Application of K-NET records to development of design long-period ground motions

*Toshimi Satoh[1]

1.Ohsaki Research Institute

Long-period ground motions in the period range from 2 to 10 s are influential to super high-rise buildings and base-isolated buildings. In order to develop design long-period ground motions for these buildings we studied long-period ground motions from 2008 to 2012 with Building Research Institute in the "Promotional project for upgrading the building standards" under the auspices of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Based on these studies MLIT called for public comments on "Countermeasure plan for super high-rise buildings against long-period ground motions caused by mega-thrust earthquakes along the Nankai Trough" on December, 2015. In this paper we mainly show technical and academic results on empirical long-period ground motion predictions using K-NET and the other strong motion records.

Firstly we develop ground motion prediction equations (GMPEs) of response spectra and Fourier phase spectra in the period range from 0.1 to 10 s using many K-NET, KiK-net, JMA-87 and JMA-95 records. About 10000 earthquake-station pairs of hypocentral distance X < 400 km for 51 subduction-zone earthquakes with M_J6.5-M_J8.2 and depth < 60 km and 6000 earthquake-station pairs of X < 350 km for 26 crustal earthquakes with M_J6.0-M_J7.3 are used. The GMPE of response spectra is modeled by rupture distance, Mw^2 and Mw considering with saturation effects on distance. The GMPEs for average and variance of group delay time which is the differential of Fourier phase spectra within narrow frequency bands is modeled by X and seismic moment. The GMPEs for average and variance of group delay time enable us to empirically generate time history. For subduction-zone earthquakes, we get different site factors in the Kanto basin for the earthquakes of the Pacific plate and the Philippine Sea plate, respectively. The site factors for earthquakes of the Philippine Sea plate are larger than those for those the Pacific plate due to 3D effects of the Kanto basin.

The site factors are obtained at strong motion stations with about 10-20 km intervals. Since the site factors in the period range from 1 to 10 s are found to be different from 1D amplification factors for S waves, we develop a regression model of site factors to predict them at any construction sites in three major urban regions. The regression model is developed using Tz, which is 1/4 of the natural period from seismic bedrock to engineering bedrock calculated from the deep substructure model with about 1 km grid space by HERP. The site factors are empirically represented by a bi-linear function of Tz well. We show that the bi-linear function can be interpreted from medium responses of surface waves. However Tz is not enough to represent the site factors in the area where the deep subsurface structure abruptly changes such as Kobe area. In that case we correct Tz so as to empirically consider 3D effects on site factors.

Time history of ground motions in the period range from 0.1 to 10 s can be predicted by the developed method using outerfault parameters. For large earthquakes whose faults are composed of several segments, time history is generated by summing up the time history for each segment considering each rupture starting time. This method is verified by simulating strong motion records of K-NET and KiK-net stations for the 2011 Tohoku earthquake. We also confirm that long-period ground motions predicted by this method are consistent with those predicted by 3D-FDM by HERP for the Tokai earthquake, the Tonankai earthquake, and the Nankai earthquake.

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Keywords: K-NET strong motion records, Long-period ground motions, Ground motion prediction equation , Mega-thrust earthquakes along the Nankai Trough, Phase spectra, Super high-rise buildings

