研究速報

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RESPONSE OF STRUCTURE SYSTEM TO A MODEL EARTHQUAKE MOTION WITH TWO PREDOMINANT PERIODS

複数の卓越周期をもつモデル地震にたいする応答曲線について

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1. Introduction

The response spectrum for earthquake acceleration usually shows a curve with more than two peaks instead of a single peak. This means that the earthquake motion is composed of a few predominant periods. In case of strong motion earthquakes the component of long period has often been observed with that of short one.

On the other hand when the mean of the response spectra to many earthquake motions are taken,[1] the motion can be assumed by a stationary random vibration having a filtered noise characteristic from the engineering view point,[2),3),4)] the spectrum for the acceleration is given by a curve with one peak at the predominant period of the ground.

This report discusses the response spectrum obtained by simulating the earthquake motion with a stationary random vibration possesing two predominant periods. The results are compared with those by actual earthquake records and good agreement is shown.

2. The Formulation of the Ground Model and the Maximum

The transfer function of a model of the ground with two predominant periods is assumed by

$$H_g(s)=\frac{2\omega_{g1}h_{g1}s+\omega_{g1}^2}{s^2+2\omega_{g1}h_{g1}s+\omega_{g1}^2}+\lambda\frac{2\omega_{g2}h_{g2}s+\omega_{g2}^2}{s^2+2\omega_{g2}h_{g2}s+\omega_{g2}^2} \qquad (1)$$

if $\lambda=0$, it is equal to that of one-degree-of-freedom system on which a lot of studies have been performed. The probability density function of extreme $p(y)$ for a time functional random process $I(t)$ with Gaussian distribution is given as follows,

$$p(y)=\frac{1}{\sqrt{2\pi}}\cdot\frac{\sqrt{I_0I_4-I_2^2}}{\sqrt{I_0I_4}}\exp\left\{-\frac{I_0I_4}{2(I_0I_4-I_2^2)}y^2\right\}+\frac{I_2}{2\sqrt{I_0I_4}}y\exp\left(-\frac{y^2}{2}\right)\times\left\{1+erf\frac{I_2}{\sqrt{2(I_0I_4-I_2^2)}}y\right\} \qquad (2)^{5)}$$

where $y=\frac{I(t)}{\sqrt{I_0}}$ and

$$\left.\begin{aligned}I_0&=\frac{1}{2\pi}\int_0^\infty|H(s)|^2kds\\ I_2&=\frac{1}{2\pi}\frac{1}{4\pi^2}\int_0^\infty|sH(s)|^2kds\\ I_4&=\frac{1}{2\pi}\frac{1}{16\pi^4}\int_0^\infty|s^2H(s)|^2kds\end{aligned}\right\} \qquad (3)^{6)}$$

$H(s)=H_g(s)\cdot H_f(s)$ and $H(s)=H_b(s)\cdot H_g(s)\cdot H_f(s)$ are substituted into (3) for the random vibration corresponding to earthquake and for that of response of one-degree-of-freedom structure system to the model earthquake. $H_b(s)$ and $H_f(s)$ are represented as

$$\left.\begin{aligned}H_b(s)&=\frac{2\omega_bh_bs+\omega_b^2}{s^2+2\omega_bh_bs+\omega_b^2}\\ H_f(s)&=\frac{s^2}{(\psi_1s+1)^2(\psi_2s+1)^2}\end{aligned}\right\} \qquad (4)$$

Where k is a constant related with constant spectrum at basement, ψ_1 and ψ_2 are time constant of high-pass and low-pass filter characteristics, ω_b and h_b are natural circular frequency and damping ratio of the structure, $T_{g1}\left(=\frac{2\pi}{\omega_{g1}}\right)$, $T_{g2}\left(=\frac{2\pi}{\omega_{g2}}\right)$, h_{g1} and h_{g2} are the predominant periods and the the equivalent damping ratio of the ground model. The maximum is represented by a point where $p(y)$ is amall enough. In this report $p(y)=0.01$ is adopted.

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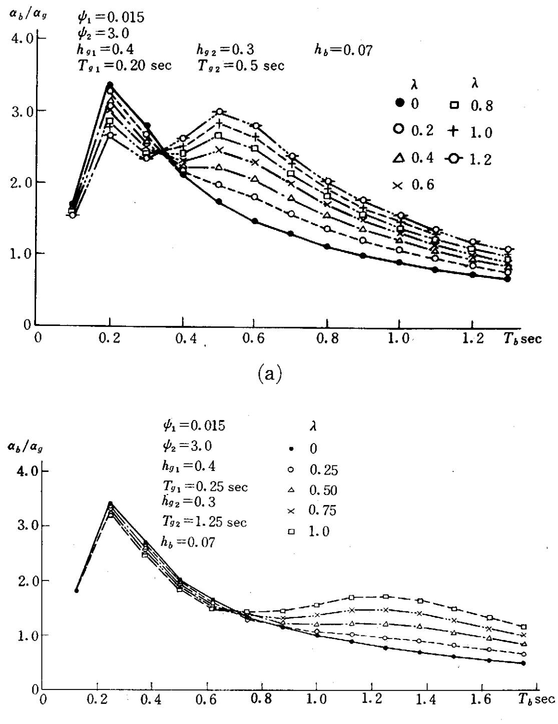

Fig. 1　The acceleration response spectrum by the statistical computation.

3. Examples of Calculated Response Spectrum

Fig. 1 (a) shows an example of acceleration response spectra by the analytical method setting $T_{g1}=0.2$ sec and $T_{g2}=0.5$ sec. h_{g1} and h_{g2} are taken as 0.4 and 0.3 respectively. The former is the value recommended as a standard for the case of single predominant period and the latter is an example for computation. The amplification factor at $T_{g1}=0.2$ sec shows maximum in case $\lambda=0$ and diminishes as it becomes larger. This implies that merging the component of long period makes the acceleration amplification factor decrease in comparison with the case of the original single predominant period. As the result for certain value of λ the spectrum has two peaks at the both predominant periods of the ground.

Even if T_{g2} gets longer than that of the example, the tendency does not change. Fig. 1 (b) shows another example. In this case the longer predominant period exists at five times as

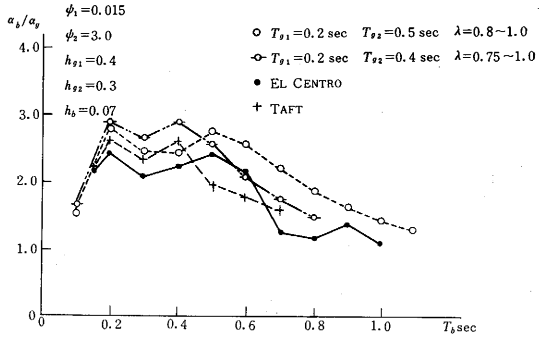

Fig. 2　The comparison of the acceleration spectra by earthquake records with that by the statistical computation.

much as the short one. The decreasing rate of the amplification factor to the variance of λ becomes smaller.

In Fig. 2 the analytical results and the spectra by actual earthquake records as El Centro (NS May 18, 1940) and Taft (NS July 21, 1952) are

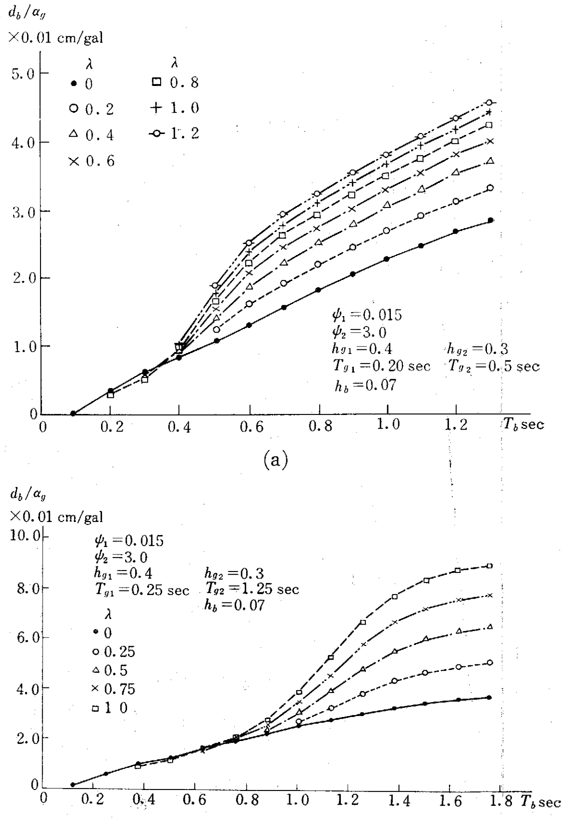

Fig. 3　The displacement response spectrum by the statistical computation.

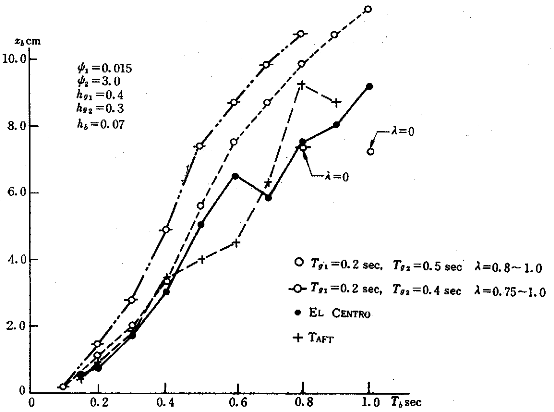

Fig. 4 The comparision of the displacement spectra by earthquake records with that by the statistical computation.

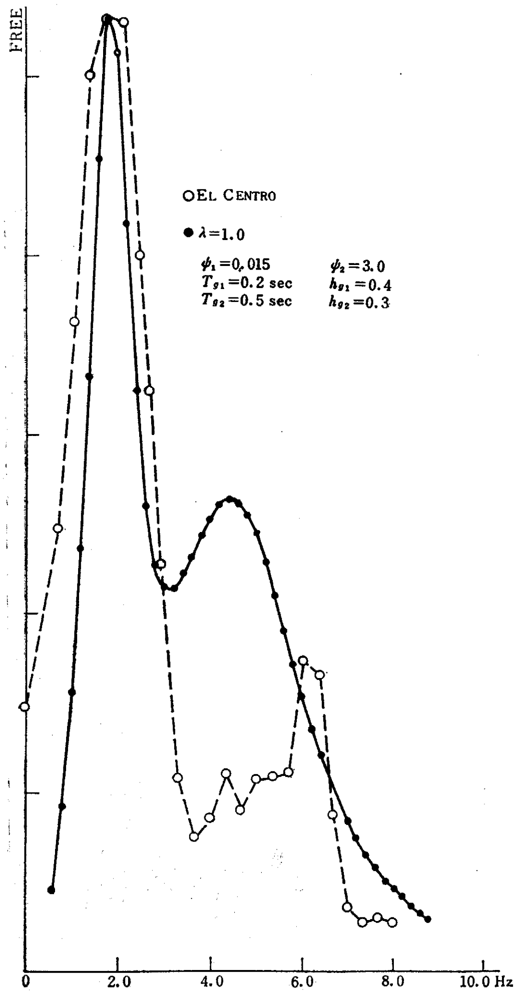

Fig. 5 The comparison of the power spectrum of El Centro with that of the theoretical model.

compared. $\lambda \fallingdotseq 0.9$ is taken for the analysis because of their analogy of spectrum figure. Although there is discrepancy between the both computations, the shape of the spectrum shows good agreement. How to evaluate the two predominant periods and how to predict the acceleration amplification factor from designer's view point depend on future accumulation of data which will describe the relation between earthquake records and the response spectra to these.

Fig. 3 (a) and (b) show the example of displacement response spectra by the analytical computation. They correspond to Fig. 1 (a) and (b) respectively. Fig. 4 is on the comparison of the displacement spectrum to earthquake records and that by the analytical computation. This also shows that this model gives better agreement than that with the single predominant period of the ground. The magnitude of the displacement spectrum at long T_{g2} depends on not only λ, but whether there is a ground predominat period in less period than that.

In Fig. 5 the power spectrum of El Centro and that of the analytical model are compared. λ is set as 1.0. Frequency where the spectrum reaches the maximum is equal for both. However, the shape of the spectrum shows differences.

4. Conclusions and Acknowledgement

As the simulation of the earthquake motion a stationary random vibration system which has band limitted spectrum at base and two ground predominant periods are studied and several conclusions are obtained.

1) The spectrum to the actual earthquake records shows better agreement with the spectrum through this analysis than that given by the system with the single predominant period.

2) In the system aforementioned it makes the acceleration amplification factor small at the original predominant period to add the component of a longer period.

3) The new existence of the long period component makes the displacement spectrum

magnify, which is even originally large in the long period. This suggests that for the structure system with a long natural period we should take the displacement response spectrum into consideration.

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正　誤　表 (10月号)

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