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SYNOPSIS: A new method for generating earthquake timeh histories compatible with the rock response spectrum as the result of seismic hazard analysis will be presented in this paper. It is suggested that the base bank, which is composed of recorded ground motions with different response spectrum characteristics, should be used to select the initial solution. And then, modifying it iteratively to match the target spectrum. In this way, the earthquake environment could be considered.

INTRODUCTION

Acceleration time history method is the main means for the earthquake response analysis of important structures and project sites, which requires the ground motion with proper characteristics as its input. Unfortunately, the recorded earthquake ground motions(EGM) on hand are rather limited and they hardly meet the demands of projects. Therefore it is a indispensable supplementary means to generate synthetic EGM on the basis of statistical characteristics of strong earthquake records. It is well known that the peak, spectral characteristics and duration have the reasonable effects on the response of structure. In practice, especially for the earthquake microzoning, it is a common requirement to synthsize the EGM that match given peak A_m, response spectrum $S(\omega)$ and duration T_d, which are predicted by certain attenuation law. Since the early of 70's, the direct method of generating EGM by superposition of sinusoidal waves has been much developed and widely used in practice. Generally, the EGM is expressed by equation 1.

$$a(t)= f(t)\sum_{K=0}^{N/2} A_K\cos(\omega_K t+\varphi_K) \qquad (1)$$

where: $a(t)$= EGM
$f(t)$= envelope function
A_K = Fourier amplitude
ω_K = frequency
φ_K = phase angle

In practical process most at use, the initial value of φ_K is a set of random numbers within the interval of $(0,2\pi)$ and A_K is evaluated by the relation between response spectrum and power spectral density. The non-stationary of EGM was acquired through the use of an envelope function. By correcting the Fourier amplitudes iteratively, the response spectrum of EGM would approach to the target. However, it has some shortcomings.
1. There are some knotty points in the iterative process now and then, which do not converge to fit the target spectrum.
2. A great number of synthetic EGMs do not resemble the recorded EGMs at all. They get bad wave form and surely lose some characteristics which real ones possess. The propagation of fault breakage determines the frequency and strength characteristics of EGM, which control the wave form of EGM. Clearly, the essential characteristics of EGM are determined with both its amplitude and frequency spectra. Following problems were found in the process of generating EGM:
(1) The phase spectrum made by random numbers does not contain the information of essential characteristics.
(2) The initial amplitude spectrum corresponding to the stationary Gauss process does not include the characteristics of recorded EGM as well.
(3) The envelope function is the result of statistics that does not suit to describe the property of concrete sample.
(4) During the iteration, the correction of the Fourier spectrum is to fit response spectrum, which does not take care of the characteristics.
To overcome above weakness thoroughly, it is necessary to hold back all information of EGM and bring it into play.

SUGGESTION AND DISCUSSION

A new method to generate EGM is suggested as follows:
1. Making up EGM base bank. EGM bank is composed of recorded EGM with different magnitude, epicentral distance and response spectrum. Among them, proper earthquake wave could be selected as the input of generating EGM process. In a sense, it is similar to the base vector group of vector space theory.
2. Searching EGM base bank. According to minimum residual principle, one could search the bank to find out the EGM with the response spectrum that is most similar to the target, or a group of EGM, saying, the first three EGMs with minimum residuum. Then, taking the result of seismic hazard analysis into count, selecting one EGM and scaling it to given peak value. That could be taken for the input of iterative process.
3. Iteration. Modifying the amplitude spectrum iteratively to fit target, finally, we can get a synthetic EGM apropriate to the given target

response spectrum and also with good wave form. The new method has made some improvements in three points.

(1) Envelope curve is a means to deal with the non-stationary characteristics of EGM. If we have gotten an initial solution that contain the essential characteristics, why should we take the envelope curve as a constraint continuously? The author suggested that envelope function could be treated as a looser constraint in new method. For example, let

$$f(t)= \underset{\sim}{f}(t)+ \sigma(t) \qquad (2)$$

where: $f(t)$= envelope function
$\underset{\sim}{f}(t)$= average of envelope function
(t)= variance of envelope function

If the synthetic EGM break the constraint, it means that the probability of the EGM is smaller.

(2) Recent advances in the seismological study of earthquake engineering have led to prediction of EGM with more accurate site-specific parameters. Thus, when we generate synthetic EGM, we must take these parameters into account. Actually, the response spectrum closely relates to the source, source to site travel path and local site conditions. During searching the EGM bank, the earthquake environment has been considered by comparing the response spectra. That implies that the smaller residuum of response spectra, the less difference of site-specific parameters.

(3) The new method is a constructive one, so, it does not ensure to success for every schemes. But it increases the proability of generating good EGM. In the past, Tsai(1972) and Rizzo (1973) had studied the means to fit response spectrum by modifying recorded EGMs and concluded that it was easy to converge im this way. The author has found that it is a conclusion with condition. In the test of matching only one response spectrum by several EGMs, author found that a few of them converge and others don't. Thus, the EGM base bank would help us quite a lot.

EXAMPLE

On the basis of abowe thoughts, the author has developed a corresponding program: Synthesizing Acceleration Time-history of Earthquake, abbreviated as " SATE ", and has found it work quite well. Following example is a synthetic EGM generated by new method for the earthquake hazard analysis of an oil plant. Fig.1 and 2 give out the time histories and response spectra respectively.

CONCLUSSION

In this paper, the author has proposed a new way to overcome the shortcomings that commonly used methods have. That is, constructing the EGM base bank, which is composed of different response spectra EGMs, then, searching the bank to find out the EGM with the minimum response spactral residuum, and next, modifying the selected EGM iteratively to match target spectrum, finally, we can get a synthetic EGM apropriate to the given response spectrum. The effect of the new method has been demonstrated by using it in five project sites for earthquake hazard analysis. The practical results showed that the new method provided us with the better syntheti EGMs comparing with other old one.

ACKNOWLEDGMENTS

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Fig. 1 Comparison of Time Histories: (a) Original and (b) Synthetic

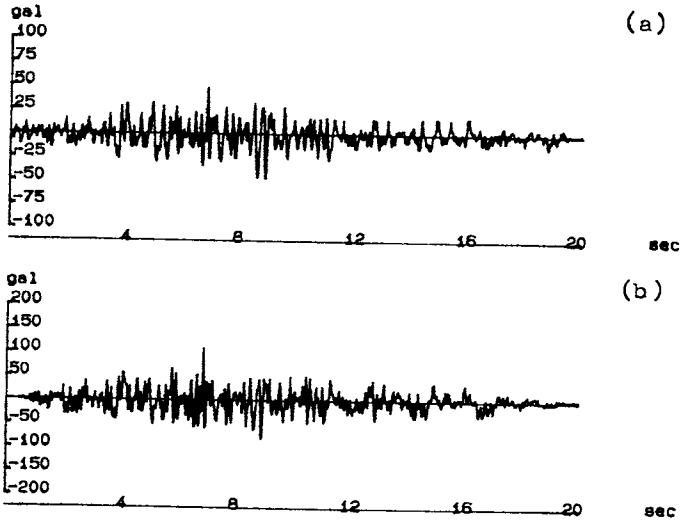

Fig. 2 Comparison of response spectra