

THE EFFECTS OF ELEVATION AND SITE CONDITIONS ON GROUND MOTION
OF THE SAN FERNANDO, CALIFORNIA, EARTHQUAKE, 9 FEBRUARY 1971

By

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ABSTRACT

The objectives of this study were to determine site effects on earthquake ground motion and the correlation between acceleration and/or velocity generated during the San Fernando Earthquake of 9 February 1971 and topography of the San Gabriel Mountain Range. It was found that the contours of peak acceleration and peak velocity generally follow the topography of the San Gabriel Mountain Range.

The topographical effects on the ground motion could be interpreted in a simple manner as a function of elevation and direction of wave transmission path. The elevation and direction become the dominant factors in the distribution of the bedrock motion using the ground motion-elevation gradient as applied in the area south of Kagel Mountain and north of Santa Monica Mountain, in the San Fernando Valley. A high acceleration of 2.29 g has been estimated at the top of Kagel Mountain by the extrapolation method. This method is validated using aftershock data. Accelerations recorded in the rock were higher than those recorded in the alluvium as might be expected, but the integrated displacements from the acceleration were indicated in an opposite direction for alluvium. The integrated velocities did not follow a definite trend.

INTRODUCTION

The purposes of this study were to determine site effects on earthquake ground motion in the near field and a general correlation between peak acceleration or peak velocity recorded during the San Fernando, California, earthquake, 9 February 1971, and topography by mapping techniques. Such techniques might produce seismic risk maps that would reflect local geological and soil conditions and also furnish input motion for practical design in earthquake engineering.

MAXIMUM ACCELERATION AND VELOCITY MAPS

Figures 1 and 2 are contour maps of the observed peak accelerations and the integrated peak velocities, respectively. The data are based on Chang (1978). The main part of the maximum acceleration and velocity maps is controlled by instrumentally recorded data from 12 rock sites and 9 soil sites (Figure 1). These sites surround the Pacoima damsite as the center which has the maximum horizontal acceleration and maximum horizontal velocity, 1.25 g and 115 cm/sec, respectively. The contour lines were drawn by an equal linear interpolation method between the Pacoima damsite and these surrounding sites. The interpolation contours do not represent actual accelerations or velocities on the ground surface.

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INTERPRETATION OF MAPS

Lower San Fernando Damsite

Scott (1973) derived the horizontal acceleration-time history from the seismoscope record of the east abutment (composed of shale) of San Fernando Dam and found a number of peaks of substantial amplitude in the range of 0.6-0.8 g. He suggested that the peak accelerations of perhaps 0.55-0.6 g were reasonable. A value of 0.67 g was recorded by the peak recording accelerograph on the crest of the San Fernando Dam, which was displaced by the movement that occurred in the upstream slope.* On the peak acceleration map, the 0.6 g contour line crosses the Lower San Fernando Dam. This provided additional evidence to show that 0.6 g is a reasonable acceleration for the bedrock on the Lower San Fernando Dam. Furthermore, this value can be determined from the acceleration-elevation gradient of the Pacoima Dam-Universal Sheraton Hotel path. This will be demonstrated in the following sections of topographic corrections. Figure 3 shows the topographic profile of the Lower San Fernando Dam-Pacoima Dam-Kagel Mountain path.

Bedrock Motion of Pacoima Dam

The maximum accelerations, velocities, and elevations for the Pacoima damsite and the Lower San Fernando damsite (seismoscope site of east abutment) are 1.25 g, 115 cm/sec, and 2067 ft; and 0.6 g, 60 cm/sec (obtained from Figure 2), and 1137 ft, respectively. The horizontal distance between the Pacoima damsite and Lower San Fernando damsite is about 9.5 km. The acceleration and velocity gradients between them can be calculated by:

$$\frac{1.25 - 0.60}{2067 - 1137} = \frac{0.65}{930} = 0.0007 \text{ g/ft (acceleration gradient)}$$

$$\frac{115 - 60}{2067 - 1137} = \frac{55}{930} = 0.05914 \text{ cm/sec/ft (velocity gradient)}$$

The difference in elevation between the Pacoima strong-motion recorder site (2067 ft) and the lowest elevation (1692 ft) of bedrock under the dam is about 375 ft. Therefore, the input bedrock motion for the Pacoima Dam estimated from the above acceleration gradient could be inferred to be about 0.995 g. This is about 20 percent less than 1.25 g, the highest horizontal peak acceleration recorded. Trifunac (1973) proposed that 10-20 percent less than 1.25 g would be the right order of input bedrock motion for the Pacoima Dam. Since the Pacoima accelerograph is located on the bedrock, the difference is caused by the effect of topographic irregularities (elevation) in bedrock. Reimer et al. (1973) found 0.40 g for the base rock by the finite element method. However, their model considered the Pacoima damsite only, while estimates of the actual ground motion should consider Kagel Mountain as a whole. Seed (1973) suggested 0.76 g for the bedrock motion of Pacoima Dam.

* R. P. Maley, U. S. Geological Survey, Personal communication, 1974.

the Hollywood Storage Building site and Pasadena Millikan Library site recorded 0.22 g, a measurement that seems to be amplified by 1000 ft of alluvium. On the southernmost part of the velocity map, the contour line of 10 cm/sec was pushed back twice the average interval, indicating that the particle velocity of long-period surface waves in the far field was amplified on the thick alluvium deposit as compared to the crystalline rock.

CONCLUSIONS

The conclusions of this study on the San Fernando Earthquake are outlined as follows:

- a. Contour maps of the observed peak acceleration and peak velocity were found in correlation with the topographic feature of the San Gabriel Mountain range. It was found approximately that 0.1 g is equivalent to 10 cm/sec within the strong shaking area which is defined within the contours of 0.2 g or 20 cm/sec on the peak velocity map.
- b. A linear relationship between the ground motion and elevation was found within the San Fernando Valley region, possibly due to the monotonic decrease in elevation from the top of Kagel Mountain toward the southern rim of the San Fernando Valley. However, this decrease was not generalized to the other direction or area.
- c. Ground motion-elevation gradients between the two strong-motion instrument sites of Pacoima Dam and Universal Sheraton Hotel were found to be 0.00071 g/ft, 0.06636 cm/sec/ft, and 0.02143 cm/ft, for acceleration, velocity, and displacement, respectively.
- d. Ground motions at the crest of Kagel Mountain calculated by the above gradients were found to be 2.29 g, 212.55 cm/sec, and 69.2 cm, respectively, values which are supported by the aftershock measurement.
- e. The base rock motions computed for the Pacoima Dam, Lopez Dam, and Lower San Fernando Dam are 0.99 g, 90.11 cm/sec, and 29.7 cm; 0.65 g, 57.93 cm/sec, and 19.3 cm; and 0.60 g, 53.3 cm/sec, and 17.7 cm, respectively.
- f. Comparisons have been made of the acceleration values recorded on the rock and the alluvium in the area of the San Fernando Valley, and of the velocities and displacements integrated from the recorded accelerations. Accelerations recorded on the rock were higher than those recorded on the alluvium; displacements, on the other hand, were greater in the alluvium than in the rock. The velocities determined for the alluvium did not follow a definite trend, with some velocities higher and some lower.

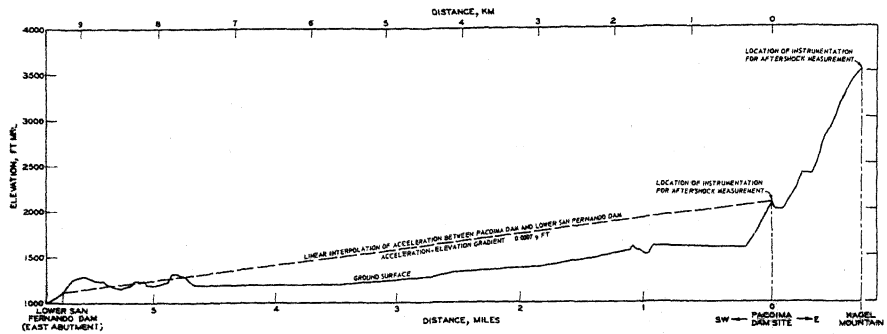


Fig. 3. Topographic profile of Lower San Fernando Dam-Pacoima Dam-Kagel Mountain Path

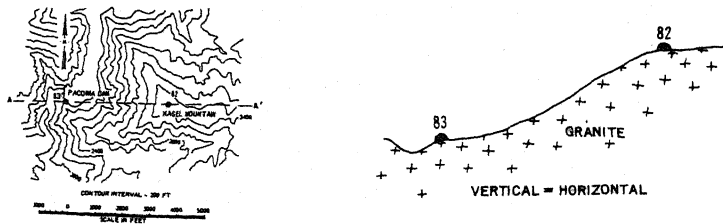


Fig. 4. Topography, geology, and station locations, Kagel Mountain (Courtesy of Seismological Society of America)

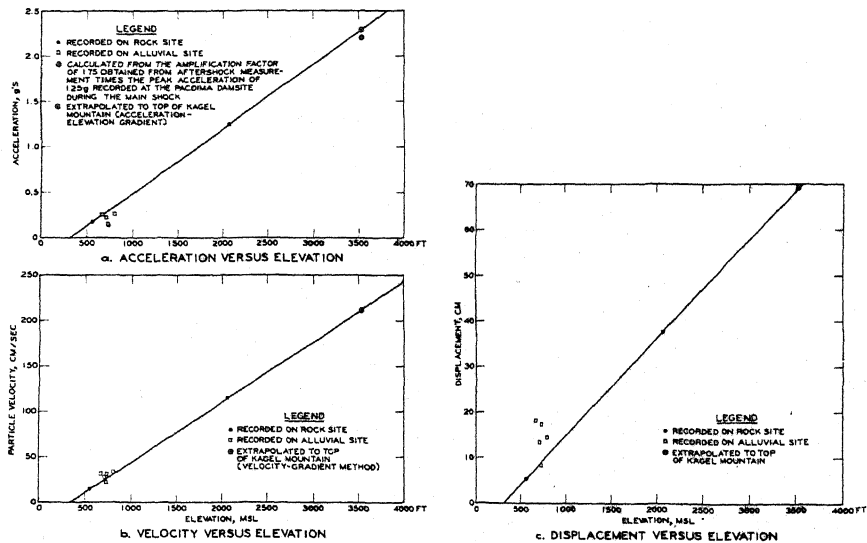


Fig. 5. Acceleration, velocity, and displacement versus elevation and site condition in the San Fernando Valley during the San Fernando Earthquake