BCGRE

PROCEEDINGS

FOURTH NATIONAL MEETING

OF THE

UNIVERSITIES COUNCIL FOR EARTHQUAKE ENGINEERING RESEARCH

June 28-29, 1976

The University of British Columbia

Sponsored by

National Science Foundation

Report No. UCEER-4

UCEER

Universities Council for
Earthquake Engineering Research

California Institute of Technology
Mail Code 104-44 Pasadena, California 91125

PROC. 4th NATIONAL MEETING UNIVERSITIES
COUNCIL FOR EARTHQUAKE ENGINEERING
RESEARCH, JUNE 28-29, 1976, U. BRITISH
COLUMBIA

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Several research projects concerned with the understanding and prediction of ground motions are being conducted with industry and National Science Foundation support: prediction of the surface wave contribution to ground motion at offshore drilling platform sites, study of ground motions from the 1906 San Francisco and 1952 Kern County earthquakes, and the development of a combined statistical-deterministic procedure to estimate ground motions close to faults.

Surface waves. Several factors make the specification of design motions for offshore drilling platforms a nonstandard problem: resonant periods of the structures are in the range of 2 to 6 sec, the nearest large fault may be 100 km or more from the site, and the ocean floor often has a thick (several tens of meters) cover of low rigidity sediments. No data are available for ground motions in this situation, and therefore we have used the computer to generate synthetic seismograms. Inspection of existing strong motion data suggests that surface waves dominate the motion in the period range of interest. This is borne out by the theoretical seismograms. The details of the motion are governed by a complicated interaction of several modes whose relative importance is controlled by frequency dependent resonance and attenuation. Although generalizations are difficult to make, we have attempted a few: phase differences across the horizontal extent of the structures (50-100 m across) should be small for periods greater than about 2 sec. The near-surface sediments have little effect on motions beyond 2-3 sec unless significant nonlinear response occurs, in which case motions with periods up to about 5 sec will be strongly influenced by the sediments. The surface waves and body waves have a similar dependence of motion with depth, suggesting that a body wave soil column analysis may adequately account for the influence of the near-surface sedimentary layers, provided that the input motion contains appropriate energy in the 2-6 sec period range.

Strong motion records. Strong motion studies are limited by the lack of data from large earthquakes, especially for recording sites close to faults. For this reason computer modeling can be a useful guide to the specification of design motions. It then becomes important to test these models against existing strong motion recordings. Here we discuss two sets of data which we are currently working on.

It is not generally recognized that the 1906 San Francisco earthquake was recorded at Mt. Hamilton, within, 35 km of the fault (fig. 1). The record went offscale after the first half cycle of the S-wave arrivals and returned to scale after about 50 sec, but enough information exists both to constrain the epicenter of the event and to provide some data against which theoretical predictions of ground motion can be checked. The recordings are comparable to those from doubly integrated accelerograms: Fig. 2 shows the 1906 data (traces #1 and #2) compared with data from other strong motion recordings. Although no comparison of amplitudes can be made, the overall duration of the records is comparable. The theoretical body waves from a propagating rupture are shown in trace #3. Not shown are the theoretical surface waves, but these have amplitudes up to 9 times larger than the body waves and also give motions after 50 sec. which are comparable to the observed motions. Because of Doppler-like effects, the absolute amplitudes are sensitive to the speed of rupture propagation; reducing the rupture velocity from 3 km/sec to 2 km/sec reduces the peak surface wave motion by a factor of 5.

The 1952 Kern County earthquake is the largest (M = 7.7) California event for which a significant amount of data is available. As part of a comprehensive study of this data we have studied accelerograms recorded at Santa Barbara, Taft, and Pasadena. The velocity records all show a simple S pulse followed by a complex series of arrivals. Simple time considerations show that the first S pulse can only represent a small part of the overall rupture. Information on the rest of the rupture is contained in the jumble of arrivals following the first pulse. We are interested in separating the effects of geology from the complications due to erratic propagation and these records should provide important data for this. Figures 3 and 4 show a simple example of the effects of slightly noncoherent rupture. Fig. 3 is a model of the rupture surface. In one case smooth propagation outward from the focus was assumed and in the other, the smooth propagation was approximated by a series of fault segments properly lagged in time. The waves at the Pasadena station are remarkable different in the two cases, with the more complex fault giving a record which is more similar to the recorded motion (Fig. 4).

Statistical-deterministic predictions of motion. The example above demonstrated the importance of slightly incoherent rupture. Since it seems unlikely that extended ruptures propagate smoothly, the radiation produced by the "chatter" in propagation will be an important part of the near fault ground motion, especially at higher frequencies. (We expect the acceleration traces to be more sensitive to this effect than the displacement traces.) The study of this effect is in the initial stages. We have constructed various theoretical waveforms for equivalent point sources and compared them favorably with accelerograms from a small earthquake near Bear Valley, California. Our future work will involve the analysis of records from extended ruptures such as the Kern County earthquake.

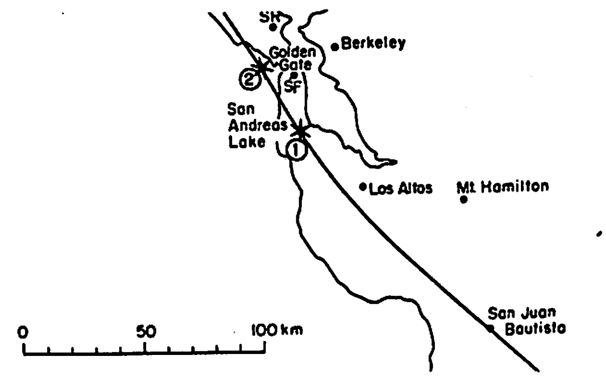

Fig.1.Dark line is the San Andreas fault.The 1906 epicenter was close to point 2.

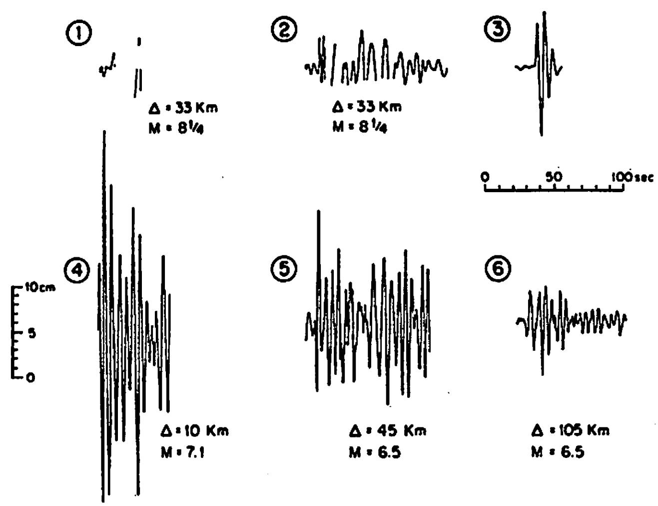

Fig.2.Comparison of 1906 and more recent data.

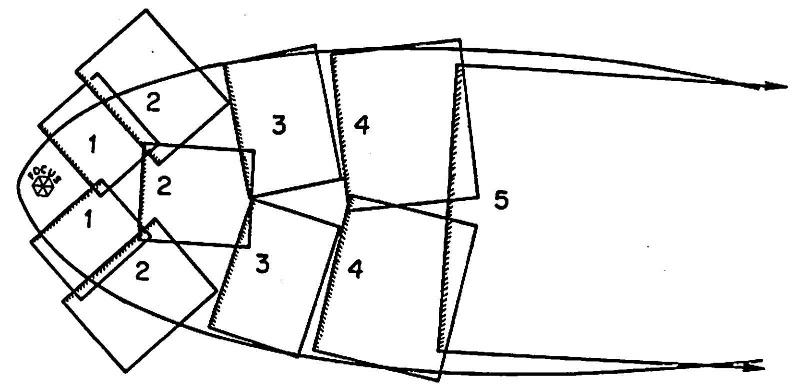

Fig.3.Schematic of 1952 Kern County earthquake rupture surface.Rupture started at the left side.

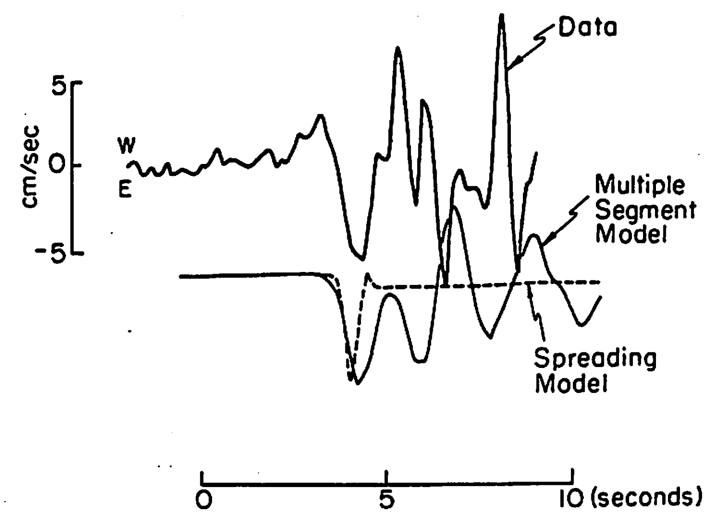

Fig.4.Comparison of waveforms for the Pasadena recording of the Kern County earthquake.