THE INFLUENCE OF SOURCE PARAMETERS ON STRONG GROUND MOTION

by

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SYNOPSIS

Near field ground motions are calculated from a rapidly propagating vertical fault located in a homogeneous isotropic visco-elastic half space. A model of the source is constructed by retaining the essential kinematic features of the faulting process. Synthetic displacements and velocities are calculated by means of an efficient computer program. The influence of the rupture speed on the nature of the ground motion is investigated by varying the speed between the Rayleigh and the P wave speed of the medium. The differences in the nature of the motions produced by strike-slip and dip-slip faultings of equal seismic moments are studied. The relative magnitudes of the body waves and the surface waves in near field motions are compared. An effort is made to determine the length of the fault segment which produces the significant strong motion at a given location near a very long fault.

INTRODUCTION

The problem of the calculation of near field ground motion from shallow earthquakes has received much attention in recent years. The major goal in these studies has been the prediction of displacement, velocity and acceleration of the ground at a given location under assumed motion at the source.

In strong ground motion calculations, reasonable models of the earthquake source and the earth in the vicinity of the source must be constructed. Since the source has a strong influence on the near field motion, an accurate model of the source must necessarily be employed. Unfortunately, the mechanics of the earthquake source is not very well understood at the present time. It has been established, however, that almost all shallow earthquakes are caused by propagating ruptures along preexisting fault surfaces. Thus, a reasonable model of the source must, at least, be consistent with the theories of fracture. The model of the ground should, in principle, be a multilayered medium containing all the discontinuities in the physical properties. Since the free surface represents the strongest discontinuity in the earth's crust, a uniform half space may serve as a reasonable exploratory model of the ground. This should account for some of the major features (e.g. reflection, surface waves) expected to be present in the ground motion. In addition, the method of analysis must be flexible enough so that the significant results of current research on fault dynamics (such as the influence of ambient

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tectonic stress, friction, etc.) may be included, as they become available. It should also be adaptable to multilayered media.

All the models considered in the literature so far are over-simplified in that they ignore one or more of the essential ingredients described above, (see, e.g. [1] and [2] for a review of the earlier work). Some of these authors were able to obtain reasonable agreement between theoretically computed ground displacements and the displacements obtained by integrating the near field accelerations recorded in two earthquakes (Parkfield 1966, San Fernando 1971). Since the inversion procedure involved in the comparison is highly non-unique, it is difficult to determine the effectiveness of their techniques for prediction purposes.

In a recent paper [3] an alternative theoretical basis was presented by retaining all of the ingredients discussed above. The technique was applied to calculate the ground displacements in the vicinity of the fault in a simplified model of the 1966 Parkfield (California) earthquake. The agreement between the predicted and recorded motion was quite good. The results presented in the present paper are based on the theory developed in [3] and are of general interest in engineering seismology.

RESULTS

We consider a vertical dip-slip or strike-slip fault of relatively small width and shallow depth - buried in a uniform half space (Fig. 1). The rupture is assumed to begin at the hypocenter H, spread rapidly through the width b and propagate unilaterally (to the right) along the rectangular fault surface. The slip across the rupture surface is assumed to vary nonuniformly between a zero value at the edge and a maximum value at the center. The maximum static offset in either dip-slip or strike-slip case is D at the center of the rectangle (a x b) swept by the rupture surface. In the numerical calculations the source parameters were assigned the values, $d = 3$ km., $a = 30$ km., $b = 6$ km., $D = 3$ m. The medium was assumed to be homogeneous and isotropic with the properties $c_1 = \sqrt{3}c_2 = 5.6$ km/sec., $c_r = 2.9$ km/sec., where c_1, c_2, c_r are the velocities of the P, S and Rayleigh waves respectively. The damping properties of the medium were realized by assigning an imaginary part to the velocities with the attenuation coefficients $Q_p = Q_s = 50$. The recording station was assumed to be located at a point halfway across the fault surface at a distance equal to the fault length.

The influence of the variation of the rupture speed c ($c_r < c < c_1$) on the calculated displacement and velocity time histories are shown in Figures 2 and 3 respectively. The DC components of the ground motion were removed by a low frequency cut-off of .07 Hz. A high frequency cut-off of 3 Hz was used for the displacements and 6 Hz for the velocities. No appreciable energy was present beyond these frequencies. The time histories were shifted in time by assuming that the motion at the station was initiated by the P wave arrival. Only the displacement components perpendicular to the fault surface are shown in the figures, the effect is similar in the other components. The major feature in these curves is the growth of the peak displacements and velocities with increasing rupture speed, especially in the dip-slip case. It should also be noted that in the strike-slip case, the peak velocity shows no significant increase except when the rupture speed is very close to the P wave speed.

In Figures 4a and 4b, the amplitudes of the body wave and Rayleigh wave displacement spectra are compared for a fixed rupture velocity of 2.9 km/sec. The notable aspect of these curves is the predominance of body wave motion in the strike-slip case and Rayleigh wave motion in the dip-slip case. This suggests that surface waves would be of considerable interest in earthquakes stemming from a rupture surface with a strong dip component. It should also be noted that the vertical displacement is of the same order for both strike-slip and dip-slip. One other somewhat unexpected feature is the relative peak in the parallel strike component at the higher frequencies. The fact that it appears in the 1 Hz region may have some bearing on the previous oscillatory behavior in the same component's time history (Figs. 2, 3).

The possibility of simplifying near-field ground motion calculations was examined by computing displacement spectra from the strike-slip case by using only portions of the rupture surface, comparing these to the results obtained using the entire fault surface. The hypothetical recording station was positioned half way along the fault, at a distance of a/2 from the fault surface and contributions from symmetric portions of the fault surface with respect to the recording station were calculated. It is to be noted that the important features of the motion begin to emerge for the case where the fault segment length is equal to the station distance. The most pronounced change is observed in the perpendicular and vertical components, and can be attributed to the proportionately smaller contribution of the tangential dislocation for the shorter fault segments. The effect of successively larger fault segments appears as attenuation of the higher frequencies, as might be expected from the longer period motion generated from increasing fault size. The results for the nearer station located one quarter fault length in perpendicular distance were very similar (not shown). Only in this case the essential ground motion was established when the portion of the fault used was equivalent to four station distances. This implies that such calculations depend strongly on location of the observation point. Even though a simplification can be expec expected with a careful choice of fault segment, there seems to be no simple formula for this procedure.

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ACKNOWLEDGMENT

This research was supported by the National Science Foundation (RANN) under Grant GI 44076.

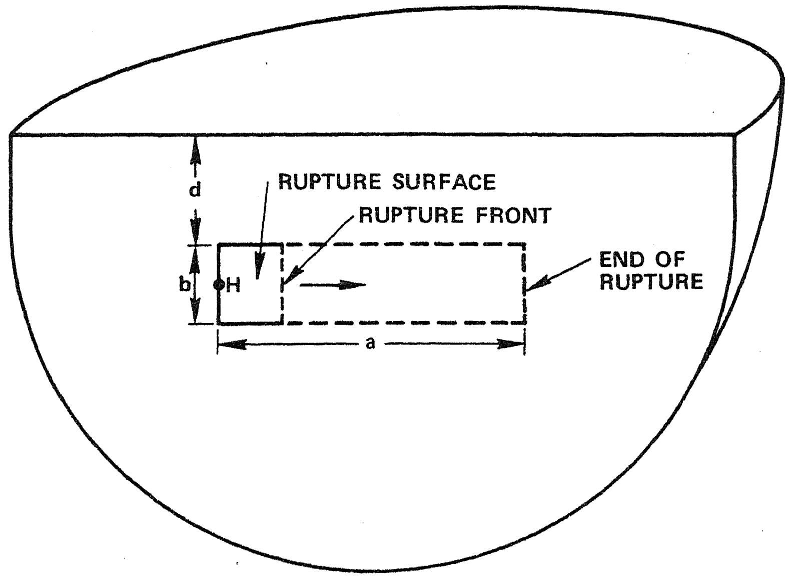

Figure 1. The Geometry of the Problem.

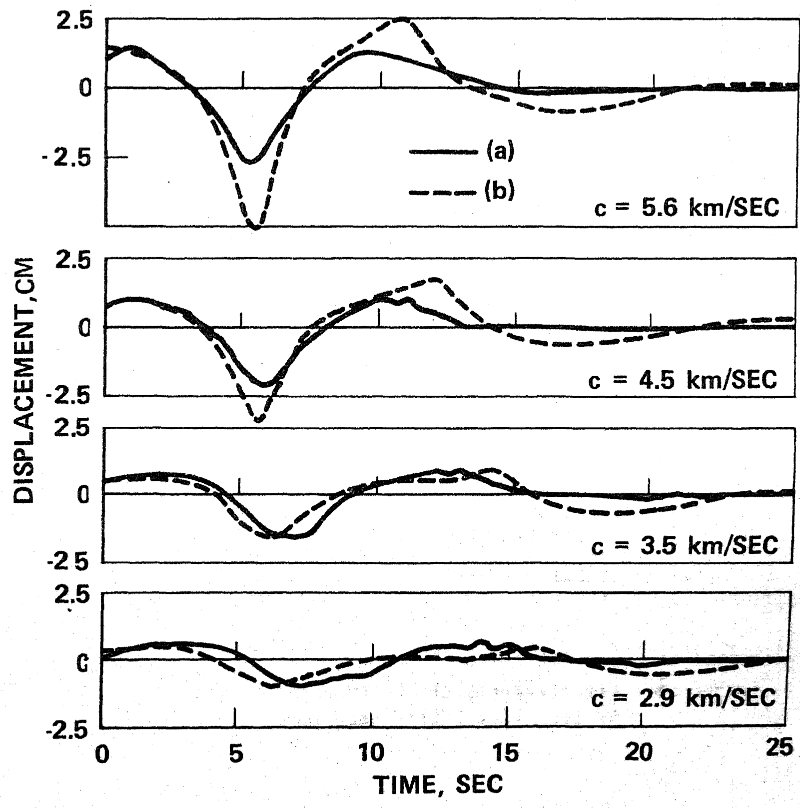

Figure 2. Horizontal Displacement Components Normal to Fault Plane: (a) Strike-slip Faulting. (b) Dip-slip Faulting.

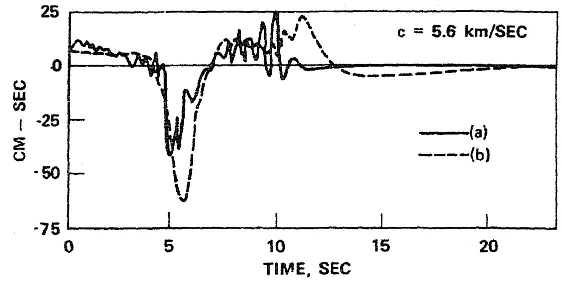

Figure 3. Same as in Figure 2 for Velocities.

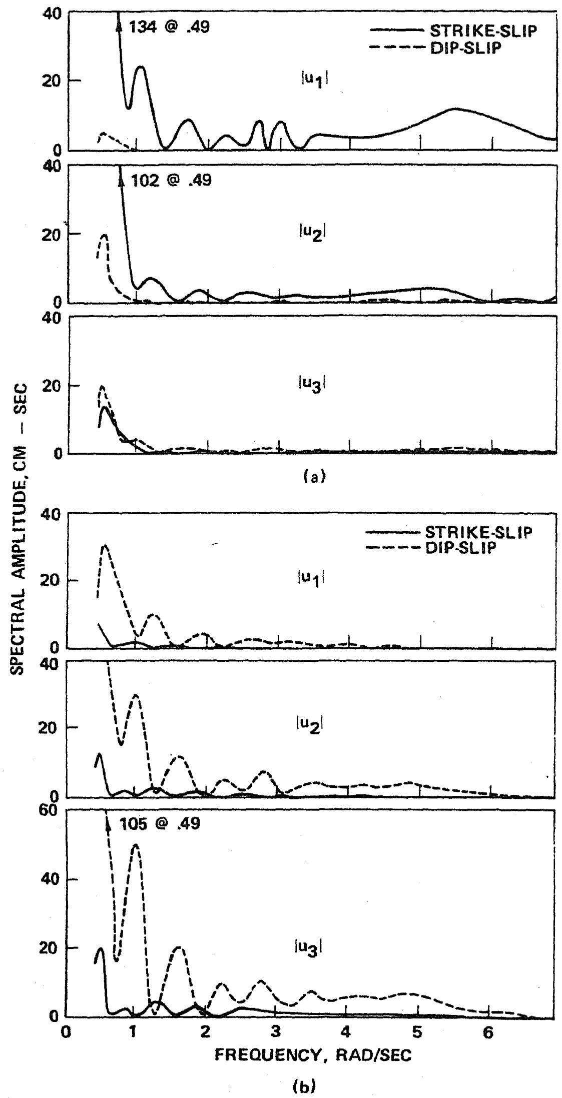

Figure 4. Displacement Spectra for Strike and Dip-slips: (a) Body Waves, (b) Rayleigh Waves.

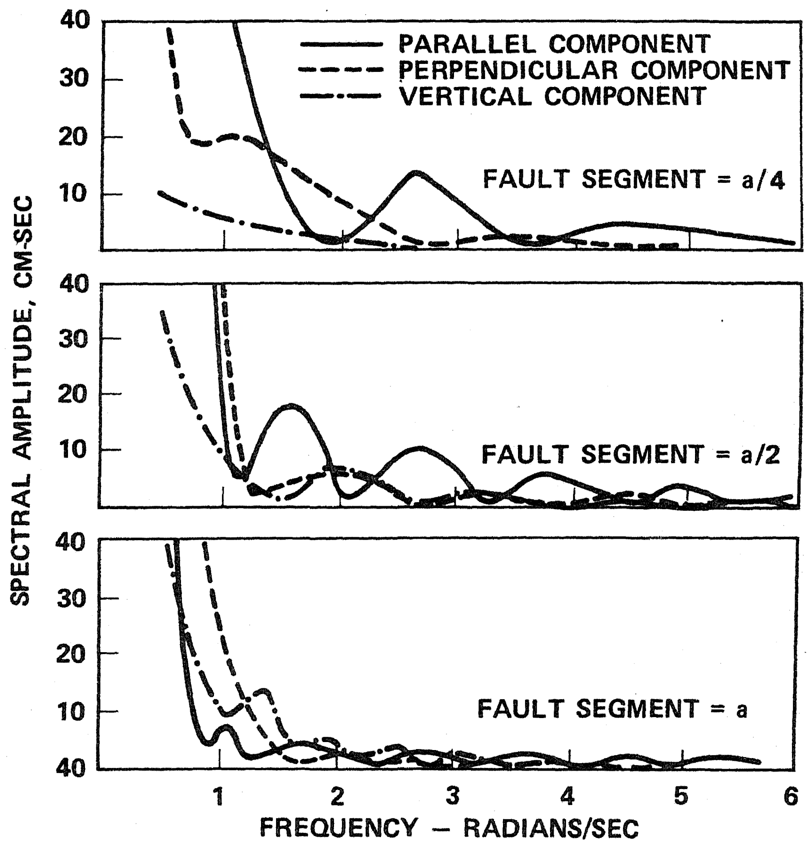

Figure 5. Displacement Spectra for Strike-Slip Faulting Calculated from Fault Segments.