Recipe for Predicting Strong Ground Motion from Subduction Earthquakes -State of the Art and Overview-

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Introduction: Urbanized areas along the Pacific coast in Japan have repeatedly suffered from heavy damage caused by subduction earthquakes such as the Tokai-Nankai, Kanto, Tokachi-oki, and Miyagiken-oki earthquakes. Very high probability is estimated for generation of the next Nankai-trough earthquakes. It is an emergent subject to establish a reasonable methodology for predicting strong ground motions. From recent development of the waveform inversion analyses for estimating rupture process using strong motion data during large earthquakes, we have understood that strong ground motion is relevant to slip heterogeneity inside the source rather than the entire rupture area. The source model is characterized by two of parameters, which we will call: outer and inner fault parameters.

Outer fault parameters: The outer fault parameters are parameters characterizing the entire source area and total seismic moment. For earthquakes (the Miyagiken-oki and Tokachi-oki earthquakes) that we have experienced after instrumental observation started, we estimate the fault areas from the aftershock distribution and total seismic moments from seismic records. For historical earthquake (the Ansei-Tokai, Ansei-Nankai, and Hoei earthquakes), the total seismic moment and entire source area are estimated indirectly from seismic intensity map, crustal movement, and tsunami data. For the hypothetical earthquakes such as the so-called Tokai earthquake, the parameters are estimated from the geological and geophysical information with respect to the plate boundary and the depth-dependent temperature. The entire source area S is expressed as a function of the seismic moment Mo assuming a circular crack (Eshelby,1957), Mo=(16/7)x(pai^-1.5)x ave(Dsc)xS^1.5 (1), where ave(Dsc) is average stress drop. Then, we need to get two of those three parameters, Mo, S, and ave(Dsc) to estimate outer fault parameters.

Inner fault parameters: The inner fault parameters are parameters characterizing fault heterogeneity inside the fault area. Asperities are defined as regions that have large slip relative to the average slip on the fault area. The stress drop at the asperity is expressed as a function of average stress drop ave(Dsc) and area ratio of asperity to entire fault Sa/S (Madariaga,1979): Dsa=ave(Dsc)xS/Sa (2). For inland earthquakes, Sa/S is given from the waveform inversion of rupture process using strong ground motion data. For subduction earthquakes, near-source ground motions are so limited to make source inversion analyses. Then we have no reliable the entire fault areas and asperity areas yet. Another method for estimating the area and stress drop of the asperity is proposed from empirical acceleration source spectral-level by Dan et al. (2001): Ao(dyne-cm/s^2)=2.46x10^17xMo^1/3(dyne-cm) (3). The acceleration source spectral-level Aoa only from the asperity area is derived following Madariaga (1977) and Boatwright (1988). Aoa=4(pai^0.5)bvrSa^0.5xDsa (4). Substituting (1) and (2) for (3), the asperity area Sa is given as follows: Sa=const x Mo^2/(SxAoa^2) (5). Therefore, as long as Aoa is known, we can estimate Sa from (5), then Dsa from (2). For inland earthquakes, we find that Aoa estimated using asperity stress drop in average is about 80 % of the empirical Ao from (3). For subduction earthquakes, we have no information about the relation between Aoa and Ao yet. Then, we assume that Aoa is almost equal to Ao for practical purpose.

Source modeling and strong ground motion: The source models for predicting strong ground motion are made for the Miyagiken-oki and Tonankai-Nankai earthquakes. The area and stress drop of individual asperities for the Miyagiken-oki earthquake are estimated from the duration and amplitude of directivity pulse. The synthetic ground motions from the above model agree well with the observed ones. Those for the Tonankai-Nankai earthquake are estimated with try and error to fit on seismic map empirically given.