Vibrational Characteristics of the Structure influenced by the Ground

Morio Takeuchi*, Kikuo Kotota** and Satoru Kazama***

SYNOPSIS:

The study which will be reported here was made of the forced and free vibrations of the models, 1) isolated foundation, 2) combined system of foundation and single-story building, and 3) two isolated foundations joined by connection-beam, for the purpose of evaluation of the spring constant and the damping constant of the ground, and of finding out a convenient method of this evaluation.

INTRODUCTION:

The model foundations were made of concrete and laid on the ground of Kanto loam, Fig. 1. The tests were made on the following three types of model by imparting them the forced vibration or by setting them on their free vibrations, Fig. 2.

Model: 1) three types of foundation (FL, FM and FS); 2) combined system (FL+Bn and FM+Bn) of isolated foundation (FL and FM) and single-story building (Bn); 3) joined isolated foundation (2FL+BG and 2FL+B) of two isolated foundations (FL) and connection beam (B)

EXPERIMENTS AND RESULTS:

1) FL and FL+Bn

The resonance frequency, mode of vibration and damping coefficient obtained by the experiments of the combined system of a model-building and an isolated foundation coincide well with those calculated by inserting the spring constant and the damping coefficient determined experimentally by using the isolated foundation only, or by using the model building only. The influence of the ground on the building may be nearly evaluated by a ratio of the amounts of rocking and swaying motions observed, Fig. 3.

In the case of a small resonance amplitude, the resonance frequency of the isolated foundation approaches the theoretical value, if we ignore the virtual earth-mass. This suggests that the pressure-distribution over the area of the plate which is in contact with the ground surface becomes akin to the distribution over a rigid base, if the type-FL (isolated foundation) is used, Fig. 4. The distribution, however, approaches to the uniform pressure distribution in the case of the type-FM (isolated foundation), while it does so to the parabolic pressure distribution in the case of the type-FS (isolated foundation). In other words, if we assume the pressure distribution be that of the rigid base, it becomes necessary to take larger virtual earth-mass as the contact area of the isolated foundation becomes smaller.

A specially different point in the results which were obtained experimentally for the isolated foundation only and for the combined system lies in a sudden increase in the spring constant which contributes to the rotation (rocking) of the structure, even though the strain of the ground is

*Morio Takeuchi; Prof., School of Sc. and Eng., Waseda Univ.
**Kikuo Kotota; Prof., Sc. and Eng. Res. Lab., Waseda Univ.
***Satoru Kazama; Res. Assist., Sc. and Eng. Res. Lab., Waseda Univ.

fully taken into consideration when the load due to the building becomes large, Fig. 4.

The decrease in the resonance frequency due to increase in the resonance-amplitude may be explained by the decrease in the shearing modulus with increasing amplitude of displacement of the soil, i.e., the increase in the shearing strain in the soil. Because, the shearing modulus which is deduced from the spring constant increases as the amplitude decreases, and coincides with the value which is obtained from the shear wave-velocity in the region of a small amplitude, Fig. 5.

As for the damping percentages, h which were obtained for the isolated foundation and for the combined system, it may be said that approximately the theoretical values become twice as large as the experimental values. If the values of C_H and C_R are deduced from the experimental values of h separately, the value of C_H (for horizontal displacement) becomes about 1/3 of the theoretical value, Fig. 6.

2) (2FL + BG) and (2FL + B)

The spring constants for model (2FL+BG) were calculated by the method of J. Elorduy[4], Fig. 7. For model (2FL+B), the constants were calculated by the following expressions, by using the spring constants which were determined for isolated foundation (FL), i.e., K'_H, K'_R and K'_V.

$$K_H = 2 \cdot K'_H, \quad K_R = 2 \cdot (K'_V \cdot l_0^2 + K'_R) \qquad l_0 : \text{See Fig. 7}$$

The theoretical values of spring constants determined for (2FL+BG) agree well with those for (2FL+G), suggesting that the influence of the connection beam which is in contact with the ground is slight, Table - 1. The agreement of the values determined for these models can be seen also in their natural frequencies and modes of vibration, Table - 2.

In the case of model (2FL+BG), the natural frequencies and modes of vibration which were determined theoretically and shown in column A of Table-2 nearly agree with those experimentally determined, whereas in the case of (2FL+B), the theoretical values as shown in column B of Table-2 agree well with the experimental values rather than those which are shown in column A.

The value h which is determined theoretically becomes generally greater than those determined experimentally, Table-2.

We can see a well correlation between the vertical displacement of the foundation and the accompanying earth-pressure. The distributions of this pressure which were determined by experiments showed an agreement with those theoretically determined in their tendency, Fig. 8.

BIBLIOGRAPHY:

1) M. Takeuchi and others "Vibrational Characteristics of the Structure influenced by Ground (1)" Bull. of Sc. and Ebg. Res. Lab., Waseda Univ. No.57
2) H. Yamahara "Practical Solutions for Soil-Structure Interaction System" Shimizu Technical Report No.1, Dec. 1971.
3) J.R. Hall, Jr. "Vibrations of Soils and Foundations" Prentice-Hall, Inc.,
4) J. Elorduy and others "Dynamic Response of Bases of Arbitrary Shape Subjected to Periodic Vertical Loading" International Symposium on Wave Propagation and Dynamic Properties of Earth Materials, August, 1967.

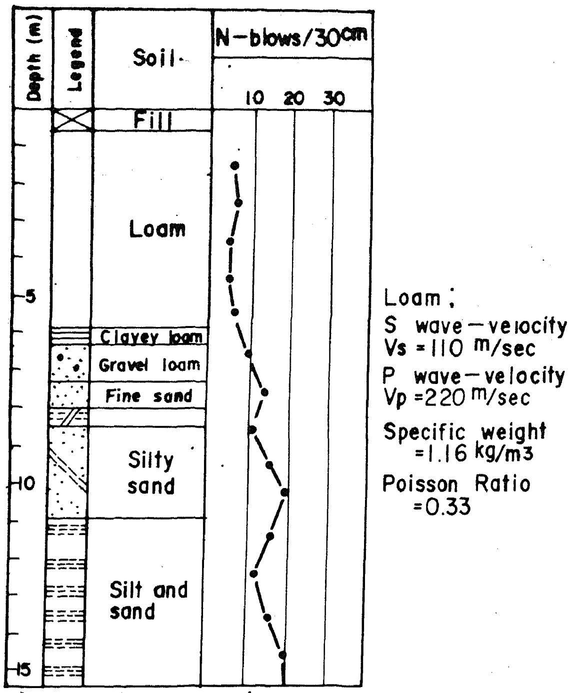


Fig. 1 Boring log and N-value of standard penetration test

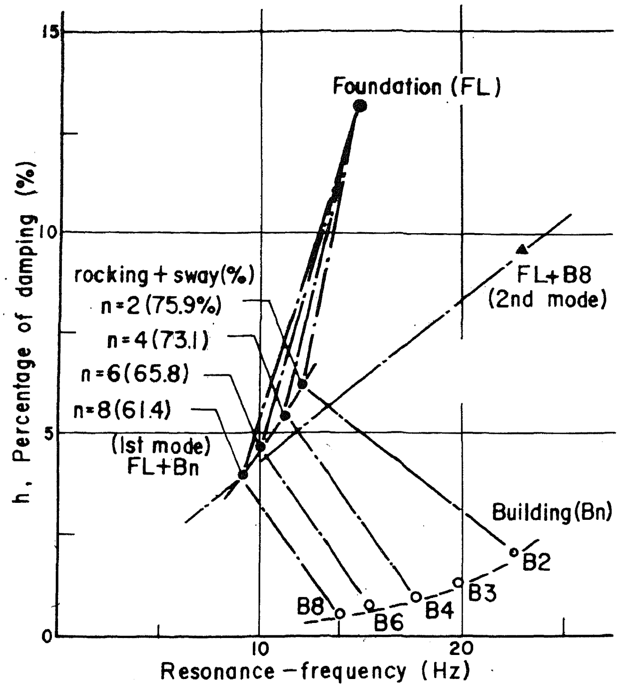
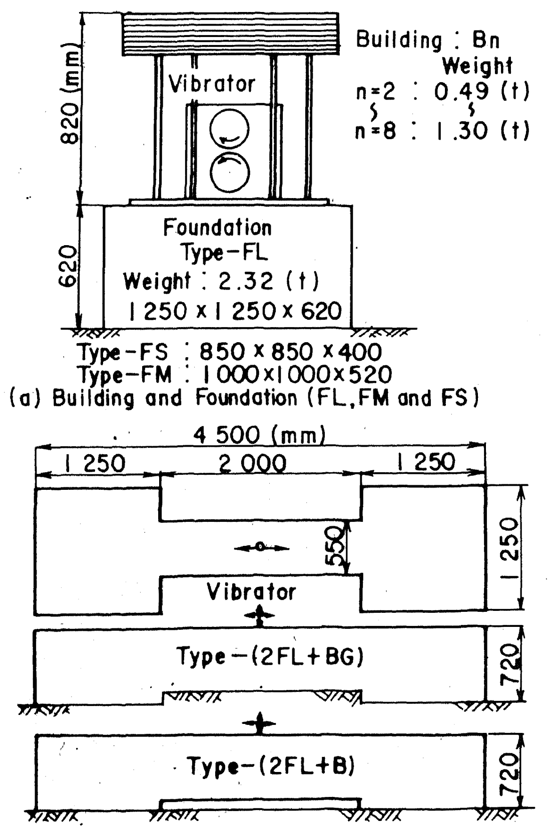


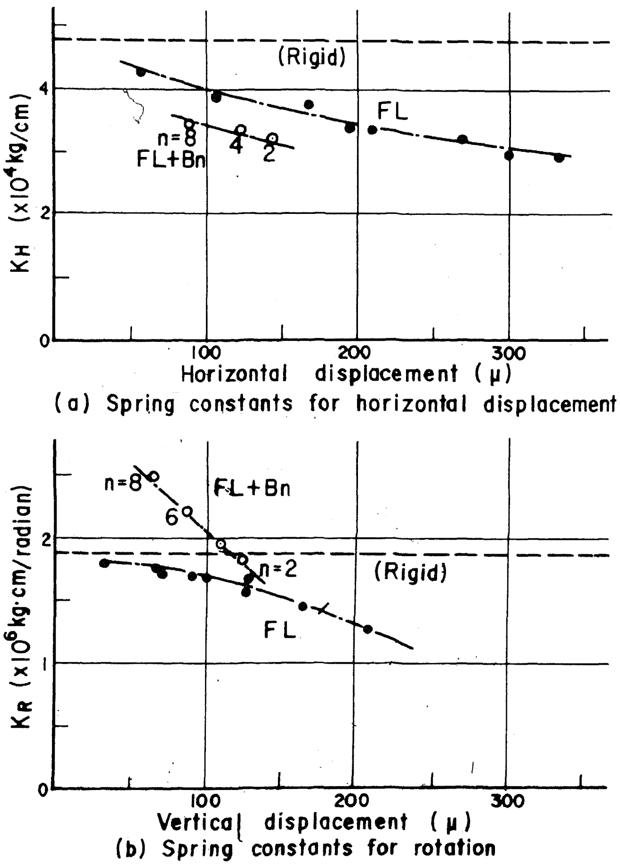
Fig. 3 Damping vs. resonance-frequency



(a) Building and Foundation (FL, FM and FS)

(b) Foundation (2FL+BG and 2FL+B)

Fig. 2 Models of Building and Foundation



(a) Spring constants for horizontal displacement

(b) Spring constants for rotation

Fig. 4 Spring constants for horizontal displacement and rotation. (FL)

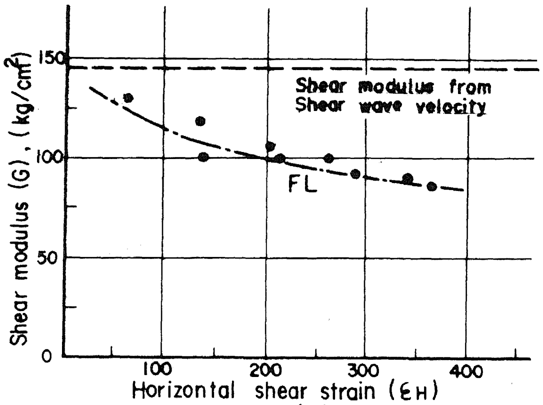


Fig. 5 Shear modulus(G) vs. horizontal shear strain (ϵ_H).

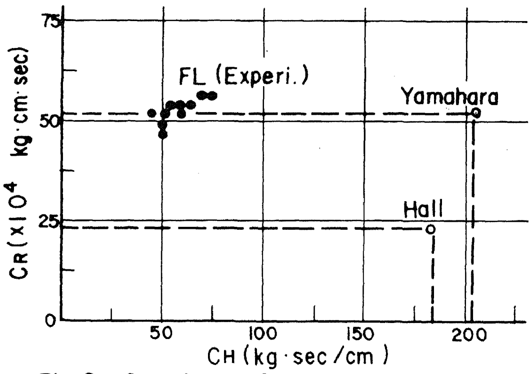


Fig. 6 Correlation between damping coefficient (C_R) and (C_H).

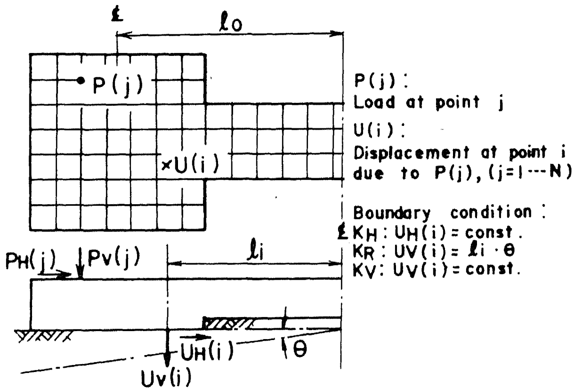


Fig. 7 Method of calculation of spring constant.

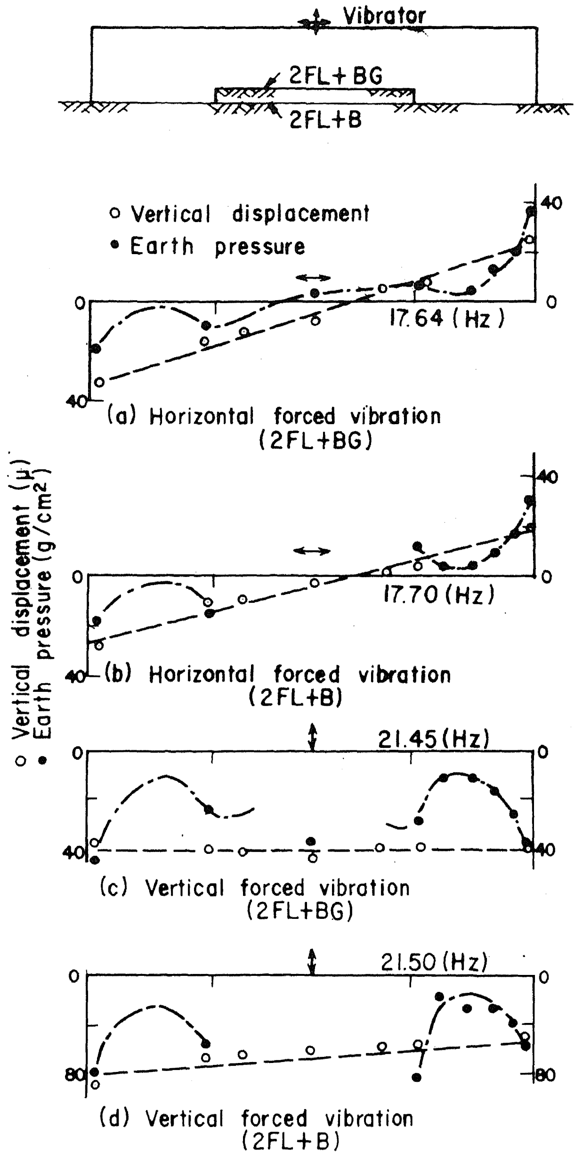


Fig. 8 Correlation between vertical displacement and earth pressure.

Table. 1 Spring costants. (calculated)

Spring costant		2FL+BG	2FL+B
K_H Hor. (kg/cm)	$\times 10^4$	9.53	9.32
K_R Rot. (kg·cm/rad.)	$\times 10^5$	4.44	3.45
K_V Vert. (kg/cm)	$\times 10^9$	1.23	1.17

Table. 2 Results of experiments and analyses.

Model / Vibrat. of model	2FL+BG Experi.	2FL+BG A	2FL+B Experi.	2FL+B A	2FL+B B
1st. frequency (Hz)	17.64	17.31	17.70	16.15	17.55
1st. mode $(\theta/u)\times 10^{-3}$	1.75	2.13	1.30	5.30	1.41
Damping, h (%)	20.5	—	19.0	24.2	9.2

θ : Angle of rotation
u : Displacement of center of gravity

Experi. : Experimental value
A : Theoretical value (C_H, C_R : Yamahara)
B : Theoretical value using experimental values obtained for Type-FL