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Strong motion characteristics of Mega-Thrust earthquake and the seismic response of NPP as a massive, stiff structure

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The 2011 Tohoku earthquake generated a large number of strong motion records with high acceleration at many observation points, mainly in Miyagi and Ibaraki Prefectures. The distribution of seismic intensities observed or collected by JMA shows that intensity 7 was recorded only at K-NET Tsukidate (MYG004) in Kurihara City, but that intensity 6 upper were recorded at 40 points in four prefectures. When we compare the distribution of the peak ground acceleration (PGA) and velocity (PGV) of the strong motion records observed by K-NET and KiK-net of NIED with the empirical attenuation relation of Si and Midorikawa we can see that PGAs exceeded 500 Gals extensively along the coast from the Central Sanriku to Ibaraki Prefecture, but that PGVs in the area were lower than 80 cm/s. Because of the stochastic nature of the strong motion generation from the large-sized ruptured area there is no site with the coherent intermediate-period (around 1 s) velocity pulse with PGA larger than 800 Gals and PGV higher than 100 cm/s, which is the primary reason for not having severe seismic damage onto the ordinary low-rise buildings.

Prof. Sakai of Tukuba Universiy investigated the structural damage around the site with JMA intensity 6 upper to find that there are no site with heavy damage. We also found that, by using the nonlinear response models which can reproduce the damage ratios caused by the 1995 Hyogo-ken Nanbu (Kobe) earthquake, the structural damage potentials of the observed strong motions were relatively minor for most of the sites. These facts suggest that the current ordinary buildings in Japan, which is basically designed by using the rigid-structure concept, are capable to survive to the strong shakings from the mega-thrust earthquakes.

On the other hand the structural damage prediction by the Cabinet Office of the Japanese Government is made from the empirical relations with respect to seismic intensities of the predicted strong motions. Since such empirical relationship are all based on the damage observed during the 1995 Kobe earthquake, the relationship is good for the inland earthquake but not appropriate to the strong motions pervasively observed during the mega-thrust earthquakes with high PGAs but not so high PGVs. To prove this we independently predict strong motions and using the nonlinear response models we estimated structural damages and found heavily damaged sites only close to the shore line with soft ground conditions.

The same kind of smaller responses were predicted for the nuclear power plant (NPP) structures by using the strong motions predicted by the Cabinet Office in 2003 (Seckin et al., 2008, WCEE). The response of the NPP for predicted strong motions were about twice larger than the elastic limit of the structure, in terms of the relative shear deformation ratios. This is because on one hand the rigid body design concept makes structures sufficiently strong to the high PGA input and on the other hand the elastic limit used for the design is quite low compared to the ordinary buildings. Thus from the structural point of view strong motions during future mega-thrust earthquakes would not be a primary risk for NPPs despite of the spectral amplitude higher than the design input.

Keywords: strong motion, Mega-thrust earthquake, Stiff structure, shear deformation