EARTHQUAKE RESPONSE OF MULTI-STORY BUILDING SUPPORTED ON PILES

BY

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SYNOPSIS

This paper discussed with a seismic design of multi-story buildings supported on piles. In this investigation, the lumped mass system coupling soil, piles, foundation and building is used as the analytical model, i.e. the building is considered as lumped mass system of shear type where the rocking and swaying of foundation is considered. Also, in this model, the piles are considered as a lumped mass system of the shear and bending type and the soil is represented as a lumped mass system of shear type. (Fig. 1)

ESTIMATION OF SPRING CONSTANT AND DAMPING COEFFICIENT FOR INTERACTION BETWEEN SOIL AND PILE

The degree of accuracy in the prediction of the seismic response of this type of constitution depends mainly in the accuracy in modelling the actural structure. Especially the estimation of spring constant and damping coefficient for the interaction between soil and pile is very important. For evaluating the equivalent sprint constant and the damping coefficient, the most simple model shown in Fig. 2 is considered.

As for spring constant, the analytical elastic theory by Tajimi and the semi-analytical elastic theory (this method) are compared for the point of view of the natural frequency for mass-pile-soil interaction system as shown in Fig. 3. In Tajimi's theory, the compression of soil on the front face of pile is considered and also the tension of soil on the rear face of pile is considered, while this method consider only the compression on the front of pile in evaluating spring constant $\overline{Esh}$. From this reason, it is understandable that Tajimi's theory gives about twice a value in comparison with this method. Authors confirmed that even the value of this method gave an excess value for the expermental results of an actural soil-pile-mass system and then consider that it is reasonable to use the value obtained by this method. The value in non-dimensional form obtained by dividing the value ($\overline{Esh}$) by Young's modulus of soil (Es) is shown in Fig. 5.

For evaluating the radiational damping into the direction of plane, the analytical elastic theory by Tajimi is simulated by this lumped mass system to find the curve to fit one given by Tajimi's theory by changing the critical damping ratio h_{1p} as shown in Fig. 4. It is observed from this figure that the radiational damping h_{1p} is 0.065.

However, in Tajimi's theory, the tension of soil on the rear face of pile is considered with compression as stated before, so that, in the actual soil system, half of the value of it should be used, that is, h_{1p} 0.0325.

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EARTHQUAKE RESPONSE OF BUILDING SUPPORTED ON PILES

For the object to evaluate the earthquake response of building supported on piles, the six story reinforced concrete building with the area of 600 m^2 is considered as model shown in Fig. 6. The natural frequency of three kinds of soil medium and building are shown in Table 1. The distribution of maximum shearing force during TAFT 1952 N.S. is shown in Fig. 7 for three kinds Young's modulus of soil. From this figure, the difference of earthquake response between building supported and not supported on piles is not observed. However, the general inclination must be mensioned as follows;

The effect of piles on the earthquake response of buildings supported on piles is evaluated by comparing the response of this type of building when the piles are included in the analytical model and when they are neglected. The earthquake response of buildings supported om piles are evaluated for time history of the earthquake ground motion at the bed rock level. The results, show that, in some cases the earthquake response of a building supported on piles becomes greater than the one is which the piles are neglected. It is considered that the total effect of piles on the earthqueke response of building depends upon the relative importance of two opposite factors. One is some kind of resistance which decreases the response of the building and another is some kind of transfer function of earthquake. If the latter is greater than the former the piles have an undesirable effect from the point of view of the seismic behavior of the building. This phenomina is produced when the coupled natural frequency of soil, pile and building become very close to the natural frequency of the surface layer of the soil.

EARTHQUAKE RESPONSE OF PILE

Besides evaluating the dynamic response of a building supported on piles, the dynamic response of piles must be evaluated also and the safety of piles during earthquake must be evaluated. Generally, very large bending moment is produced at top of pile during earthquake. (Fig. 7) The response of dynamic bending moment during earthquake is compared with the statical calculation result, which is evaluated by the theory of beam on elastic medium against the load of base shear at top of the pile. It is observed that the static result is of the order of five times the dynamic one. This results is explained by the release of bending moment as a consequence of the movement of the soil around the piles.

The possibility that a gap occurs, between the bottom surface of the foundation and the soil, should be considered. This gap can be developed due to the settlement of the surface soil layer. If this gap is produced, the interaction (spring force and damping force), between the bottom surface of the foundation and soil, is lost and the response of building becomes very large. A worked example shows that when the gap is considered the response is twice as large as that neglecting the gap. Also, the maximum bending moment at the top of piles becomes six times larger. Authers also emphasize that the lateral reaction and damping of embedded footing or retaining wall of basement can be significant factors in the seismic design of buildings supported on piles.

CONCLUSION

(a) Radiational damping for interaction between soil and pile (h_{1p}) should be less than 0.0325.

(b) Precaution should be taken so that the resonance between soil medium and soil-pile-building system should not coincide.

(c) The importance of embedding the foundation into the ground should be emphasized for aseismic design of building supported on piles.

REFERENCE

1) H. Tajimi : "Dynamic Analysis of a Structure Embedded in an Elastic Stratum" Proc. of 4th World Conf. 1969.

2) S. Yamamoto T. Seki : "Earthquake Response of Multi-Story Building Supported on piles" Trans. of A.I.J. November 1970.

3) J. Penzien et al : "Seismic Analysis of Bridgeson Long Piles" Proc. of A.S.C.E. June, 1964.

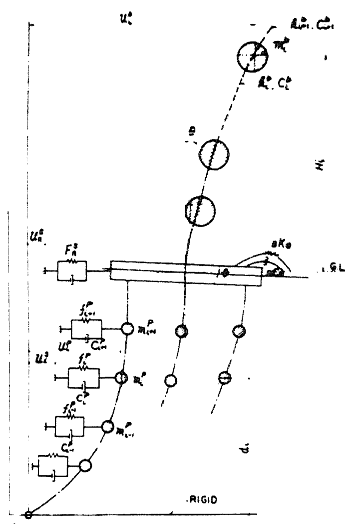
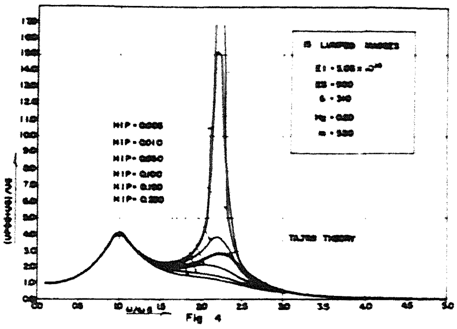


Fig 1



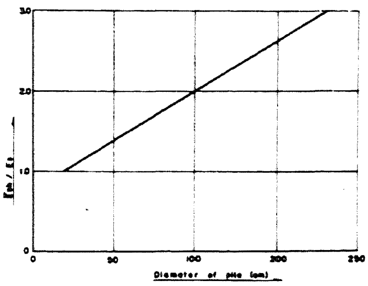


Fig. 5

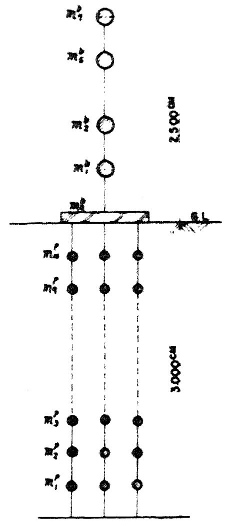
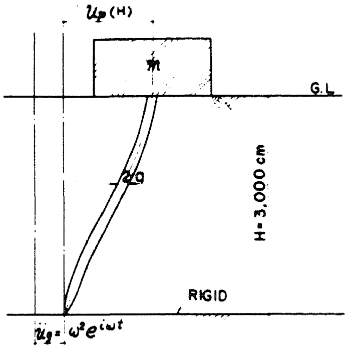


Fig 6



$EI = 5.03 \times 10^{10}$ KG.CM $\quad \nu = 0.45$

$H = 3{,}000$ cm $\quad \rho_s = 1.63 \times 10^{-6}$ KG.SEC^2/CM^4

$m = 50$ KG·SEC^2/cm $\quad \rho_p = 2.45 \times 10^{-6}$ KG.SEC^2/CM^4

$a = 25$ cm

Fig. 2

	a) SOIL MEDIUM Young's Modulus of Soil (Es) 600	900	1200 kg/cm²	b) BUILDING
1ST MODE	0.94 cps	1.13 cps	1.33 cps	1.55 cps
2ND MODE	2.8	3.35	3.95	4.08
3RD MODE	4.6	5.5	6.5	6.70

TABLE 1

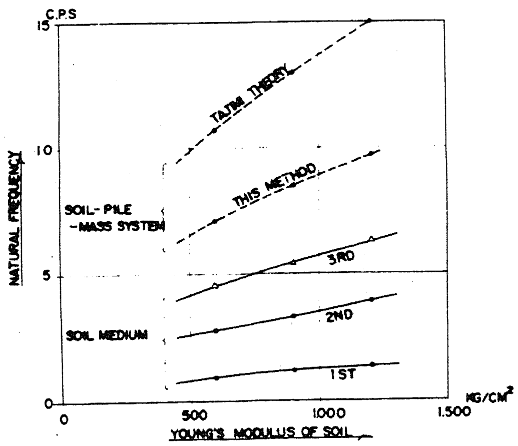


Fig. 3 Comparison between Tajimi's theory and this method for natural frequency of soil-Pile-mass system

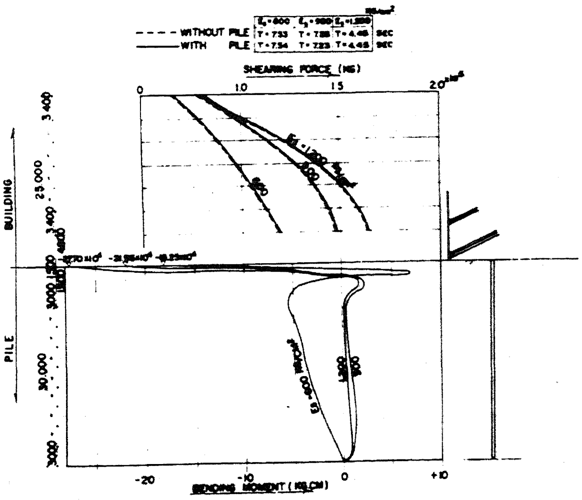


Fig 7