# INFLUENCE OF MAGNITUDE, SITE CONDITIONS AND DISTANCE ON SIGNIFICANT DURATION OF EARTHQUAKES

by

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## SYNOPSIS

A study was made of significant duration of horizontal motions recorded in the Western USA on site conditions ranging from rock to soft clays. Consistent correlations were found between duration on rock, magnitude and distance to the source. Durations at soil sites showed much more scatter, with the duration on rock for similar magnitude or distance being a lower bound. These larger durations for soil are usually caused by long period motions at the end of the record, which may be associated with surface waves.

## INTRODUCTION

The characterization of earthquake strong motion for engineering purposes requires defining the level of shaking, its frequency content, and the significant duration of motion. A number of studies are available showing the influence of magnitude, distance to source and site conditions, on the level and frequency content of ground motion. Much less work has been done on duration. Some authors have proposed different definitions of significant duration and have obtained correlations showing the general increase of duration with magnitude (eg, 2, 3, 4); summaries of these correlations are presented in references 6 and 9. More recently, Trifunac and Brady (9) considered the influence on duration of magnitude, distance and geologic conditions at the recording station.

This paper summarizes the results of a study of duration of horizontal records in the Western United States. Data on magnitude, distance and site conditions were obtained mostly from references 7 and 8. The earthquakes studied are summarized in Table 1, and all the accelerograms used were obtained from Caltech (10). The definition of duration used in this study is that proposed by Trifunac and Brady (9). This definition is based on the plot showing the buildup of Arias Intensity (1) with time proposed by Husid (5) and it is illustrated in Fig. 1. Duration is defined as the time needed to develop between 5 and 95 percent of the Arias Intensity for the entire record.

## DURATION, SITE CONDITIONS AND DISTANCE

The San Fernando 1971 earthquake occurred to the north of the San Fernando - Los Angeles area and it had a magnitude of about 6.6; the source was a thrust fault. The fault dips to the northeast, and the zone shown in Fig. 2, which coincides approximately with the lower block of the thrust fault, was selected and studied in further detail. Figure 2 also shows the locations of stations inside the zone which were used in this study. The site conditions at each station were classified in the four groups suggested in reference 8 (rock, stiff, deep cohesionless, and soft to medium sites). Figure 3 presents a plot of duration versus distance for the stations in Fig. 2. There is a large scatter in the results, with

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durations ranging from 7 seconds to more than 25 seconds. The longest durations were recorded at stations on alluvium in the San Fernando Valley, located 12 to 15 miles from the source. If only rock sites are considered in Fig. 3, a consistent correlation between duration and distance is obtained, with the duration of shaking being 7 - 10 seconds very close to the fault, with 12 - 15 seconds at 25 miles; this correlation is indicated by the hatched range in Fig. 3. This range of durations for rock is also a lower bound for the duration values on soil, which show a much larger scatter. The fact that duration on soil is equal to or longer than on rock, suggested by Fig. 3, is consistent with the findings of Trifunac and Brady (9). To understand the reason for this, accelerograms and Husid plots on rock and soil were examined. Figure 1 shows typical results for records on rock and soil, obtained at about 15 miles from the source. The main difference in the two accelerograms is the existence, at the end of the soil record, of significant long period motions, which are absent in the rock record. The beginning of these long period motions in Fig. 1, at about 14 to 16 seconds, coincides approximately with the time at which rock records would end at that distance.

The San Francisco 1957 earthquake was a local event, and it had a magnitude of about 5.3. Strong motion records were obtained at a rock site, at three stiff sites and at one soft site (see Fig. 4). Figure 5 presents a plot of duration versus distance for these accelerograms. The minimum durations were obtained at the rock site, and Fig. 5 suggests that durations at rock sites were also, in this earthquake, generally lower than durations at soil sites. Soil records examined also showed more prominent long period motions at the end as compared with the rock records, similar to those found for San Fernando.

## DURATION, SITE CONDITIONS AND MAGNITUDE

Figure 6 shows a plot of duration versus magnitude for all rock sites considered in this study. Thirty accelerograms were used to construct this graph, which shows a fairly consistent trend. The data for San Fernando in Fig. 6 include some stations not shown in the map of Fig. 2. The proposed correlation for the expected duration, D, in seconds, corresponding to earthquake magnitude M was obtained from a linear regression analysis between log D and M; this correlation is presented in Fig. 6. The upper and lower bound curves in Fig. 6 correspond to $A + 2\sigma$ and $A - 2\sigma$, respectively, where A is the average and $\sigma$ the standard deviation of log D. Figure 7 presents a similar plot of duration versus magnitude, for all soil sites considered in this study. The range for rock sites from Fig. 6 has been superimposed in Fig. 7, for comparison. Several records on soil fall inside the range of durations for rock sites, but many have durations which are significantly longer.

Figures 6 and 7 confirm the conclusions advanced for the San Fernando earthquake, and suggest that: a) durations of records obtained on rock sites have consistent and reasonably predictable values, b) durations on soil show a much larger scatter, with the duration for rock being a lower bound.

## CONCLUSIONS

A consistent correlation, valid for rock sites, was established between significant duration of strong-motion records and magnitudes of earthquakes for the Western United States, for magnitudes between 4.5 and

7.5. A consistent correlation between duration and distance was also found for records on rock during the San Fernando earthquake.

Duration of records on soil exhibit a much larger scatter than duration of similar records on rock. For the same magnitude (and distance), the range of durations on rock constitutes a lower bound for the durations on soil. In some accelerograms studied, this larger duration on soil was associated with long period motions at the end of the record. The existence of more prominent longer period motions which increase the duration of some records on soil, as compared with that of records on rock, may have important engineering implications. These differences between motions in rock and soil may well be associated with surface waves; however, further study by seismologists and engineers is still required for a fuller understanding of the phenomenon.

## ACKNOWLEDGMENTS

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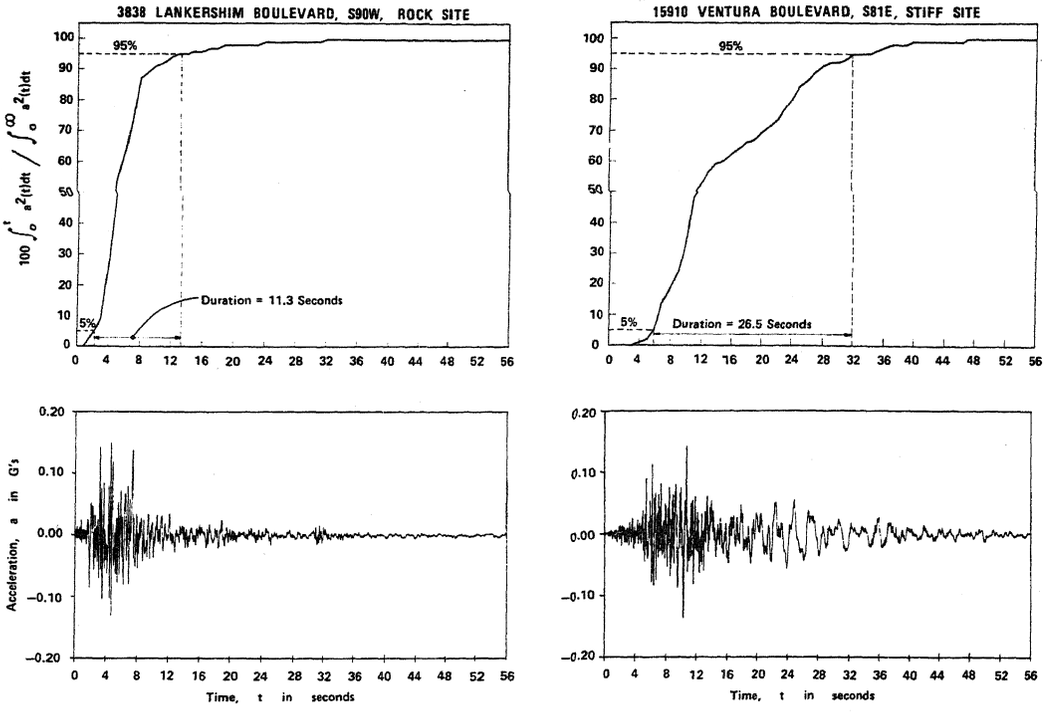


Fig. 1 – HUSID PLOTS AND SIGNIFICANT DURATION FOR ACCELEROGRAMS ON SOIL AND ROCK (San Fernando 1971)

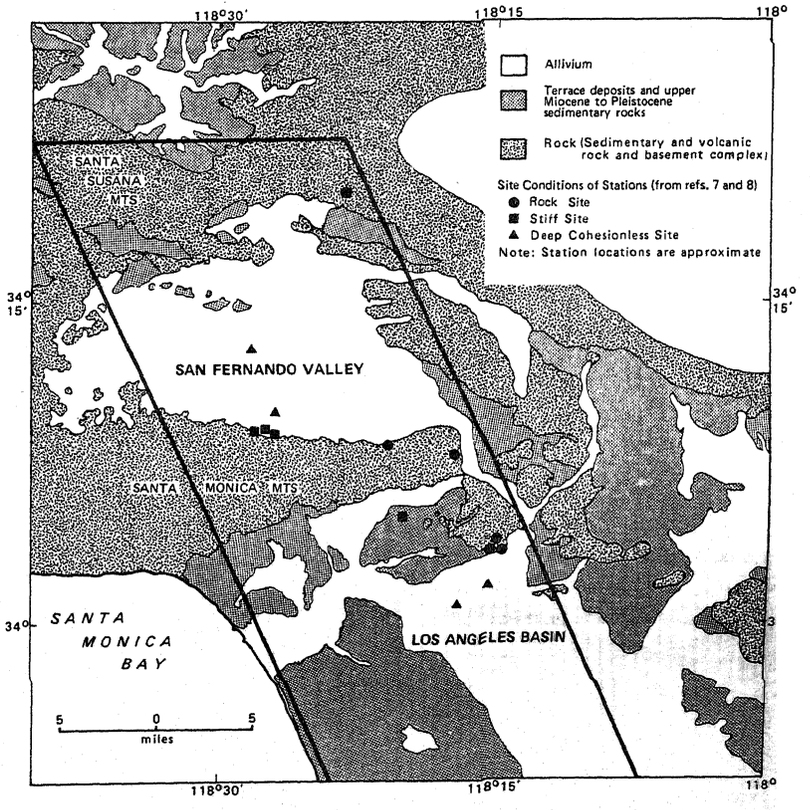


Fig. 2 – GEOLOGIC MAP OF SAN FERNANDO VALLEY – LOS ANGELES AREA AND LOCATIONS OF STATIONS USED IN THIS STUDY

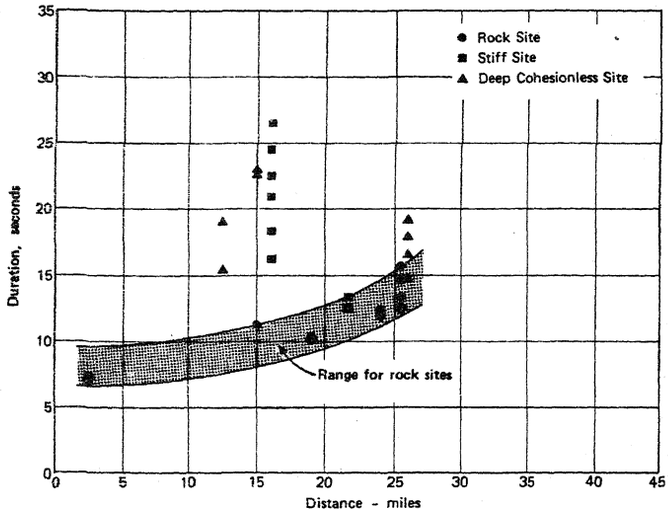


Fig. 3 -- DURATION AS A FUNCTION OF DISTANCE TO SOURCE AND OF SITE CONDITIONS, SAN FERNANDO, 1971

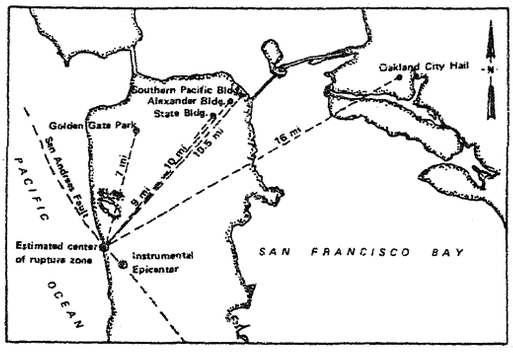


Fig. 4 -- LOCATIONS OF STATIONS, SAN FRANCISCO EARTHQUAKE, MARCH 22, 1957

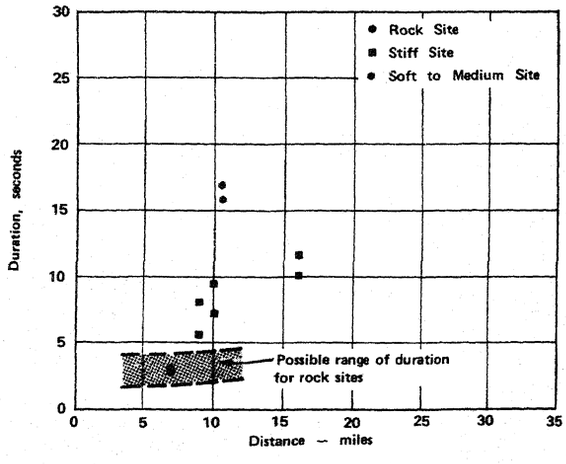


Fig. 5 - DURATION AS A FUNCTION OF DISTANCE TO SOURCE AND OF SITE CONDITIONS, SAN FRANCISCO, 1957

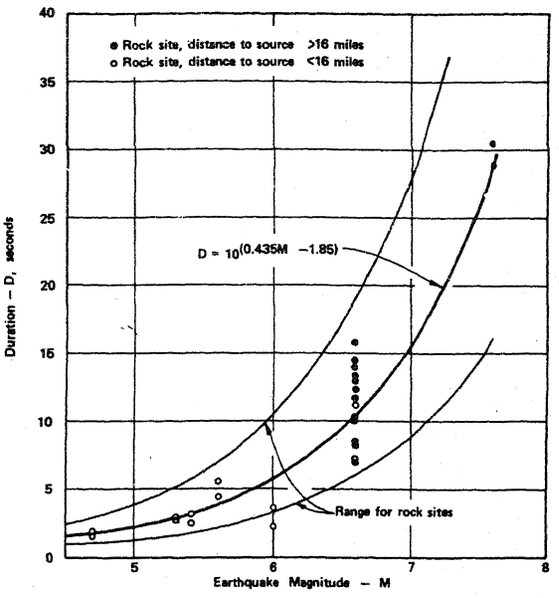


Fig. 6 – DURATION VERSUS MAGNITUDE FOR ROCK SITES IN WESTERN UNITED STATES

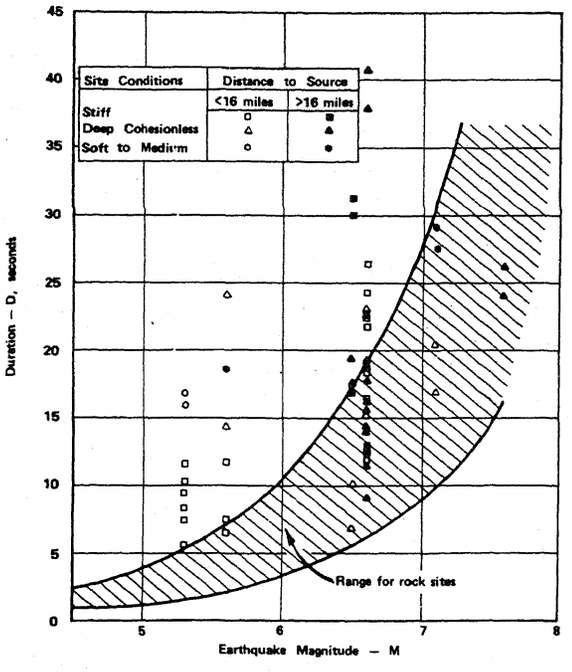


Fig. 7 – DURATION VERSUS MAGNITUDE FOR SOIL SITES IN WESTERN UNITED STATES

TABLE 1
LIST OF EARTHQUAKES STUDIED

| Earthquake | Magnitude | Date | No. of Records |
|---|---|---|---|
| Bear Valley | 4.7 | 9-4-72 | 2 |
| San Francisco | 5.3 | 3-22-57 | 10 |
| Lytle Creek | 5.4 | 9-12-70 | 2 |
| Ferndale | 5.6 | 12-10-67 | 2 |
| Parkfield | 5.6 | 6-27-66 | 5 |
| Hollister | 5.6 | 4-8-61 | 1 |
| Helena | 6.0 | 10-31-35 | 2 |
| Eureka | 6.5 | 12-21-54 | 4 |
| Lower California | 6.5 | 12-30-34 | 2 |
| Borrego Mountain | 6.5 | 4-8-68 | 2 |
| El Centro | 6.6 | 5-18-40 | 2 |
| San Fernando | 6.6 | 2-9-71 | 46 |
| West Washington | 7.1 | 4-13-49 | 4 |
| Kern County | 7.6 | 7-21-52 | 4 |
| | | Total = | 88 |