Bulletin of the Seismological Society of America, Vol. 88, No. 6, pp. 1392–1401, December 1998

Stochastic Finite-Fault Modeling of Ground Motions from the 1994 Northridge, California, Earthquake. I. Validation on Rock Sites

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Abstract The stochastic method of simulating ground motions from finite faults is validated against strong-motion data from the *M* 6.7 1994 Northridge, California, earthquake. The finite-fault plane is subdivided into elements, each element is assigned a stochastic ω^2 spectrum, and the delayed contributions from all subfaults are summed in the time domain. Simulated horizontal acceleration time histories and Fourier spectra at 28 rock sites are compared with observations. We first perform simulations using the slip distribution on the causative fault derived from strong-motion, teleseismic, GPS, and leveling data (Wald *et al.,* 1996). We then test the performance of the method using quasi-random distributions of slip and alternative hypocenter locations; this is important because the rupture initiation point and slip distribution are in general not known for future earthquakes.

The model bias is calculated as the ratio of the simulated to the observed spectrum in the frequency band of 0.1 to 12.5 Hz, averaged over a suite of rock sites. The mean bias is within the 95% confidence limits of unity, showing that the model provides an accurate prediction of the spectral content of ground motions on average. The maximum excursion of the model bias from the unity value, when averaged over all 28 rock stations, is a factor of approximately 1.6; at most frequencies, it is below a factor of 1.4.

Interestingly, the spectral bias and the standard deviation of the stochastic simulations do not depend on whether the fault slip distribution and hypocenter location are based on data or are randomly generated. This suggests that these parameters do not affect the accuracy of predicting the average characteristics of ground motion, or they may have their predominant effect in the frequency range below about 0.1 Hz (below the range of this study). The implication is that deterministic slip models are not necessary to produce reasonably accurate simulations of the spectral content of strong ground motions. This is fortunate, because such models are not available for forecasting motions from future earthquakes. However, the directivity effects controlled by the hypocenter location are important in determining peak ground acceleration at individual sites.

Although the method is unbiased when averaged over all rock sites, the simulations at individual sites can have significant errors (generally a factor of 2 to 3), which are also frequency dependent. Factors such as local geology, site topography, or basin-propagation effects can profoundly affect the recordings at individual stations. To generate more accurate site-specific predictions, empirical responses at each site could be established.

Introduction

Stochastic modeling of earthquake radiation is widely used in the prediction of strong ground motions (Hanks and McGuire, 1981; Boore, 1983, 1986, 1996; Boore and Atkinson, 1987; Chin and Aki, 1991; Atkinson and Boore, 1997; Toro *et al.,* 1997; Atkinson and Beresnev, 1998). The method assumes that high-frequency earthquake motions can be represented as band-limited Gaussian noise having an ω^2 mean spectrum. A limitation of the model, as it is