UDC 624.042.7

RESPONSE OF STRUCTURE MODEL SUBJECTED TO TWO SEISMIC MOTIONS WITH CERTAIN TIME-LAG INTERVAL

時間差のある２入力を受ける構造物モデルの地震応答

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1. Introduction

The authors have investigated the dynamic behaviour of the one-degree-of-freedom system subjected to two seismic motions.[1),2)] A simple model of the structure is shown in Fig. 1. This is the simplest one subjected to multi-seismic motions.[3)]

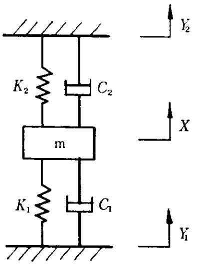

Fig. 1 A simple model of the structure

The behaviour of such structures as piping, transporter, bridge and so on would be simulated fundamentally by this model. Response of the system to earthquake motions which are same wave form, but one of which lags behind the other with a certain interval is computed. This is a simulation for wave propagation.

2. Response of the System to an Earthquake Record

The equation of motion is given as

$$m\ddot{X}+C_1(\dot{X}-\dot{Y}_1)+K_1(X-Y_1)$$
$$-C_2(\dot{X}-\dot{Y}_2)-K_2(X-Y_2)=0 \quad (1)$$

where X, Y_1, Y_2 are the absolute displacements, m is the mass of the model, K_1, K_2 are the stiffness, C_1, C_2 are the damping coefficient. Putting the spring constant and the damping coeffccient as $K_1=K_2=K$, $C_1=C_2=C$ for simplicity, (1) can be written as

$$\ddot{q}_1+2h_s\omega_s\dot{q}_1+\omega_s^2 q_1$$
$$=-\ddot{Y}_1+h_s\omega_s(\dot{Y}_2-\dot{Y}_1)+(\omega_s^2/2)(Y_2-Y_1) \quad (2)$$
$$\ddot{q}_2+2h_s\omega_s\dot{q}_2+\omega_s^2 q_2$$
$$=-\ddot{Y}_2+h_s\omega_s(\dot{Y}_1-\dot{Y}_2)+(\omega_s^2/2)(Y_1-Y_2) \quad (3)$$

where $\begin{cases} q_1=X-Y_1 \\ q_2=X-Y_2 \end{cases}$ and $\begin{cases} \omega_s^2=K/m \\ T_s=2\pi/\omega_s \\ h_s=C/2\omega_s m \end{cases}$

In order to investigate the response spectrum for the system by (2) and (3), it is necessary for us to obtain not only the records of acceleration,

AKITA WAVE (1964, 6, 16)

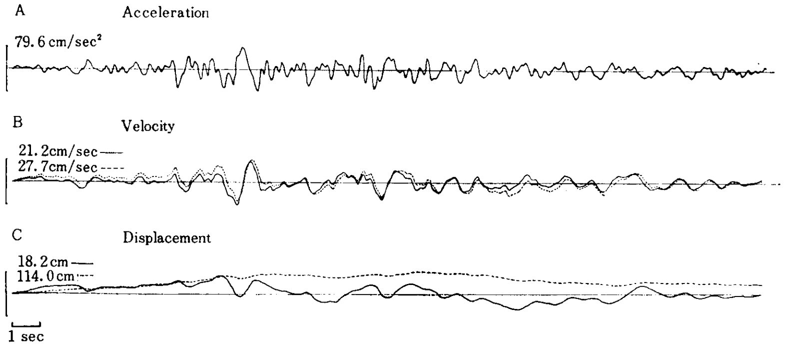

Fig. 2 Earthquake record and its integrated velocity and displacement

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but those of velocity and displacement of ground. A record of acceleration, EW-component in Akita for Niigata Earthquake[4)] (June 16, 1964) is used. It is integrated so that time avarage of the velocity is equal to zero at first. Dotted lines for velocity and displacement in Fig. 2 show this. Solid lines are that the components of long period are got rid of the dotted lines through high pass filter with broken period of 5 sec. These solid lines are used as Y, $\dot{Y}$, $\ddot{Y}$ in (2) and (3). To look over the characteristic of this earthquake, we show in Fig. 3 the response spectra of one-mass-spring system. It has an extreme value at the period 0.3, 0.9 sec for acceleration. spectrum When an input to the system at an end in Fig. 1 is precisely lag behind of that at the other end with time interval T_l, earthquake motions are written as follows,

$$\ddot{Y}_2(t)=\ddot{Y}_1(t+T_l),\ \dot{Y}_2(t)=\dot{Y}_1(t+T_l),$$
$$Y_2(t)=Y_1(t+T_l) \qquad (4)$$

This is the simplest idealization for actual system. However the situation might not be completely same to it, some response characteristics of the system to earthquake motions would be made obvious. Fig. 4 through Fig. 6 are the acceleration response spectra of the model by taking T_l as the abscissa.

Let us call these T_l-response spectrum. T_s=0.3, 0.5, 0.9 sec are taken for these figures respectively and the damping ratio to critical damping is set to h_s=0.05.

These spectra show wavy shape which has maximal value at $T_l=(n-1)T_s$ and minimal value at $T_l=\frac{(2n-1)}{2}T_s(n=1, 2, \cdots\cdots)$. However, the response at $T_l=0$ is the maximum for any case. If a sinusoidal function with phase difference are taken as the inputs to the system, the shape of spectrum is given by $\left|\cos\left(\pi\frac{T_l}{T_s}\right)\right|$.

On the other hand the displacement spectra as shown in Fig. 7 through **Fig.** 9 start from minimum displacement at $T_l=0$ and become greater as T_l increases and reach maximum nearly at T_l=0.6～0.8 sec. Relative displacement $X-Y_1$ and $X-Y_2$ show some different behaviour as conspicuous in Fig. 9. This difference is greater for the longer period T_s.

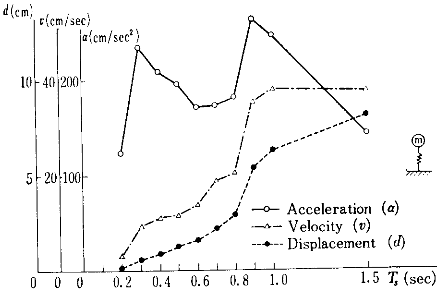

Fig. 3 Response spectra of one-mass-spring system (h_s=0.05)

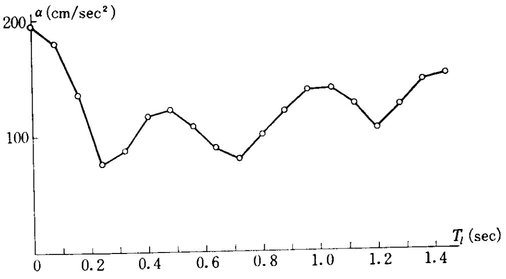

Fig. 5 Acceleration response spectrum (T_s=0.5 sec, h_s=0.05)

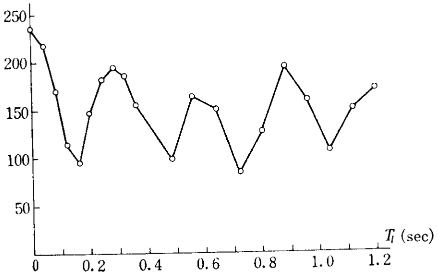

Fig. 4 Acceleration response spectrum (T_s=0.3 sec, h_s=0.05)

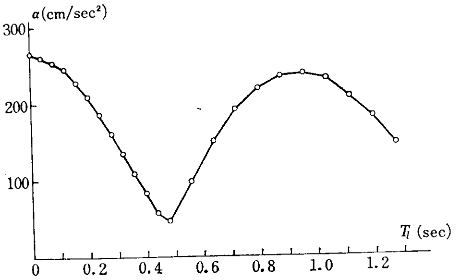

Fig. 6 Acceleration response spectrum (T_s=0.9 sec, h_s=0.05)

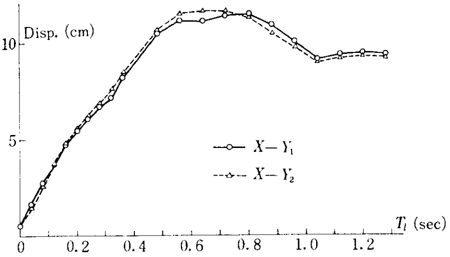

Fig. 7 Displacement response spectum
($T_s=0.3$ sec, $h_s=0.05$)

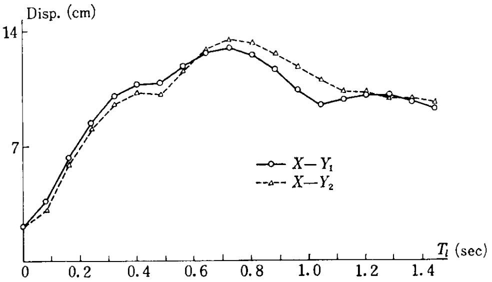

Fig. 8 Displacement response spectra
($T_s=0.5$ sec, $h_s=0.05$)

As for the characteristics of the spectrum of displacement, the compornent of long period in earthquake which appears remarkably in motion of displacement pays an important role.

From the viewpoint of dynamical aseismic design, the spectra make it obvious that the response of displacement should be taken into consideration as well as that of acceleration.

3. Conclusions and Acknowledgement

As for a simple model for the structure system subjected to two different seismic motions response of the system has been investigated and several interesting facts which would be important for dynamical aseismic design have been made obvious.

(1) The acceleration spectra show maximum at $T_l=0$ and have the wavy shape which is close to $\left|\cos\left(\pi\dfrac{T_l}{T_s}\right)\right|+A$ where A is constant.

(2) The displacement spectra have minimum value at $T_l=0$ and become greater and reach maximum as T_l increases.

(3) (1) and (2) show that T_l-response spectrum of displacement should be taken into consideration as that of accelearation.

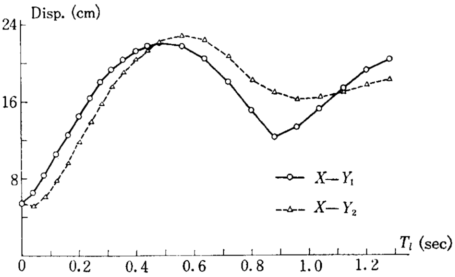

Fig. 9 Displacement response spectra
($T_s=0.9$ sec, $h_s=0.05$)

(4) It is necessary for us to obtain records of ground motion about acceleration, velocity and displacement simultaneously for aseismic design of the system.

In conclusion the authors would like to express their thanks to Professors S. Fujii, A. Watari and H. Shibata at University Tokyo for their unremitting suggestions and encouragements.

They are also grateful to Professor Okamoto and Mr. Hayashi for their useful discussions.⁵⁾ Authors were informed while engaging in the investigation that they were studying same problem.

They finally add that the computation was carried out by HITAC 5020 at University of Tokyo and IBM 7090 through UNICON.

(Manuscript received December 9, 1968.)

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