Prediction and Geographical Information System (GIS) Mapping of Ground Motions and Site Response in Charleston, SC and two Neighboring Counties: First Phase Development of a GIS for Seismic Hazard Evaluation

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INVESTIGATIONS UNDERTAKEN

The study area includes Charleston County and parts of Berkeley and Dorchester Counties, South Carolina. The study uses existing geotechnical data and ground motion modeling procedures for eastern North American earthquakes to quantify site response characteristics on a scale useful for the engineering community and policy planners. The results of the study will be in the form of GIS coverages showing predicted levels of peak ground acceleration and response spectral ordinates for scenario earthquakes, as well as site amplification factors as a function of frequency for several levels of input ground motion.

RESULTS

Work to date has involved three aspects of the study: 1) the development of scenarios for the August 31, 1886 "Charleston" earthquake, 2) testing of stochastic finite fault modeling procedures for predicting ground motions including the effects of the geological conditions of the study area, and 3) collection of geotechnical data, in particular, shear wave velocity information.

Scenario Earthquakes

There exists an abundance of near surface geotechnical data for the study area that can be used in assessment of seismic hazard. In addition, there is a valuable historical record of the geotechnical behavior during the 1886 earthquake. However, the utility of the historical information is limited because the input bedrock ground motions in 1886 are uncertain, due to uncertainty concerning the size of the earthquake and nature of the rupture process. One of the scenario shocks to be used in this study will be a repeat of the 1886 event. Two alternative representations of the 1886 rupture process are indicated in Figures 1 and2. These alternatives involve 1) mostly right lateral

strike-slip motion on a SSW striking, vertical or steeply NW dipping fault(Figure 1). The other alternative (Figure 2) is based on the hypothesis of slip on two faults: strike-slip motion on the SSW striking Woodstock fault, and oblique slip on the NW striking, SW dipping Ashley River fault. In both alternatives the moment magnitude assumed is 7.0. The moment is constrained by consideration of the spatial distribution of maximum intensity effects (primarily secondary ground failure observed and documented by E. Sloan following the 1886 shock), in conjunction with the correlation between fault length, width and moment by Wells and Coppersmith (Bull. Seism. Soc. Am., v. 84, 1994). The fault length and downdip width inFigure 1 is 49 x 17 km. The models for the Ashley River and Woodstock faults(Figure 2) involve equal moment release on both faults, both with length 24.5 km and width 17 km. Both bilateral and unilateral rupture scenarios are being examined for the single fault scenario and a variety of rupture scenarios are possible for the composite model involving the Ashley River and Woodstock faults.

Single fault rupture scenario: M=7.0, strike=N212E, dip=70, rake=168.

Figure 2. Combined fault rupture scenario, M=7.0. Woodstock fault, strike=N14E, dip=90, rake=180. Ashley River fault, strike=N137E, dip=60, rake=60.

Ground Motion Simulation

A finite fault source model is used to simulate ground motions for scenario earthquakes. The model combines theoretical crustal response for far field direct S waves, computed by the Thomson-Haskell method at low frequencies, with a stochastic Green function and average source radiation pattern at high frequency. The kinematics of the faulting process is simulated using a modification of the approach described by Zeng et al. (Geophy. Res. Lett., v. 21 no. 8, 1994). The theoretical Green function for a layered crust, used at low frequency, is replaced at high frequency (greater than approximately 1-3 Hz) by a stochastic function with decaying exponential time domain envelope shape. The faulting process and the theoretical crustal response controls the duration of the low frequency motion. At high frequency, the faulting duration and an empirical adjustment for multipathing and scattering controls the duration. The modeling procedure simulates the fault strike parallel and perpendicular components of horizontal motion.

Figure 3 shows simulations for the scenario indicated inFigure 1. InFigure 3, the top two traces show fault strike parallel and normal components of horizontal velocity for the single fault scenario, assuming bilateral rupture. The next two traces show, for comparison, the strike parallel and normal components for the 1989 M=6.9 Loma Prieta earthquake recorded at the Anderson dam site, at a distance of approximately 20 km from the surface projection of fault rupture. The source-receiver geometry and rupture models for the 1886 scenario and that of the 1989 Loma Prieta shock at the Anderson dam (downstream) site are very similar, and the modeling procedure appears to give good agreement for fault parallel ground velocity. The simulated motions of the 1886 shock include the propagation through approximately 700 m of Coastal Plain sediments, but do not include the site response due to the upper 10-75 meters of very low velocity (100-500 m/sec) near surface material present in the study area. The effects of anelastic attenuation in the Charleston crustal model (Q=800 at 1.0 Hz) and assumed kappa of 0.03 for the Coastal Plain section are apparent in the four lower traces of Figure 3, which

compare acceleration simulations with recordings at Anderson dam.

Figure 3. Comparison of velocity (top) and acceleration (bottom) simulations of the single fault (1886) scenario with recorded motions at Anderson dam (downstream) from the M=6.9, 1989 Loma Prieta earthquake. The simulations do not include the spatially variable effects of near surface beach and barrier island deposits in the study area.

Geotechnical Data:
More than 1000 SPT borings are available for the study, and are being collected and assembled into a GIS database. In addition, a number of insitu shear wave velocity measurements are available. Figure 4 shows an example shear wave velocity profile for the James Island area. The profile exhibits the most important characteristics of the study area: very low velocity shallow material overlying a stiff calcareous clayey-silt know as the "Cooper Marl". The depth to the marl is spatially variable: the impedance contrast can result in expected ground motion amplifications of 4-5 at frequencies of a few Hertz (Figure 5).
The geotechnical data are being assembled and will be combined with the scenario ground motion models to develop ground shaking and site response maps in GIS format.
Figure 4: Shear wave velocity profile from seismic cone penetrometer test, John's Island, SC, courtesy of Wright, Padgett, Christopher Engineering and Construction Services, Inc.

Figure 5. Modulus of (linear) transfer function for vertical incident SH motion, based on velocity profile shown in Figure 4.

NONTECHNICAL SUMMARY

The study uses existing geotechnical data and ground motion modeling procedures for eastern North American earthquakes to quantify site response characteristics on a scale useful for the engineering community and policy planners. The results of the study will be in the form of GIS coverages showing predicted levels of peak ground acceleration and response spectral ordinates for scenario earthquakes, as well as site amplification factors as a functions of frequency for several levels of input ground motion.

REPORTS PUBLISHED

Chapman, M. C. (2000). 1886 Ground Motion in Charleston, South Carolina: Scenarios Using Finite Rupture Models, (abst.), *Seismological Research Letters*, (in press).