VISCOUS DAMPING OF STRUCTURES RELATED TO FOUNDATION CONDITIONS

by
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SYNOPSIS

Authors had pointed out the importance of the effects of the ground conditions for the characteristics of viscous damping of structures. In this paper they showed several observed data of viscous damping of high rise buildings, which are existed in Tokyo. These actual data present the effects of ground conditions, that is the relationship of fundamental and higher mode vibration. They discussed also the mechanism of viscous damping based on the observed data. As the results of this study they proposed a damping mechanism of the model of lumped mass system with rocking motion model of its foundation.

INTRODUCTION

Damping effects of the structures are consisted of hysteretic energy consumption, energy dissipation to the subsoil, and viscous damping due to inner friction and external friction caused by surrounding soil. The hysteretic energy consumption is taking account in the plastic deformation of structure or foundation, so the effects of this reason should be avoided from those discussions. Both effects of energy dissipation to the subsoil and viscous damping due to inner friction of structure and external friction caused by surrounding soil are mixed, so it is very difficult to separate each other. However, it is very similar effects for the building structures. In this paper authors treated these two kinds of damping, simultaneously, and converted these two effects to the equivalent lumped mass system.

There are many discussion about the mechanism of the structural damping sytem, however, there is a few consensus among the investigators. Authors collected actual data as many as possible, and they studied the mechanism of damping system, which is most adequate for evaluation of the observed data of actual buildings, and they have less consideration about the ordinary mechanism of damping. For the collection of large amount of data, they used measurements of oscillation of buildings at given floor level caused by microtremors under the consideration of differences between the micro-oscillation measurements and the ordinary shaking tests or earthquake observations.

Authors carried out the studies about same problem, already, and pointed out the effects of surrounding soil *1)*. In this paper, authors elaborate more accurate measurements of the oscillation and tried to separate the torsional component of the structural vibrations from horizontal motions.

1. MEASUREMENTS OF THE OSCILLATION OF STRUCTURES

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The measurements of building structures performed on the floor, which selected by the point of view, that is most convenient to emphasize the individual vibration mode of the structures. As shown in Fig.1, at the middle of the height of building, first and second modes of vibration are dominant, because the nodal point of the third mode exist at this level generally. At three quarters of the height, first and third modes will dominate, and at the top of the building, fundamental mode of building oscillation is dominant. As an example, they showed power spectra of the floor oscillation of 40-storied building in Fig.2, that is the power spectra of 36th, 28th, 16th and 8th floor were shown. It is very clear that the characteristics mentioned above.

The measurements of the building oscillation due to microtremor were performed by using three seismometers simultaneously, whose natural period of pick-up are 1 sec. In Fig.3, they showed an example of the location of instruments in the observed floor. By this way, they obtained the records of longitudinal, transversal and torsional vibration of individual floor of structure. They used also the technique of Fourier analysis on the each record for getting the natural periods and damping coefficients of individual vibration mode, that is fundamental mode to second or third mode, sometimes up to fifth mode. An example of these power spectra of the observed building was shown in Fig.4.

2. GENERAL TRENDS OF VISCOUS DAMPING CHARACTERISTICS OF BUILDING

Using the power spectra, they determined the damping coefficients h. First of all, they checked these observed damping values against other methods. In Fig.5, they compared the results of this method and other shaking tests, which were performed by other organizations in Japan. The data from this method showed same trends. So these data can be used as same as other methods.

In Fig.5, general trends of viscous damping of structures can be explained by following formula:

$$h \times T = Constant \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

But in rather longer period, the trends of damping coefficient are rather changed. About the higher mode of vibration, almost same trends can be found in Fig.6, but the value of the damping coefficients is rather smaller than fundamental mode of vibration. The relationship between the damping value of fundamental mode and higher modes were shown in Figs.7, 8 and 9. These results illustrate the effects of the surrounding soil conditions. In case of loose boundary condition, structure shows above mentioned natures as indicated in Fig.9. And in case of fixed boundary condition, higher mode damping coefficients are parallel to the frequency of natural vibration, so the relation of damping coefficient h_s and natural period T_s of structure were:

$$h_s \times T_s = Constant \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The difference between the formula (2) and Fig.9 means the effects of surrounding ground conditions.

3. EFFECTS OF THE SUBSOIL CONDITIONS

General trends of the relation between natural period T and damping coefficient h of structure can be illustrated as following formula:

$$h \times T = F(K) \qquad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where K is the kind of ground, which is defined by the Japanese Building

Code. The value of *F(K)* is 0.04 for the soft and deep soil ground (Kind IV) and 0.02 for hard soil ground (Kind II). These results were led from Fig.5 and the map of subsoil condition of Tokyo.

Damping coefficients of the observed buildings were checked by the point of view of subsoil conditions. Location of observed buildings were shown in Fig.11. Subsoil conditions of these buildings were classified into Kanto loam and deep alluvium. The deviations of damping coefficients from mean trends were calculated. Relationship between the classification of ground and the deviation of damping coefficients were checked in Fig.10. About the fundamental mode of vibration, it is evident that the group of building on Kanto loam showed minus values and the group of building on deep alluvium showed plus values.

4. PROPOSAL FOR DAMPING MECHANISM OF VISCOUS DAMPING OF BUILDING STRUCTURE

As the concluding results, authors proposed a damping mechanism for the viscous damping of building structures, generally. The mechanism of the viscous damping of structures should be considered as the composite system of the lumped mass system and foundation rocking system supported by surrounding soil. In Fig.12, they showed proposed system of anlysis of building structure, which is most adequate for the evaluation of viscous damping of structures. Fig.13 showed a result of calculation of this proposed system which was performed by Y.Sawabe. This results can explain the observed results very well.

CONCLUSION

From these measurements they led several conclusions about the viscous damping of building structures as following:

(1) The movements of the vibration of structure are very complex, but it is possible to separate to the individual mode of vibration by using the technique mentioned in this paper. Especially, it should be separate the torsional mode, because the effcts of the torsional vibration are always appeared in every records of measurements.

(2) The relation of the viscous damping between fundamental mode and higher modes is not similar to the relation of lumped mass system without foundation rocking motion system, which is using commonly for the dynamic analyses of building structures.

(3) Viscous damping of building structures depends the ground conditions sufficiently. Surrounding soil conditions are very important, and for the determination of the seismic coefficients of the design criteria on strctures in the procedure of seismic microzoning projects these effects of soil conditions should be considered.

(4) The mechanism of the viscous damping of building structures should be considered as the composite system with foundation rocking system.

REFERENCE

(1) Kobayashi,H.;"Damping Coefficients of Structural Vibration Related to Subsoil Conditions", Proc. of 5WCEE, Rome, 1973

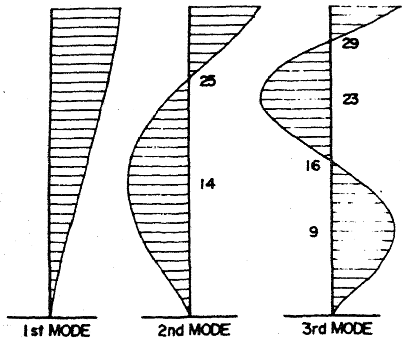


Fig. 1 Vibration shap of typical tall building

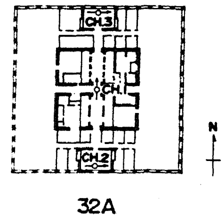


Fig. 3 Plan of the observed building and location of instruments
BLDG NO.32A

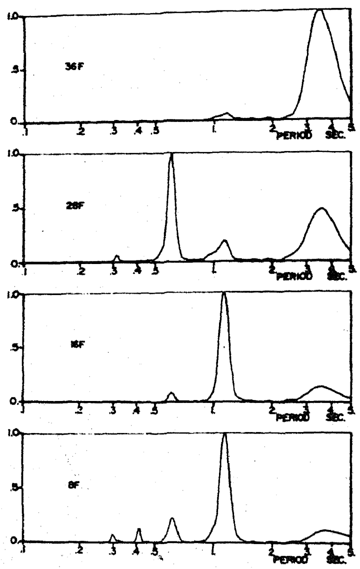
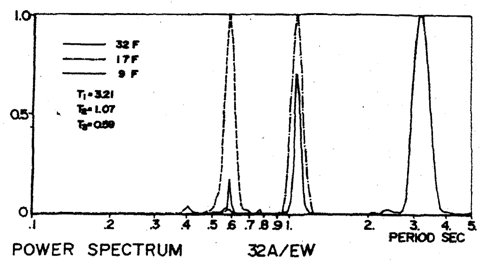
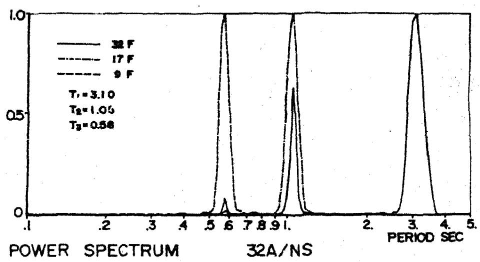


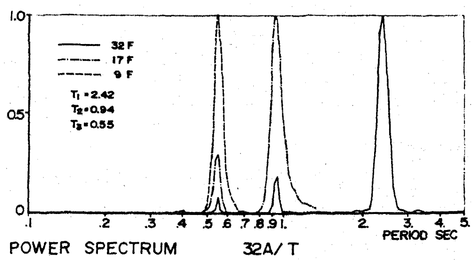
Fig. 2 Power spectra of individual floor
40-storied building,NO.40A



4-a EW-direction

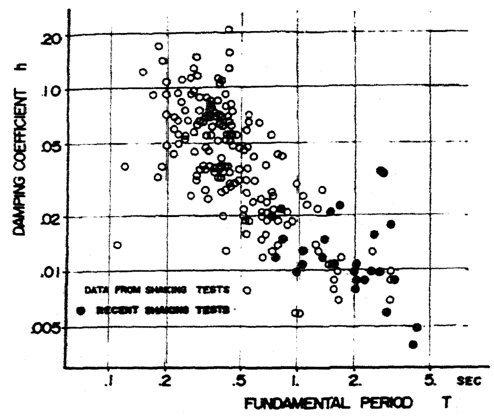


4-b NS-direction

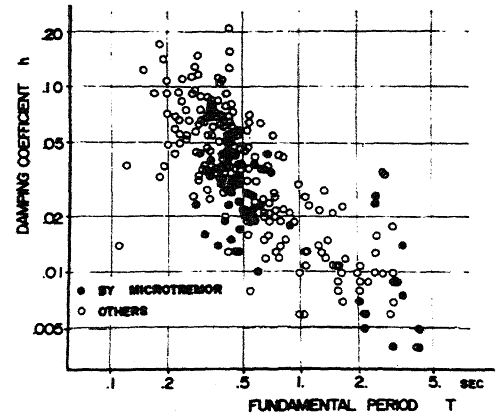


4-c Torsional vibration

Fig. 4 Power spectra of floor motion due to microtremor
32-storied building, NO.32A



5-a Accuracy of the experiments



5-b Comparison between the method of microtremor and others

Fig. 5 Checking of the method used in determination of damping coefficient

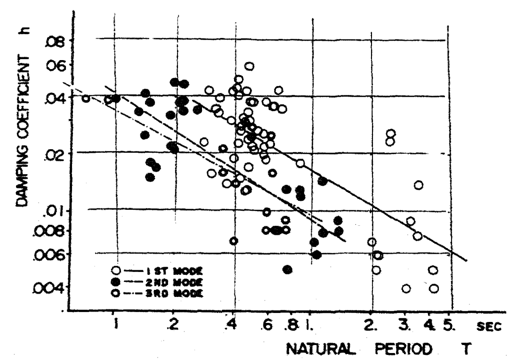


Fig.6 Relationship of the higher mode damping

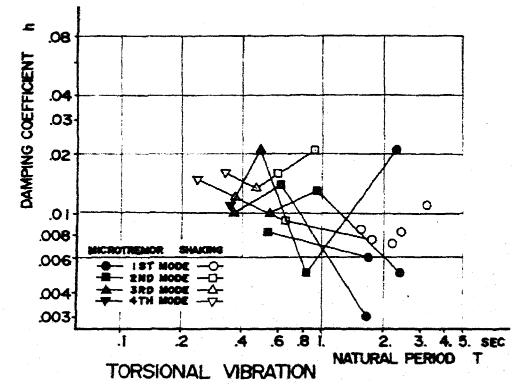


Fig. 7 Damping coefficients of torsional vibration

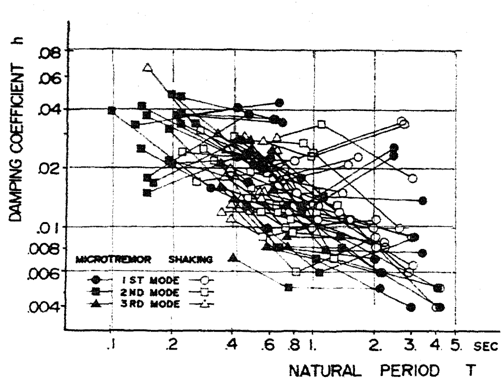


Fig. 8 Comparison of results between mehtod of microtremor and shaking test

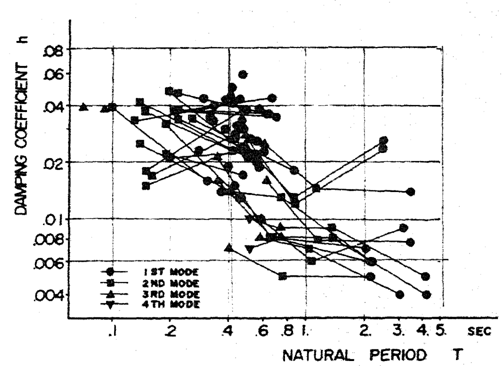


Fig. 9 Relationship of the higher mode damping of individual building

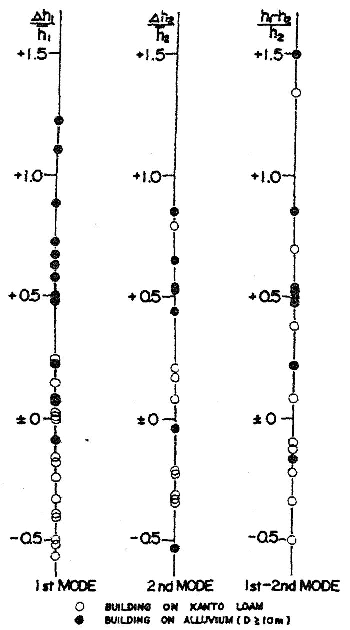


Fig. 10 Deviation of damping coefficient from mean trend

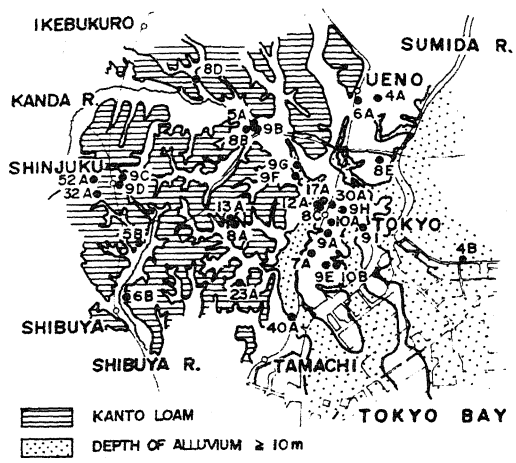


Fig. 11 Location of the measured buildings and soil conditions

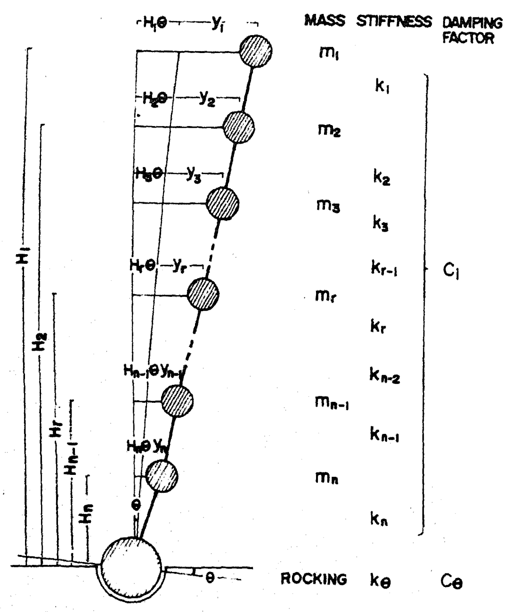


Fig. 12 Proposed damping mechanism for building structures

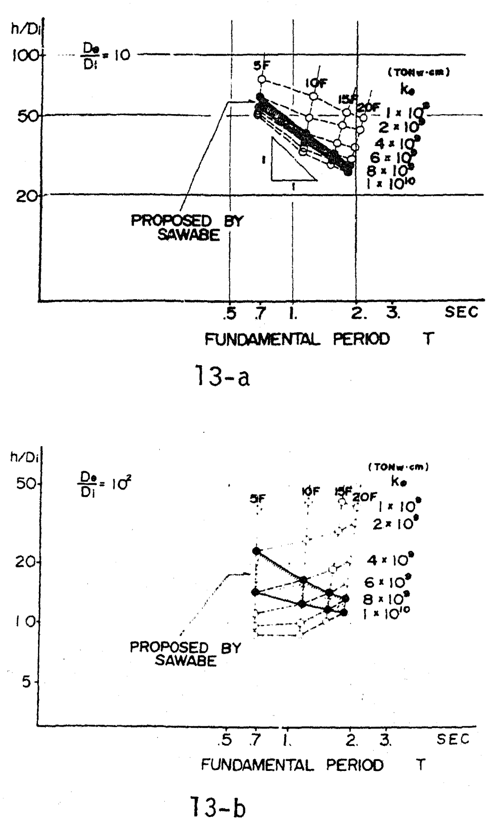


Fig. 13 Calculated damping coefficients from proposed model of Fig. 12

DISCUSSION

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Normally for designing earthquake resistant structure 5% damping for concrete and 2% damping for steel structures is adopted. These values take into account inelastic deformation of structures as the higher earthquake forces act for a very short duration and once or so in the life time of a building. I will request the authors to kindly elucidate the damping coefficient. In their opinion for structures located close to quarry areas where blasting operation is carried out frequently - may be once or twice a weak or some times daily also. In such cases it may be desirable to maintain the structures within elastic limits.

Author's Closure

With regard to the question of Mr. Srivastava, we wish to state that the authors defined the viscous damping already in the papers of "Damping coefficients of structural vibration related to subsoil conditions" Proc. of 5-WCEE, 1973 and "The deflection of tall building due to earthquake", Proc. of 3-WCEE, 1965. In these papers, they mentioned viscous damping of structures as the term of force, depends on the velocity of structural deformation, and hysteretic damping values were separated from the viscous dampings. Effects of inelastic damping should be considered in the term of force-deformation relationship.

The importance of the viscous damping values to the response of structures during earthquake had been discussed in the previous papers, under the consideration of the effects of various conditions of viscous damping and various inelastic characteristics. For the deflection of tall buildings in the elasto-plastic response due to earthquake motions, the effects of viscous damping value of elastic range is evident.