Ground Motion Prediction Using a Dynamic/Pseudo-Dynamic Approach

Hiroe Miyake[1]; Martin Mai[2]; Mariagiovanna Guatteri[3]; Gregory Beroza[4]

[1] ERI, Univ. of Tokyo; [2] ETH Zurich; [3] Swiss Re; [4] Stanford University

The past several years have seen substantial progress in physically based approaches to earthquake source modeling for the prediction of strong ground motion. Using the characteristics of the dynamic faulting based on the frictional law, the pseudo-dynamic source modeling (e.g., Mai et al., 2001; Guatteri et al., 2003a) has been proposed without carrying out the full-dynamic simulation. We explore the use of this approach for predictions of wave generation from the source at higher frequencies, where important engineering needs exist. Here is the procedure of the pseudo-dynamic approach summarized in Guatteri et al. (2003b).

(a) Target Slip Distribution: Given as a spatial random field by Mai and Beroza (2002).
(b) Static Stress Drop: Calculated as a spatial gradient of the slip using the method of Andrews (1980).
(c) Fracture Energy: Calculated based on an empirical relationship that is consistent with a given slip and rupture propagation. The distribution of the fracture energy is expressed as a function of the static stress drop and distance from the hypocenter.
(d) Rupture Time: Calculated as a cumulativeness of rupture velocity obtained by Andrews (1976)'s equation.
(e) Max Slip-Velocity: Previous dynamic rupture simulation shows that maximum slip velocity of each subfault correlates well with the stress drop. Max slip-velocity is calculated using a formulation of Day (1982).
(f) Rise Time: The rise time in the heterogeneous slip distribution varies inversely with the time after rupture initiation, as long as the slip-weakening constitutive law is adopted. The rise time is expressed as a function of the way among the fault boundary locations aligned with the hypocenter and each point of the fault.
(g) Pulse Width: We assume that wave generation for strong ground motion is controlled by maximum slip velocity and effective pulse width. The pulse width is expresses as a product of the rise time and a coefficient c, where c is a function of the aspect ratio of the fault.

Once the slip velocity functions are obtained, ground motions are simulated by convolution of the slip velocity and Green functions using the discrete wave-number method (e.g., Bouchon, 1981) in the low-frequency range, and by the ray-theory calculation using isochrone integration (Spudich and Frazer, 1984) in the high-frequency range. The pseudo-dynamic approach provides similar waveforms and response spectra to those from the dynamic approach. We examine the variability of the ground motions and response spectra, particularly in the extremely near-fault region within 5 km of the fault. For identical slip and static stress drop distribution, variations in hypocentral location result in strong variations in the intensity of ground motions, indicating that the influence from the hypocenter location cannot be neglected for ground motion prediction in empirical attenuation relations.