ESC2016-95-1, 2016
35th General Assembly of the European Seismological Commission

35th General Assembly of the European Seismological Commission
4–10 September 2016
Trieste

Estimation of nonlinear time-dependent soil behavior in strong ground motion (vertical distributions of stresses and strains in soil layers) based on vertical array data

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Interpreting near-source vertical array records of the 1995 Kobe (Japan) earthquake, we suggested a method for processing strong-motion records of seismic vertical arrays (Pavlenko and Irikura, 2000) aimed at extracting maximum information from the records. Records of the deepest device of a vertical array are used as input motion to soil layers, and we calculate their propagation up to the surface, selecting stress-strain relations in soil layers, which show the best agreement between the observations and simulations on the surface and at locations of other devices of the vertical array. To account for possible changes in soil behavior, input-motion time series are divided into small time intervals of 1.5-5-second duration; soil behavior is assumed stable within each interval and varying from interval to interval. We applied our method to study soil behavior during recent strong earthquakes, for which vertical array records are available. Similar models of soil behavior during the 1999 Chi-Chi (Taiwan) earthquake were also constructed with applying stochastic simulation of motion at the bottoms of soil layers. All the studied earthquakes were accompanied by softening of subsurface soils and reduction of shear moduli in soil layers. However, 2011 Tohoku mega-thrust earthquake was different: shear moduli in soil layers in the near-fault zones increased at the moments of the highest intensity of motion. Since soil hardening in strong ground motion leads to high PGA on the surface, we should study these phenomena, i.e. how often and in what conditions soil hardening occurs. We hope that our method and vertical array records of future earthquakes could help us to find the answers.