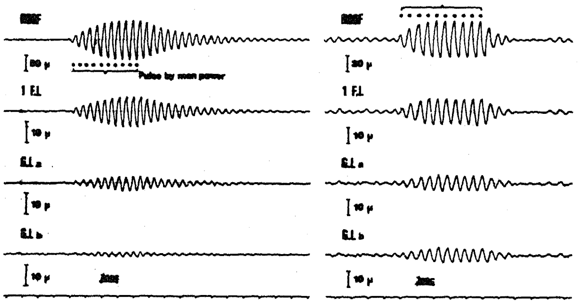


Fig.6 Measuring positions



7.1 On hard ground 7.2 On soft ground

Fig.7 Man-excited records

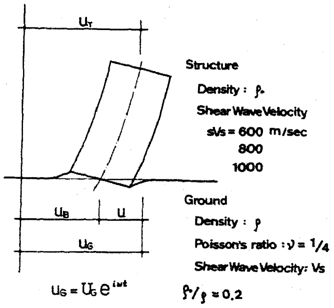


Fig.8 Mathematical model (Shear type)

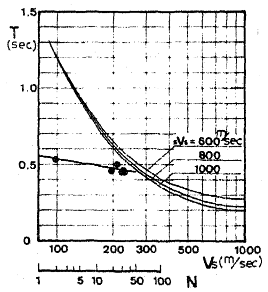


Fig.9

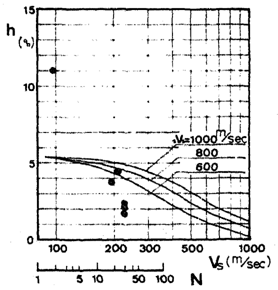


Fig.10

Comparison of theoretical results with experimental results