Evaluation of site amplification factors at Kashiwazaki-Kariwa Nuclear Power Plant and its application to strong motion simulation

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During the 2007 Chuetsu-oki, Japan, earthquake, very strong ground motions were observed in the near-source region, including pulse-like strong ground motions observed at Kashiwazaki-Kariwa Nuclear Power Plant. According to recent seismological studies, it has been revealed that the earthquake took place on a south-east dipping reverse fault. In the field of engineering seismology, pulse-like strong ground motions in the near source region of large crustal earthquakes have often been attributed to forward-directivity effects. In the case of the present earthquake, however, it is difficult to interpret the pulse-like motions at the power plant as a result of a forward directivity effects if we have to assume that the earthquake took place on a south-east dipping fault. Therefore, it is very important to investigate how such strong ground motions were generated at the power plant, i.e., what kind of source models are required to reproduce ground motions recorded at the power plant. Before evaluating the source models, the author investigated the site amplification factors at the power plant. Basically the site amplification factors were evaluated by taking the ratio of the Fourier spectra observed at the power plant during small earthquakes and the corresponding bedrock spectra estimated from omega-square source model. Several small earthquakes were selected that were recorded both at the power plant and three K-NET (Kinoshita, 1998) stations surrounding the power plant, i.e., Teradomari, Nagaoka and Kashiwazaki. It was assumed that the source spectra of these earthquakes follow omega square spectral model (Aki, 1967) and the parameters were identified to mach the observed Fourier spectra at K-NET stations. In this process, conventional site amplification factors at K-NET stations (Nozu and Nagao, 2005) were used. Then the site amplification factors at the power plant were evaluated by dividing the observed spectra by the estimated bedrock spectra. According to the results, although the site amplification factors at the power plant do not have a very significant peak at low frequencies, they are relatively large at low frequencies compared to, for example, K-NET Teradomari. The site amplification factors are around 10 in the frequencies lower than about 1 Hz. This suggests that the nuclear power plant is located on relatively thick sediments. Based on the site amplification factors thus obtained, strong motion simulation was conducted to reproduce mainshock ground motions at the power plant. Kowada's (1998) method was used in the simulation, which can take into account both empirical site amplification and phase characteristics. In the conventional research, it has been shown that the method can reproduce pulse-like ground motions due to forward directivity effects such as in Kobe during the 1995 Hyogo-ken Nanbu earthquake (Nozu et al., 2007; Nozu and Sugano, 2008). A characteristic source model was newly developed for the 2007 Chuetsu-oki earthquake, refering to results of the waveform inversion (Nozu, 2008), which suggests that there was an area with significantly large slip on the fault about 20 km south-west of the rupture starting point. By employing a characteristic source model with a largest asperity in the area, the strong ground motions at the power plant was successfully reproduced. It should be noted that the area of this asperity is significantly small relative to the moment release estimated on the asperity. This fact might be significantly important for the future of strong motion prediction. Further studies should be conducted on the source characteristics of large crustal earthquakes. The site amplification factors at K-NET sites and the computer program for the strong motion simulation used in this study are open from our research institute (Technical Note of the Port and Airport Research Institute, No.1112 and No.1173, respectively).