Paper No. 2037. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3
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GROUND MOTION SIMULATION IN 3D USING AN ADAPTIVE GRID

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ABSTRACT

We have used a new 3D finite difference method based on adaptive gridding to simulate low-frequency ground motion from large earthquakes in the Los Angeles region. The adaptive gridding strategy greatly increases the bandwidth over which such simulations are feasible.

The simulation of earthquake ground motion in three-dimensional, sediment-filled basins, such as the Los Angeles Basin and the San Fernando Valley, presents major technical and computational challenges. One requirement for such simulations is a seismic velocity model whose spatial resolution is comparable to the minimum S wavelength being modeled. To simulate 1 Hz ground motion, for example, velocity model features of the order of several hundred meters in scale may be important. For the Los Angeles Basin, this level of resolution is not available from regional-scale seismic travel-time studies alone. However, there exists a great deal of information about the age and depth of the sediments in the Los Angeles basin from oil exploration activities and other studies. Furthermore, empirical studies have established approximate relationships between sediment age, maximum depth of burial, and seismic velocity. We have constructed a seismic velocity model from the geologic information about depth to crystalline basement, depths to sedimentary horizons, uplift of sediments, and surface geology, using the velocity-depth-age function of Faust. The resulting seismic velocity model is consistent with earthquake travel time data. In addition, the model correctly determines the timing and amplitude of late arriving waves in earthquake ground motion simulations.

A second requirement for such simulations is a computational method capable of simulating elastic wave propagation in a 3D medium in which the ratio of highest to lowest seismic wave velocity is very large. For example, P wave velocities in excess of 6500 m/s characterize the basement rock underlying the Los Angeles Basin, while S velocities of under 300 m/s are present in the upper few 10's of meters of some soil deposits. Finite element and finite difference methods are both capable of modeling 3D structure. However, each requires that the structure be discretized at a scale of several node points per S wavelength corresponding to the highest frequency to be modeled. The required node spacing is thus approximately proportional to local S wave velocity. Since computing time and storage requirements each grow with the number of nodes, large computational advantages accrue if the node spacing can be made to vary over the grid, adapting to the local seismic wave velocities. While variable node spacing is conventional in finite element methods, finite difference methods used in most previous seismological modeling have used uniform grids. We have developed a finite difference method in which node spacing adapts to local seismic wave velocities, permitting low-seismic-velocity volumes to be more finely discretized than are high-seismic-velocity volumes. This is accomplished by recursively embedding finer grids inside coarser grids. Each embedded grid has the same uniform structure as its parent. Thus, the overall computations retain the simple structure of uniform-grid finite difference computations, and therefore remain readily adaptable to parallel processing. In a region of high velocity contrasts such as the L. A. Basin, this stratagem greatly increases the computational efficiency and makes feasible computations which would otherwise be out of reach.

We have completed simulations of the Northridge Earthquake mainshock and several aftershocks to investigate the sensitivity of ground motion predictions to the rupture model and source location and mechanism. The simulations have an upper cutoff frequency of 0.8 Hz. In these simulations, maximum low-frequency horizontal velocity in the San Fernando Valley is correlated with depth to basement. In most cases, the predicted maxima are concentrated within the 10,000 ft. depth-to-basement contour.

KEYWORDS

Finite difference; adaptive grid; sedimentary basin; strong motion simulation; Northridge Earthquake