THE DURATION OF STRONG MOTION AND ITS DEPENDENCE ON THE RECORDING SITE GEOLOGY

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SUMMARY

The duration of strong shaking, as defined by the time contributing to 90% of the mean square integrals of the band-pass filtered strong ground motion, has been examined by correlating the duration with the earthquake magnitude, epicentral distance, intensity, frequency of motion, and the depth of sediments at the recording site. This study is a refinement of previous regression analyses which categorized the sites into three types (rock, intermediate, alluvium). The results indicate that the duration increases by more than 2 seconds per km of sediments for shaking at frequencies near 1.1 Hz, and by as little as 0.5 sec/km at 0.7 Hz.

ANALYSIS

The duration of strong shaking can be an important characteristic of earthquake motion, particularly for structural response analysis purposes. For this study, the duration has been defined as the total time during which the shaking contributes to 90% of the integrals

$$\int_0^T \{a^2(t), v^2(t) \text{ or } d^2(t)\} dt$$

where a, v and d represent the acceleration, velocity, and displacement of the ground motion and T is the total time length of non-zero motion and represents the time period during which a site receives all of the "seismic energy." The duration at a site is clearly dependent on the nature of the source, the faulting process, and the characteristics of the medium through which the waves travel. As an approximation, it is assumed that

$$\text{DURATION} = d_{source} + d_{\Delta} + d_{site} \qquad (1)$$

where d_{source} is the duration at the source, d_{Δ} is the duration extension due to the dispersion of the waves, and d_{site} represents the dependence of the duration on the local site geology. To examine the relative influence on the duration of each of these three factors as a function of the frequency, the strong motion records were filtered into six frequency bands, each one characterized by its center frequency, ω_c.

Regressions of the calculated duration with equations postulated from Eq. 1 have shown that the site effects on the duration are significant [1, 2]. For these studies, the site was classified roughly as being on either hard rock, intermediate, or soft sediments. The results suggested that it

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is worthwhile to refine this classification further by increasing the resolution of site classification and in terms of the depth of sediments at each station. The depth of sediments above hard rock was determined for each recording station and this depth, h, was incorporated into the regressional equation replacing the previous site classification. The depth h represents the estimated vertical distance from the source to the local basement rock. The resulting model equations are

$$\text{DURATION} = a(\omega_c) + b(\omega_c)I_{MM} + c(\omega_c)h \tag{2a}$$

or

$$\text{DURATION} = a(\omega_c) + b(\omega_c)M + c(\omega_c)\Delta + d(\omega_c)h \tag{2b}$$

where a, b, c and d are the calculated coefficients, M is the published magnitude, I_{MM} is the Modified Mercalli Intensity, and Δ is the epicentral distance. The data base consisted of 186 free-field strong motion records of 57 earthquakes in the western United States. Statistical analysis showed that the coefficients resulting from the regression were significant at the 95% confidence level. The residuals, or the actual duration minus the duration evaluated from Eq. 2, were also calculated, and $a(\omega_c)$ was specified as $a(\omega_c)p$, where p is the ratio of the number of sites with durations less than the calculated duration to the total number of sites. In most cases, a double exponential distribution fit this empirical $a(\omega_c,p)$ with statistical significance. This is discussed in more detail in [3,4].

The duration, as calculated from Eq. 2 is shown vs. ω_c for both the horizontal and vertical components and for several values of I_{MM} and h in Fig. 1. The curves show the duration to decrease with an increase in the center frequency, ω_c, or with the intensity. For all cases, the duration increases with increasing depth, this increase being greater than 2.0 sec/km for horizontal motion at $\omega_c = 1.1$ Hz. The high frequency motion, $\omega_c = 7$ Hz, is least sensitive to the site depth, with the duration increasing by less than 1.0 sec/km.

Similar estimates for the duration calculated from Eq. 2b are shown for both components and for several values of M, Δ (the epicentral distance), and h in Fig. 2. As with the intensity correlations, the trend is for the duration to decrease with increasing frequency of the band-filtered motion, with the low frequency duration, $\omega_c = 0.5$ Hz being as much as 20 sec longer than the duration at $\omega_c = 18.0$ Hz. Dispersion and scattering of the waves along their paths causes the duration to increase with the epicentral distance by roughly 0.07 to 0.13 sec/km, depending on the frequency. At all frequencies the duration increases with depth more for the vertical duration component than the horizontal. For $\omega_c = 0.5$ and 1.1 Hz, the vertical duration increases by rougly 1sec/km more than the horizontal component of the duration. The duration increases by about 0.5 sec/km for both components at $\omega_c = 7$ and 18 Hz.

REFERENCES

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FIGURES

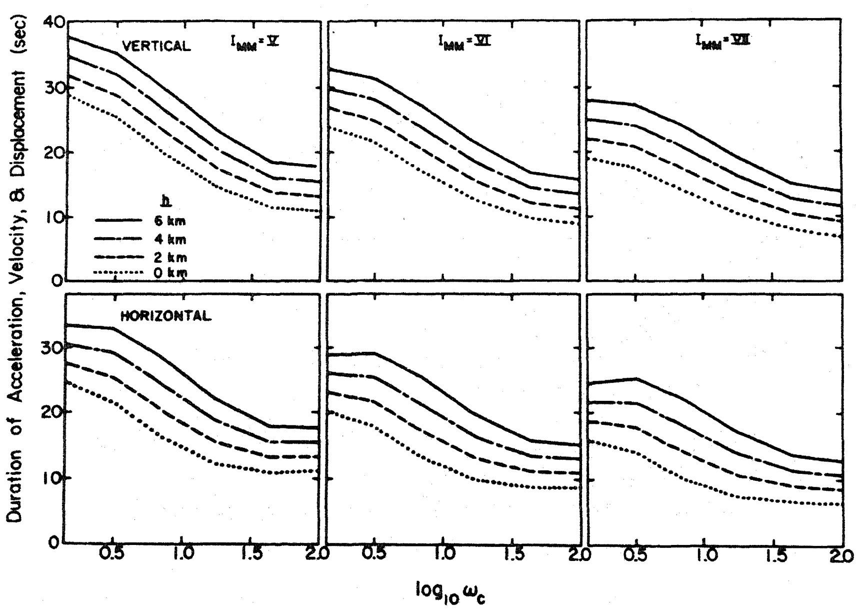

Fig. 1

The Strong Motion Duration vs. ω_c Calculated from Eq. 2a

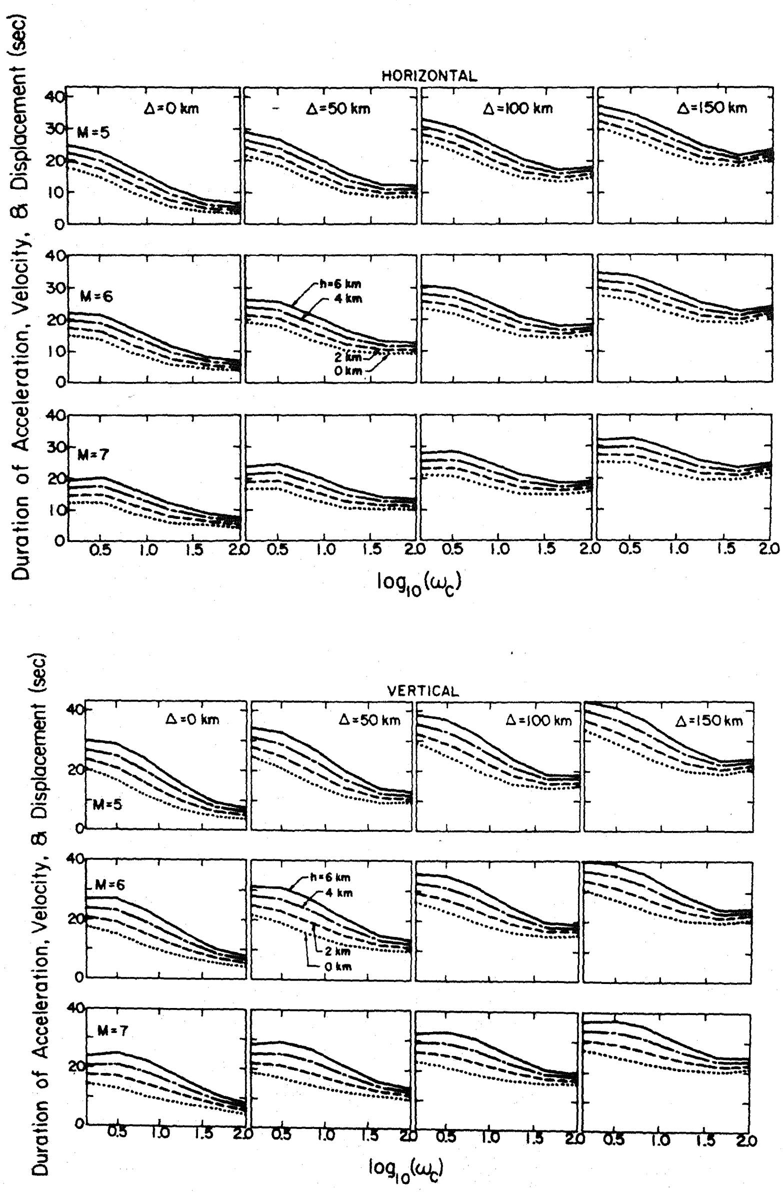

Fig. 2

The Strong Motion Duration vs. ω_c Calculated from Eq. 2b