Empirical Prediction of Strong Ground Motion for Subduction Zone Earthquakes

Robert R. Youngs
Geomatrix Consultants, San Francisco, California

Presented are the results of recent analyses of strong ground motion data from subduction zone earthquakes. Several new sets of attenuation relationships are presented for estimating peak horizontal accelerations and response spectral ordinates. These relationships were developed from regression analysis of recorded data augmented by numerical ground motion simulations. Attenuation relationships were developed for rock, shallow, and deep soil site classifications for both interface (plate boundary) and intraslab (Benioff) earthquakes.

The regression analyses were conducted using a *random effects* regression model, which provides an equivalent method to the two-stage regression technique. The random effects model also allows for explicit evaluation of the event-to-event variability and within event variability, providing a more complete model for the covariance matrix of the data. Numerical simulations of strong ground motion were performed to aid in interpreting the empirical data in terms of soil/rock amplifications in the near field, rate of attenuation with distance, and scaling to magnitudes greater than M 8. The numerical simulations were conducted using an extended source formulation of the band-limited-white-noise/random-vibration-theory model. Soil site motions were simulated by incorporation of one dimensional wave propagation into the model, with the soil properties modeled by the equivalent linear method.

The results of both the regression analyses and the numerical modeling studies show a lower rate of attenuation with distance for large subduction zone earthquakes compared to shallow crustal earthquakes. These results confirm results reported by many previous investigators. The shape of the attenuation curve in the distance range of 50 to 200 km is strongly magnitude dependent, possibly reflecting the effects of the great extent of the source for the largest subduction zone earthquakes.

Both the empirical data and the numerical simulations show significantly higher motions on soil than on rock sites at large distances from the source, as has been reported by previous investigators. However, as one approaches the source, the numerical simulations indicate that soil and rock ground motion levels converge, similar to near field observations from crustal earthquakes, while the empirical data suggest significant differences. Several alternative formulations for the attenuation model in the near field were applied to the data. The results of the analyses indicate that the limited near field empirical data do not provide a definitive choice for the form of near field ground motion attenuation relationships on rock.

Differences between interface and intraslab earthquakes have been attributed to either basic source differences between the two types of earthquakes or to the effect of source depth. The results of the regression analyses indicate that both effects are present in the data at a statistically significant level.