THE DEPENDENCE OF STRUCTURAL RESPONSE UPON STRONG GROUND MOTION CHARACTERIZATION

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SUMMARY

This paper summarizes an examination of the effectiveness of the existing characterizations of earthquake induced strong ground motion in structural response studies. The dependence of the response distributions on the particular method of approximating the excitations is examined. The significance of the dispersive properties of the wave transmission path is determined along with estimates of its relative influence on the response distributions. These are studied by way of numerically and analytically derived responses for linear, elastoplastic, and hysteretic elastoplastic systems.

INTRODUCTION

The problem of establishing the structural response to an earthquake is difficult because of the large number and variety of strong ground motion characteristics induced by the source, the wave propagation paths, and the local site effects. It is helpful therefore to determine the minimal amount of information, or degree of characterization, required to accurately estimate the structural response to such motions. This paper is a summary of a study, Ref. 1, whose purpose is to evaluate the effectiveness of methods of characterizing the response and to examine the relative influence of each parameter or characterizer in determining the structural response.

REVIEW

Response distributions calculated from sets of synthetic acceleration records were used in this study. The synthetic accelerograms were generated by the method outlined in Ref. 2, where the acceleration is modelled as a collection of linear wave groups propagating with their respective group velocities and amplitudes. The modal amplitudes are either defined or calculated from the given Fourier amplitude of the excitation or from the ground motion parameters such as the local magnitude, epicentral distance, and local site condition. The accelerograms are inherently random. The wave mode phasing was chosen to be randomly distributed because there are no realistic methods to estimate the phase of the Fourier amplitude of excitation for general earthquake motions. Sets of 100 synthetic records, generated for identical parameters, were used as data sets for the response distribution calculations. The Fourier amplitude of acceleration and duration of strong motion quantities were used in calculating the synthetic records and empirical relationships for these, described in Ref. 1, were used in the processing. To fully quantize the expected Fourier amplitude values, the empirical formulations used define the amplitudes in terms of the probability of exceedance, denoted as p_e.

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This distribution in p_e represents the total deviation of the real data from the chosen empirical model. The response distributions were calculated in terms of an amplitude exceedance probability, p, defined by the randomicity in the source and dispersion phasing. Figure 1 shows the PSV response distributions, calculated for the ground motion parameters listed, for three probability levels each of p and p_e.

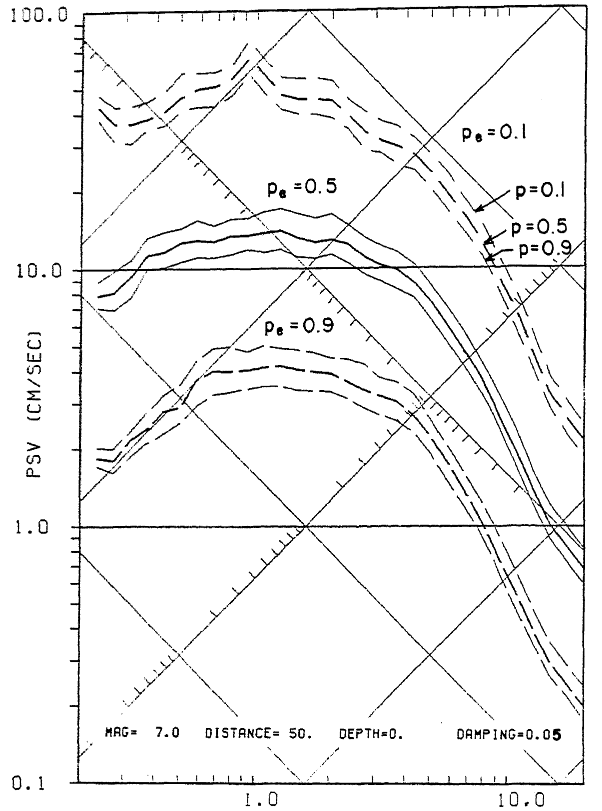

Figure 1

The dispersion model used in the synthetic accelerogram generation was for the El Centro, California region. This figure shows that the distribution range due to the uncertainty in the Fourier amplitude estimation is much larger than the relative distribution variation due to the inclusion of the source and dispersion characteristics. These characteristics may be important to the estimation of the Fourier amplitude however, because none of these characteristics were used in the regression analysis for developing the empirical Fourier amplitude. There are other significant features lacking from these regressions that are also possibly responsible for the large response distributions for p_e.

To determine the specific influence of the dispersion upon the response, the critical excitations of a single degree of freedom linear oscillator were derived. The critical excitations are defined as those members of some admissable class of excitations that produce the maximum energy input to the oscillator. The dispersive properties required for such critical excitations will then yield the upperbound to the significance of the dispersion and source characterization to the response. Figure 2 shows a comparison of the PSV response distributions calculated from three different dispersion models, labeled as D=1,2, or 4.

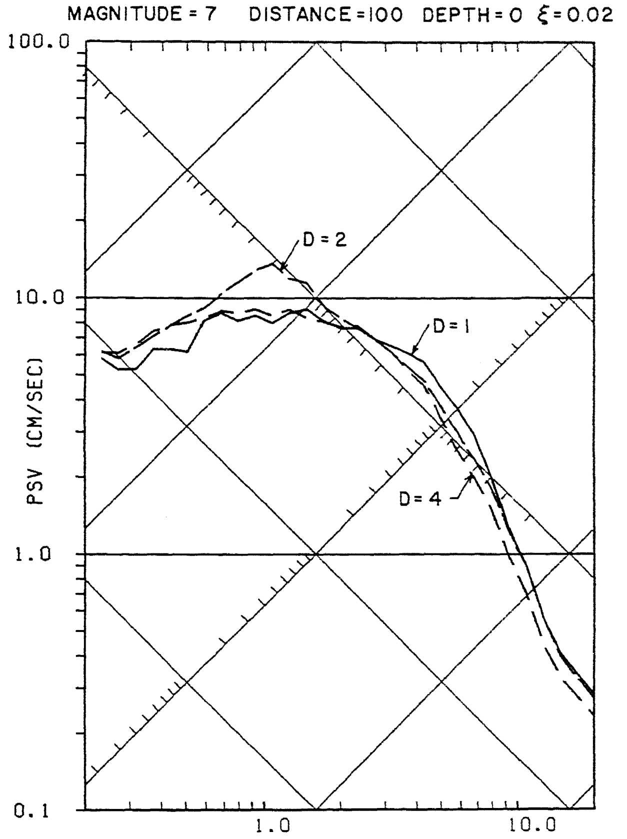

Figure 2

The D=1 dispersion is the 14 mode group velocity model for El Centro used in figure 1. The D=2 model is nondispersive, that is, the group velocity of each mode is a constant independent of the frequency. The D=4 model is a critical dispersion derived from the critical excitation as the dispersion necessary to produce a maximum response at a specific structural natural frequency and damping. D=4 represents a critical single mode dispersion for 2% damping, a natural frequency of 1. hz., and an epicentral distance of 50 km. The response for these three dispersions varies by at most a factor of two around 1. hz. The derivation of the critical excitations given in Ref. 1 shows that the dispersion is responsible for increasing or decreasing the nondispersive response by at most a factor of two, independent of the spectral amplitudes.

A comparison of the synthetic response distributions to the critical excitation is shown in figure 3. The solid curve represents the critical excitation response while the dashed are the respective response distributions for the same three dispersions, shown for three probability levels.

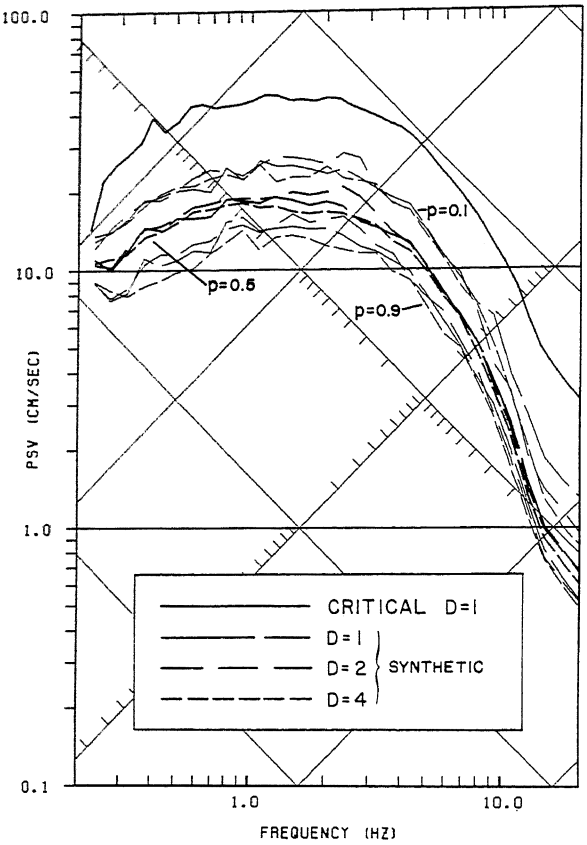

Figure 3

The critical response is roughly 2.5 times as large as the p=0.5 response for the synthetic sets independent of frequency. Comparisons were done for an extensive range of ground motion parameters with similar results as shown here indicating that the critical response can be scaled to produce approximations of the response distributions.

To give a brief comparison of the effect of the type of characterization used in estimating the ground motion has upon the calculated response, the PSV responses calculated by two different methods are shown in figures 4 and 5.

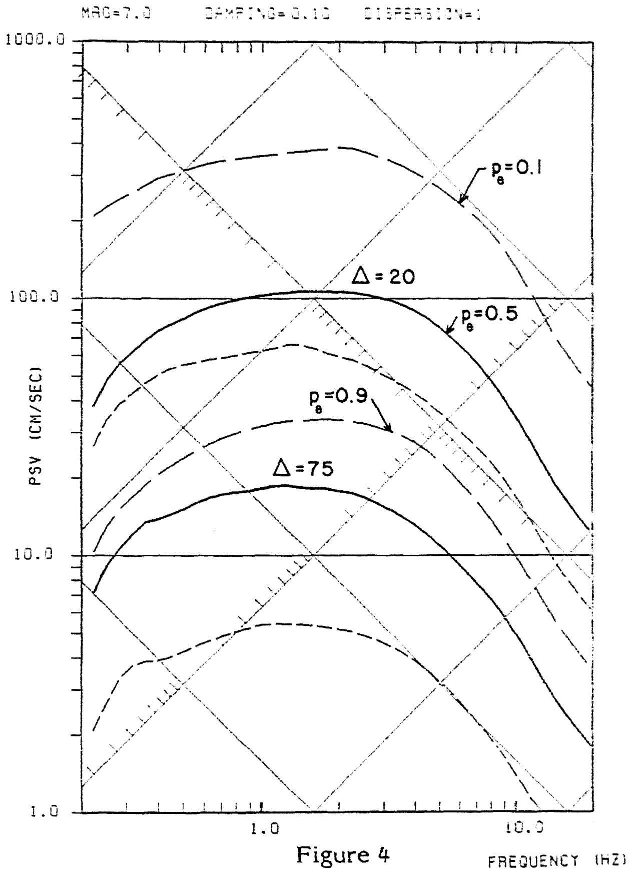

Figure 4

Figure 4 shows the PSV response calculated from the critical excitations for epicentral distances of 20 and 75 km. and for 10% damping. These distributions essentially represent the response to a given Fourier amplitude of excitation assuming the most critical accelerations are experienced at the site.

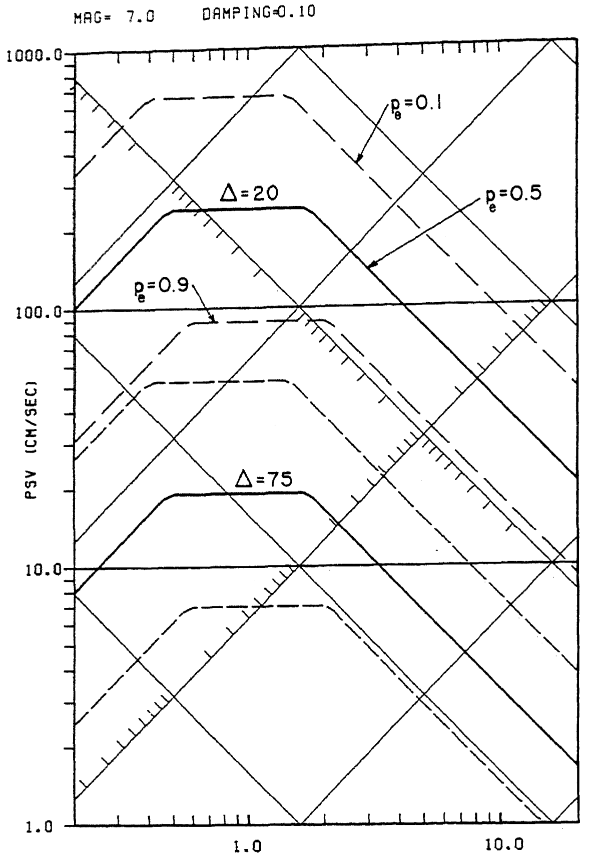

Figure 5

Figure 5 shows the PSV response calculated from the peaks of the ground displacement, velocity, and acceleration only. The differences in the estimated response are not too great for this case, however, the peak ground motion estimates of the PSV exceed the critical estimates by up to a factor of five at damping values of 2%.

REFERENCES

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