Site amplification from coda waves in Japan

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We estimated site amplification factors in whole Japan based on the analysis of waveform data from high-density nation-wide strong motion network. We employed the coda normalization method [e.g. Phillips and Aki, 1986] which assume that the variation of the coda wave amplitude at each station is mainly characterized by their local site condition rather than due to the source and path effects. We used the K-NET and KiK-net strong motion network of about 1,800 stations and the SK-net intensity-meter network in Tokyo metropolitan area. Totally, 3,004 waveform data from 48 shallow ($h < 40$ km) and intermediate-scale ($M = 3.6 - 6.3$) earthquakes are used in this analysis. The site amplification characteristic at each station in four frequency bands (f = 0.5-1 Hz, 1-2 Hz, 2-4 Hz, and 4-8 Hz) is estimated by least-square method assuming a reference station for F-net Tashiro broadband station on rock site. Distribution of the obtained site amplification factors shows that in low-frequency band, major sedimentary basin areas have large site amplification factor. On the other hand estimated site amplification factor in high-frequency band shows larger amplification due to shallower structure than low frequency band. The area where thin weathered layers (less than 10 m) overlying rigid bedrock shows higher amplification. Large difference in the site amplification factor in low-frequency (0.5-1 Hz) and high-frequency band (4-8 Hz) means that the cause of site amplification of seismic wave differs in each frequency band. We calculated correlation coefficients between distribution pattern of the estimated site amplification factors at the free-surface and 100-200 m below surface derived by the analysis of the KiK-net free-field and borehole stations. The result shows that in the low frequency band (0.5-1 Hz), the spatial patterns of the amplification factors shows a good correlation between borehole and free-field station with a large correlation coefficient of 0.34. On the other hand there is no correlation between these spatial patterns of site amplification factors for the high-frequency band (4-8 Hz) with a very small correlation coefficient of -0.02. This means that the site amplification in low frequency is seemed to be affected by more deeper geology over 100-200 m. The results warn that the site amplification effect at each station cannot be simply estimated by surface geology, as most study did as empirically, but can only be estimated by the analysis of observed seismic waveform. In order to check the reliability of the estimated site amplification factors at each station and frequency and to examine how they modify seismic intensity during large earthquakes, we removed the site amplification characteristic at each station and at each frequency from the observed acceleration record of the 2004 Niigata Chuetsu earthquake (M6.8), the 2005 Western Fukuoka earthquake (M7.0) and the 2008 Coast of Iwate earthquake (M6.8). The results shows isoseismal intensity contours around the hypocenter with decreasing intensity with distances. Standard deviation of intensity from average attenuation curve with distances became smaller (from 0.41 to 0.37) by removing site characteristic from intensity. Also anomalous

extension of intensity contours, which are often observed during deep subduction zone earthquakes due to the guiding of high-frequency signals along the subducting Pacific Plate, is observed more clearly after correcting site amplification factor due to local structure. Acknowledgement; We acknowledge the National Research Institute for Earth Science and Disaster Prevention, Japan (NIED) for providing the K-NET, KiK-net and F-net waveform.