SPECTRAL CHARACTERISTICS OF NEAR SOURCE STRONG GROUND MOTION

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SUMMARY

A study was performed to quantitatively incorporate source- and site-dependency directly into the Newmark-Hall procedure for estimating response spectra. Ground motion ratios of v/a and ad/v^2 and amplification factors for acceleration, velocity, and displacement were estimated as a function of magnitude, for three site conditions and for distances of less than 20 kilometers from the source. Results of the analysis were extrapolated to magnitudes greater than 6-1/2 assuming M_L saturation at magnitude 7 and utilizing Aki's (1967) magnitude dependent displacement source spectra.

INTRODUCTION

Statistical studies of strong motion response spectra have been conducted by Newmark and Hall (1969), Seed and others (1976), and Mohraz (1976). However, these studies did not directly consider distance and magnitude effects on spectral shape. For example, the procedure developed by Newmark and Hall (1969) incorporates the influence of magnitude and distance indirectly by scaling a constant spectral shape to a peak acceleration. It is thus assumed that acceleration is magnitude and distance dependent, but spectral shape is not; however, the amplitude and shape of a response spectrum should change independent of peak acceleration. Recent strong motion seismological studies have indicated that spectral characteristics are significantly influenced by magnitude (Johnson, 1975); however, insufficient strong motion data has hampered efforts to estimate magnitude effects for large earthquakes. The purpose of this study is to extend the results of Johnson and Traubenik (1978), who studied near source v/a and ad/v^2 ratios as a function of magnitude, by utilizing basic seismological information such as the saturation of the M_L scale near magnitude 7 (Kanamori and Jennings, 1978) to estimate spectral shape and spectral amplitude of earthquakes greater than magnitude 6-1/2 to 7.

ANALYSIS

Newmark and Hall (1969) concluded that response spectra can be estimated if an approximation of free-field acceleration (a), velocity (v), and displacement (d) can be made. Smooth response spectra can then be estimated from ground motion parameters, v/a and ad/v^2, using straight line segments on tripartite paper and empirically derived amplification factors for different values of critical damping.

For purposes of this study, an evaluation of near source response spectra was performed using a procedure developed by Mohraz (1976). A general description is as follows: 1) ground motion ratios, v/a and ad/v^2, for various percentiles using log-normal distribution are calculated; and 2) the selected response spectra are normalized to obtain amplification factors. At each frequency point, the ratio of the spectral response to the maximum ground motion (i.e., amplification factor) is obtained for acceleration, velocity, and displacement in the corresponding

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frequency ranges. Averaged amplification factors are then calculated for 50 percentile values using a log-normal distribution.

The accelerograms used in this study were chosen for their magnitude (greater than or equal to 4.5), the local geologic conditions at the accelerograph site (rock, thick and thin alluvium), peak acceleration (approximately 0.10g or greater), and source- to site-distance of 20 kilometers or less.

RESULTS

Numerical results of the analysis are presented in tabular form. Summaries of v/a and ad/v^2 ratios as a function of magnitude and local geologic site conditions are shown in Table I. Amplification factors for 1/2, 5, and 10 percent critical damping are summarized in Table II. Comparisons of the Mohraz (1976), Seed and others (1976) and the near source response spectra for a Magnitude 7 earthquake, normalized to 1.0g for 5 percent damping are presented on Figure 1. All near source spectra shown on Figure 1 were estimated using extrapolated mean v/a and ad/v^2 ratios and extrapolated 50 percentile amplification factors (assuming M_L saturation at approximately Magnitude 7), and free-field displacement (d) does not reach a limiting value or saturate, as does velocity at Magnitude 7. It can be seen from Figure 1 that the short period range of the spectra are similar; however, the long period portion of the spectra are significantly different in amplitude and shape, reflecting magnitude effects. Therefore, preliminary results indicate that the use of currently accepted site-dependent response spectra may lead to underestimation of spectral amplitudes for periods greater than 0.3 seconds.

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TABLE I

SUMMARY OF v/a AND ad/v^2 RATIOS
(LOG-NORMAL DISTRIBUTION)

LOCAL SITE GEOLOGY	M_L	NUMBER OF ACCELEROGRAMS	v/a (in/sec)/g PERCENTILE		ad/v^2 PERCENTILE	
			50	MEAN	50	MEAN
ROCK	4.7-4.9	7	14	14	1.6	1.7
	5.4-5.6	4	22	23	3.7	4.0
	6.5	5	31	33	4.0	4.3
THIN	4.7	4	15	15	1.0	1.1
ALLUVIUM	5.5-5.9	10	27	30	4.1	5.3
DEEP	4.7-5.2	14	26	28	3.6	5.1
ALLUVIUM	5.5-5.9	10	34	36	2.7	3.1
	6.3-6.5	8	54	57	4.2	4.6

TABLE II
SUMMARY OF AMPLIFICATION FACTORS
(LOG-NORMAL DISTRIBUTION)

LOCAL SITE GEOLOGY	DAMPING (PERCENT CRITICAL)	MAGNITUDE (M_L)	AMPLIFICATION FACTORS 50 PERCENTILE DISPLACEMENT	VELOCITY	ACCELERATION
ROCK	1/2	4.7-4.9	4.57	0.87	3.52
		5.4-5.6	1.99	1.82	3.21
		6.5	2.64	2.22	3.79
	5	4.7-4.9	3.81	0.62	2.29
		5.4-5.6	1.51	1.22	2.10
		6.5	2.10	1.47	2.12
	10	4.7-4.9	3.35	0.54	1.85
		5.4-5.6	1.31	1.02	1.78
		6.5	1.78	1.18	1.68
THIN	1/2	4.7	4.04	0.71	3.07
ALLUVIUM		5.5-5.9	2.37	2.26	3.28
	5	4.7	3.57	0.54	2.25
		5.5-5.9	1.92	1.43	2.07
	10	4.7	3.26	0.49	1.84
		5.5-5.9	1.65	1.14	1.71
DEEP	1/2	4.7-5.2	2.13	1.51	3.17
ALLUVIUM		5.5-5.9	1.90	1.99	3.23
		6.3-6.5	2.57	2.27	4.12
	5	4.7-5.2	1.69	1.04	2.15
		5.5-5.9	1.56	1.26	2.08
		6.3-6.5	1.90	1.43	2.21
	10	4.7-5.2	1.48	0.87	1.77
		5.5-5.9	1.40	1.01	1.74
		6.3-6.5	1.55	1.14	1.75

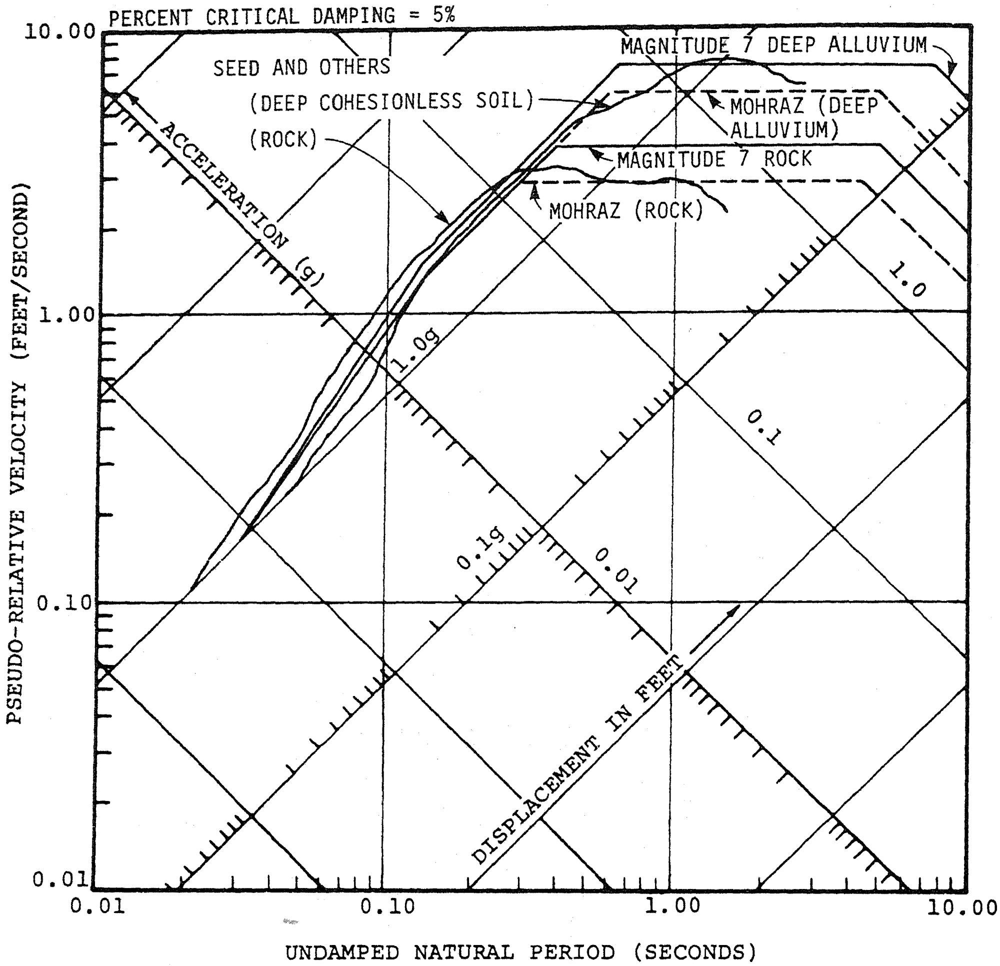

FIGURE 1 - COMPARISON OF SEED AND OTHERS (1976) MEAN ROCK AND DEEP COHESIONLESS SOIL SPECTRA FOR MAGNITUDE 6½ EARTHQUAKE AT 5 MILES AND MOHRAZ (1976) AND NEAR SOURCE ROCK SPECTRA AND DEEP ALLUVIAL SPECTRA FOR MAGNITUDE 7 (NORMALIZED 1g)