Ground Motion Simulation and Prediction

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Abstract

To date, most ground motion prediction models have been based on regression analysis of recorded strong ground motion. The simplest versions of these models make the simplifying assumptions that all of the complexities of the earthquake source can be represented by an earthquake magnitude, that all of the complexities of seismic wave propagation from the source to the vicinity of the recording station can be represented by the source-to-site distance, and that all of the complexities of site response can be represented by a simple site category. In recent years, there have been major improvements in these models, due to the systematic compilation of metadata describing the earthquake source and recording site characteristics, and to the rapid increase in the volume of recorded strong ground motions. The range of source and path parameters contained in these models has also increased to include rupture directivity, hanging wall and basin effects. These models typically have a large amount of random variation in ground motion level for a given magnitude, distance and site condition. It has been recognized that most of this variability, which is present even between different recordings at equal distances from the same earthquake, is due to aspects of the earthquake source, including the geometrical relationship between the earthquake source and the recording site, that are not included in the ground motion model. The evolution of rupture on a finite fault from the hypocenter and the propagation of the seismic waves from the various parts of the fault to the various recording sites give rise to large variations in ground motion characteristics from site to site due to rupture directivity effects and other geometrical effects. This is true even without taking account of the additional variations caused by seismic wave propagation effects related to lateral variations in crustal structure, the presence of basins, and the complex near-surface geology beneath the recording site. In order to reduce the large degree of uncertainty in the prediction of ground motion levels using these models, broadband simulation procedures can be used to take account of the particular characteristics of the earthquake source, crustal structure, basin structure and near surface geology that pertain in the region of interest. These simulations are themselves subject to uncertainty in the specification of models that represent the earthquake source, crustal structure, basins, and site. However, at least for long ground motion periods, where simulation techniques are able to match the recorded waveforms of strong ground motion, these simulation procedures provide more reliable estimates of ground motion levels than those provided by models based on the regression of recorded strong motion data. Simulations of ground motion wave fields throughout urban regions such as Los Angeles for specific scenario earthquakes have been used as inputs into the nonlinear time domain analysis of the response of buildings throughout the region to gain insight into the particular features of strong ground motions that cause damage to buildings. In the SCEC CyberShake Project, the simulation approach has been tested against the regression equation approach within the framework of probabilistic seismic hazard analysis. This has involved the simulation of 100,000 seismograms (generated from 12,700 earthquake sources) at each of several sites within the Los Angeles basin. At some sites, there is close agreement between the seismic hazard curves predicted by the two approaches, but at others, rupture directivity and basin effects cause the simulated motions to be larger at long periods.

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