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Spatial interpolation of empirical amplification factors for response spectra of long-period ground motions

Toshimi Satoh[1*], Izuru OKAWA[1], Takao NISHIKAWA[3], Toshiaki SATO[4]

[1]Ohsaki Research Institute, [2]Building Research Institute), [3]Tokyo Metropolitan University, [4]Shimizu Corporation

We (Satoh et al, 2010) developed attenuation relations of acceleration response spectra with a damping factor of 5 % in a period range from 0.1 to10 seconds including long period using many strong motion records observed at about 1870 stations to make design spectra for long-period structures. In the attenuation relations, amplification factor at each station was obtained, and so the long-period ground motions can be predicted at the stations considering the site-specific amplification factors. In this study we develop empirical regression relations to spatially interpolate the amplification factors in order to predict long-period ground motions at any places in the Kanto basin, the Nobi basin, and the Osaka basin. In addition we put a theoretical interpretation on the empirical relations.

In previous attenuation relations for long-period ground motions, the depth of the seismic bedrock with S-wave velocity of around 3.0 km/s, the depth of the hard rock overlaid on the seismic bedrock, or the combination of one of them and Vs30 (the average S-wave velocity down to 30 meters) are used as parameters for the empirical relations of amplification factors. The reason why the depths were used is that the depth information is easier to obtain than the velocity structure information. In 2009, long-period ground motion maps and the three-dimensional velocity structure models were open in public by the Headquarters for Earthquake Research Promotion in ministry of education, culture, sports, science and technology, Japan. In this study we calculate the average propagation time Tz3.2 from the seismic bedrock with the S-wave velocity of 3.2 km/s to the engineering bedrock using the velocity structure models and develop empirical regression relations of amplification factors using Tz3.2.

It is found that the logarithm of the empirical amplification factors C are represented bi-linear-type regression lines with the connection Tz3.2 of 1 second in a period range from 0.5 to 10 seconds in three basins. The C is modeled by the equations (1) and (2).

$\log_{10}C=a1+b1Tz3.2$ $(Tz3.2>1.0)$ (1)

$\log_{10}C=a2+b2Tz3.2$ $(Tz3.2<1.0)$ (2)

Here a1, a2, b1, and b2 are regression coefficients. The correlation between C and Tz3.2 is better than that between C and the depth of the seismic bedrock. We simulate the C at eight stations in three basins using the regression relations and confirm that the regression relations reasonably represent the C by considering the standard deviations of the regression relations and the standard deviations of C.

Then we put a theoretical interpretation on the empirical relations of the amplification factors using medium responses. First, we calculate medium responses of the fundamental mode of the Love waves and Rayleigh waves from the velocity structures just beneath the observation stations using the three-dimensional structure models. Secondly, we get horizontal components of the Rayleigh waves multiplying the medium responses by horizontal-to-vertical spectral ratios of the Rayleigh waves. Then we add the medium responses of Love waves to them and define them as MR in this study. Finally we analyze the relation between MR and C at each period. It is found that the relation between Tz3.2 and logarithm of MR is correlated well with the relation is between Tz3.2 and logarithm of C. This results suggest that the empirical regression relations of the equations (1) and (2) have the theoretical basis.

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Keywords: long-period ground motions, empirical attenuation relations, amplification factors, velocity structure model, medium response