Construction of a recipe for predicting strong ground motions from subduction mega-thrust earthquakes

*Kojiro Irikura[1], Susumu Kurahashi[1]

1.Aichi Institute of Technology

Introduction
Before the 2011 Mw 9 Tohoku earthquake, there are considered six segments for the region off the coast of Tohoku from Middle Sanriku-Oki to Ibaragi-Oki with seismic activities of past 400 years by the Headquarter of Earthquake Research Promotion, Japan (HERP). Then, they made a long-term forecast that Mw 7-8.4 earthquakes would occur within those segments, having different recurrence times from one to the other. Prior to the Mw 9 event, the possibility of a megathrust earthquake of magnitude larger than 8.5 was never expected from a scientific point of view. On the other hand, we find the segmentation might control the characteristics of ground motions from the rupture process inversion of near-field strong motion records as well as earthquake occurrence in the source region of this event. Then, we propose an improved idea for recipe of predicting strong ground motions for subduction earthquakes.
Segmentation
There were not only along-strike segments but also along-dip ones for the source region of the Mw 9 event. The high frequency radiation is dominated from SMGAs in segments located in a down-dip region closer to Japan coast similar to high-frequency backprojection studies using teleseismic short-period P waves data. The low frequency radiation from the asperity inverted from long-period strong-motions data tends to dominate in the shallow segment closer to the trench. Similarly, apparent along-dip rupture differences were observed for several other large megathrust events such as the 2010 Mw 8.8 Maule earthquake in Chile, the 2005 Mw 8.6 Sumatra earthquake, and the 2004 Mw 9.2 Sumatra earthquake by comparing the slip distribution with HF radiation observations (Yao et al., 2015).
Short-period Source model
From the observed strong motions during the Tohoku event, there are recognized distinctive five wavepackets that correspond to ground motions from respective small asperities. The origins of the wavepackets were retrieved from data arrays consisting of the strong motion stations using a semblance analysis. Then, we estimate a short-period source model for generating strong ground motions from this earthquake by comparing the observed records from the mainshock with synthesized motions based on a multiple-asperity source model and the empirical Green's function method. We find that five small-asperities in the down-dip areas generate short-period motions of engineering interest but large asperities in the shallower area east of hypocenter generate mainly large slip and long-period ground motions. We call such small asperity strong-motion generation area (SMGA). This model provides broadband ground motions including long-period motions from 2 s to 10 s that are engineering interest for aseismic design and base-isolation.
Impulsive waves from SMGA
Another problem is that the short-period source models with such SMGAs cannot simulate impulsive waves with high acceleration and velocity seen at onsets of the wave-packets in strong motion records observed near the source fault. To generate such impulsive waves, multi-scale source model is needed with heterogeneity of maximum slip velocity and rise time inside the SMGAs. Then the recipe of predicting broadband ground motions from 0.1 s to 10 s for mega-thrust subduction earthquakes is needed to consider the multi-scale heterogeneous model.

Keywords: subduction mega-thrust earthquakes, strong ground motions, short-period source model, strong motion prediction recipe

