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Site Effects (Parameters of Soil Response) Revealed from Surface Records of a Strong Earthquake: Example of the 1999 Chi-Chi, Taiwan, Earthquake

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The 1999 Chi-Chi, Taiwan, earthquake (M_w=7.6) was one of the strongest earthquakes in recent years recorded by a large number of strong-motion devices. Though only surface records are available, the obtained strong-motion database indicates the variety of ground responses in the near-fault zones. In this study, accelerograms of the Chi-Chi earthquake were simulated at soil sites, and models of soil behavior were constructed at thirty one soil sites located within ∼50 km from the fault. For reconstructing stresses and strains in the soil layers, a method was used similar to that developed for the estimation of soil behavior based on vertical array records. As input for the soil layers, acceleration time histories simulated by stochastic finite-fault modeling with a prescribed slip distribution over the fault plane were taken. At all the studied sites, resonant oscillations of the soil layers (down to ∼40-60 m) and the nonlinearity of the soil response were found as the main factors defining soil behavior.

At TCU065, TCU110, TCU115, CHY101, CHY036, and CHY039 liquefaction phenomena occurred in the upper soil layers, estimated strains achieved ∼0.6-0.8%; at other stations, maximum strains in the soil layers were as high as 0.1-0.4%, according to our estimates.

The constructed models of soil behavior were used for estimation of various parameters, characterizing soil response during the Chi-Chi earthquake, such as, average stresses and strains in soil layers, reduction of the shear moduli, amplification of seismic oscillation by soil layers, nonlinear components of soil response and impulse characteristics of soils. Distribution of these parameters around the fault plane is analyzed, the size of the area of strong nonlinearity is estimated.

Thus, valuable data on the *in situ* soil behavior during the Chi-Chi earthquake was obtained. Similarity in the behavior of similar soils during the 1995 Kobe, 2000 Tottori (Japan), and Chi-Chi (Taiwan) earthquakes was found, indicating the possibility of forecasting soil behavior in future earthquakes. In the near-fault zones of the three earthquakes, “hard-type” soil behavior and resonant oscillations in the upper surface layers prevail, both leading to high acceleration amplitudes on the surface.