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Real-time correction of site amplification factors estimated by the coda normalization method

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1. Introduction

Hoshiba (2011, SSJ) proposed a method for expectation of ground motion based on real-time monitoring, in which hypocenter and M are not required. In this method, site amplification factor must be corrected in real-time manner. Iwakiri & Hoshiba (2011, JpGU) concluded that the preciseness will be improved when frequency dependency is introduced into the site amplification correction in comparison with the correction of the scalar values such as average difference between observed and expected seismic intensities. Hoshiba (2012, SSJ) designed a recursive digital filter having similar amplitude property to site amplification factor, and proposed a method for real-time site correction. In this study, we will design the recursive filters for the JMA seismic intensity stations, of which site amplification factors were systematically estimated by the coda normalization method, and test a real-time site correction.

2. Site amplification factor

Aoki & Hoshiba (2012, JAEE) estimated relative site amplification factors of the JMA seismic intensity stations for 11 frequency bands (f=0.75-15.0Hz) by the method of Takemoto et al.(2012, BSSA). In this method, we used average amplitudes (over a time window with 5 s length) of the vector sum of the 3-component band-pass filtered coda waves as a data set. The parameters of source and path effects and those of relative site effects were simultaneously estimated by the least-squares method. 15 sequential time windows were set sliding by 2.5 s after 60 s from the origin time. Only the amplitudes with high S/N (more than 2), of which the lapse time exceeded twice the S-wave arrival time, were used in this analysis. We selected 370 shallow and intermediate depth ($H < 90$km) earthquakes that occurred in the area around Japan from 1996 to 2010 with $4.0 < M < 7.4$ and made use of the amplitude data at the epicentral distance less than 200km. Consequently, we estimated the relative amplification factors for more than 540 sites.

Our results show that the amplification factors in low frequency bands (0.75-2Hz) are in good agreement with the thickness of sedimentary basins, and the regional contrasts tend to weaken in the high frequency bands. There were positive correlations among our results, the values of the station correction estimated from topographic data and those from observed seismic intensities except for the higher frequency bands than 10Hz.

3. Feasibility study of site correction

The filters for site correction [Hoshiba, 2012] are composed by the combination of some 1st order and 2nd order analogue filters, and the parameters of the filters are evaluated by the non-linear least-squares method to fit amplitude property to frequency-dependent site amplification factors. The digital recursive filters are designed by applying the bilinear transform and pre-warping to the analogue filters. While the filter described here is what is called 'convolution filter', which adds characteristic of the site effect to simulate the ground motions on the surface based on the seismograms observed in the ground, the deconvolution filter could be expressed by the reciprocal of the analogue filter. When we evaluate the filter parameters in this study, the site amplification factors in the frequency bands over 15Hz and under 0.75Hz are assumed to equal to those of both ends.

In this test, firstly, a deconvolution filter of each station is applied to each seismogram of an earthquake. Secondly, a common convolution filter is applied to all seismograms due to adding the common site effect. In order to confirm the effect of this correction, we compared the distributions of the seismic intensities before and after the correction. While there were some outliers before the correction, the number of the outliers tended to become small after the correction. These results show the amplification factors estimated in this study are useful for the site correction.

Keywords: Site amplification factor, Coda normalization method, Real-time processing, JMA seismic intensity station, Prediction of ground motion