COMMENTS ON EARTHQUAKE TRANSMISSION FROM BASEMENT ROCK TO SURFACE

by

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SYNOPSIS

For earthquakes in certain locations, as for example the soft volcanic clays of Mexico City, peak spectral responses occur at nearly the same frequency for various directions of motion. However, recent studies of response spectra for different U.S. earthquakes indicate that the peaks and valleys of the response spectra do not necessarily occur at the same frequency for the various directions of motion for a particular earthquake, nor for the same direction for different earthquakes at the same location. The relationships appear to be essentially random in nature. A brief discussion of the observations arising from these studies is presented.

OBSERVATIONS

Local site properties and geological conditions have a significant influence on the response arising from seismic excitation. For example, in Mexico City(1,2) it has been noted that the peak responses occur at nearly the same period (2.5 sec -- See Figs. 1 and 2) for both horizontal directions of motion, which is consistent with the assumption that shear waves are propagated vertically from below to the surface in the normal manner assumed for calculation of one-dimensional shear wave transmission in soil. Similar observations have been obtained for different locations in several earthquakes in Mexico City, and the frequency of the peak spectral response is consistent with the computed fundamental period of vibration of the lake bed on which Mexico City rests. Indeed, it can be noted in Figs. 1 and 2 that secondary peaks occur at frequencies corresponding to the next two harmonics of the fundamental frequency.

In contrast, during the 1971 San Fernando, California Earthquake, records from several accelerographs located on the California Institute of Technology campus indicated a lack of correlation of amplitude and frequency for peaks in the response spectra computed from data obtained by instruments located on essentially the same site conditions but some small distance apart.(3)

Although the usual one-dimensional approximation is probably the best practical calculational tool at present, it is our belief that soil amplification effects may not be given accurately enough by it.(4) Other effects may be so important that they control the near surface motions in

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other than very soft material.

The examination of the response spectra of some 14 earthquakes made recently by us indicates in general a lack of correlation between the frequencies at which the peaks and valleys occur at the same site in the three directions, i.e. the two horizontal and the vertical directions.

DISCUSSION

The response spectra for low amounts of damping indicate by its peaks and valleys those frequencies which correspond to natural frequencies of the medium itself. If the amplification were large, one would expect that the input motion of the rock, in general, would not have its pattern of frequencies reproduced very closely in the motion near the surface in alluvium. It would be reasonable to expect that the natural frequencies of the soil strata would generate amplifications that were large at the same frequencies in both horizontal directions with a clearly predominant response frequency at the natural frequency of the site. However, one would not expect any correlation between vertical and horizontal responses.

As an illustration, in Fig. 3 are shown the three spectra for the components for the 1971 San Fernando, California Earthquake, Holiday Inn, First Floor. It will be noted in these spectra that at a frequency of about 0.35 hertz, there is a pronounced dip in one of the horizontal response spectra whereas the other one reaches its maximum at that point; a similar comment applies at 1.6 hertz. There is no correlation between the spectra in the horizontal directions, nor between those for the vertical and either horizontal direction.

The foregoing example was for a particular earthquake at a site. Similar evidence also is available for three relatively strong motion different earthquakes at the same site. In Figs. 4, 5, and 6, sets of horizontal and vertical response spectra for three different earthquakes recorded at the El Centro site are plotted. It will be noted that the relative position of peaks and valleys occur almost at random for each component of the motion, including vertical motion.

The observations cited are typical. Other data for some 20 different earthquakes, reported(5) in the form of both response spectra and Fourier amplitude spectra, lead to the same general conclusions that there is little correlation between the frequencies of the peak responses in the two horizontal directions, nor between the frequencies of the peak responses in the vertical and either horizontal direction. The absence of the former correlation can be interpreted as an indication that the one-dimensional shear wave propagation model for earthquake horizontal motions is inadequate.

The results obtained by calculation with such a model must be used with caution, supplemented by actual observed data, where available, and interpreted with judgment.

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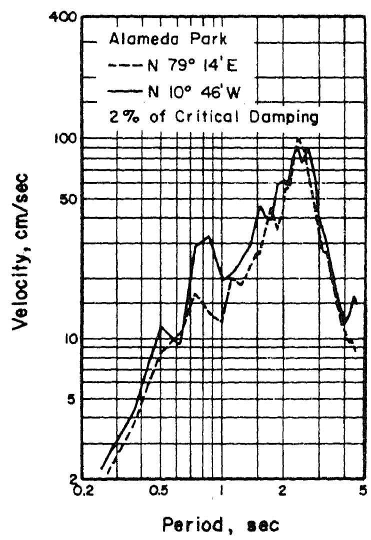

FIG. 1 RESPONSE SPECTRA FOR MEXICAN EARTHQUAKE OF 11 MAY, 1962 (AFTER HERRERA, et. al.)

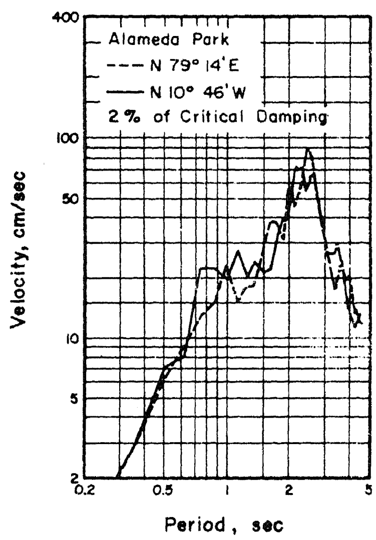

FIG. 2 RESPONSE SPECTRA FOR MEXICAN EARTHQUAKE OF 19 MAY, 1962 (AFTER HERRERA, et. al.)

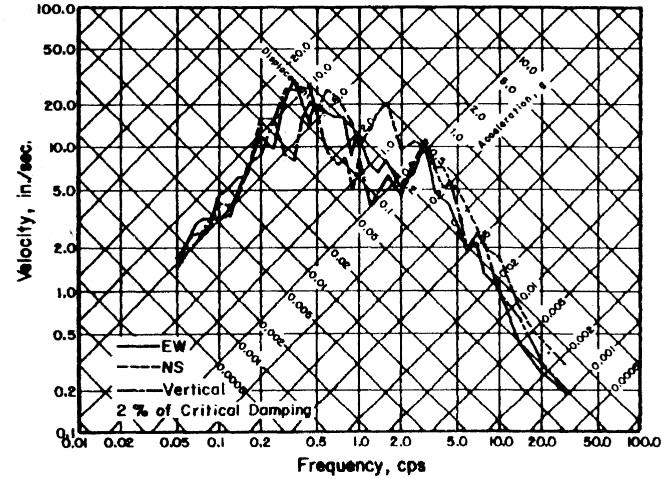

FIG. 3 RESPONSE SPECTRA FOR SAN FERNANDO, CALIFORNIA EARTHQUAKE OF 9 FEBRUARY, 1971 - HOLIDAY INN, FIRST FLOOR

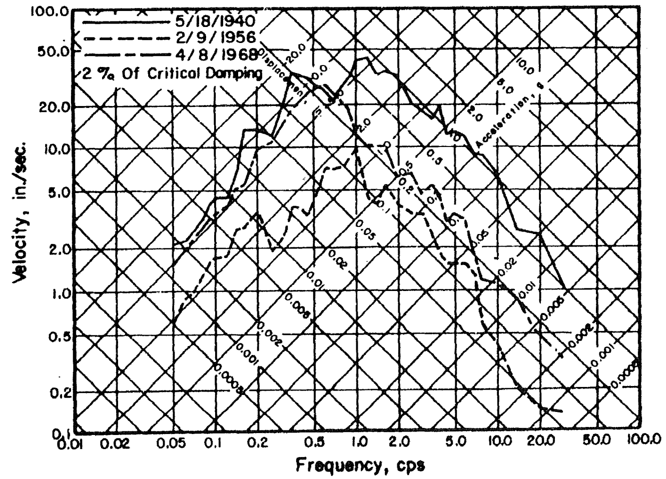

FIG. 4 RESPONSE SPECTRA FOR EL CENTRO, CALIFORNIA — N-S COMPONENT FOR THREE DIFFERENT EARTHQUAKES

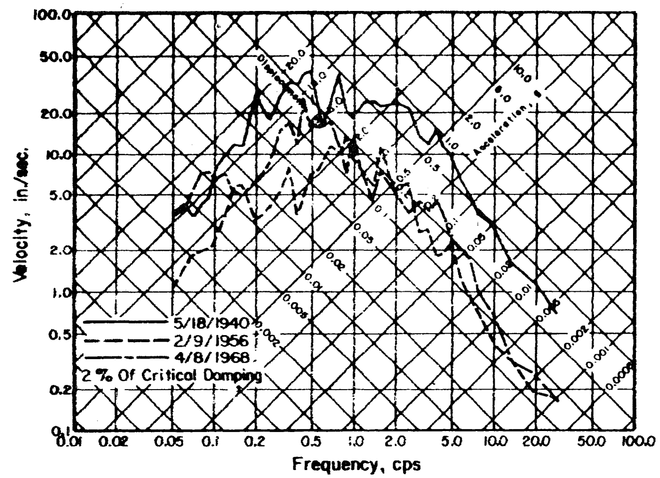

FIG. 5 RESPONSE SPECTRA FOR EL CENTRO, CALIFORNIA — E-W COMPONENT FOR THREE DIFFERENT EARTHQUAKES

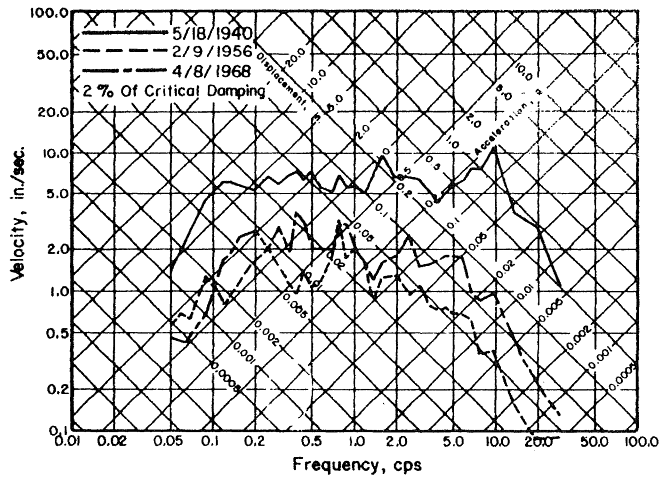

FIG. 6 RESPONSE SPECTRA FOR EL CENTRO, CALIFORNIA-VERTICAL COMPONENT FOR THREE DIFFERENT EARTHQUAKES