Source spectra and nonlinear site factors based on the spectral inversion methods

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The first earthquake occurred in Kumamoto prefecture at April 14 in 2016. The JMA magnitude (M_{JMA}) of this earthquake is 6.5, and Kumamoto Prefecture’s shindokei-network recorded the instrumental JMA seismic intensity of 7 at Mashikimachi in Kumamoto prefecture (“JMA” is abbreviation of Japan Meteorological Agency). After the occurrence of the earthquake, another earthquake with M_{JMA}7.3 occurred at April 16 in 2016. We called the former the foreshock, and the latter the mainshock here. These earthquakes and subsequent aftershocks named as the 2016 Kumamoto earthquake sequence. In the mainshock, Kumamoto Prefecture’s shindokei-network recorded also the instrumental JMA seismic intensity of 7 at Mashikimachi as well as Nishihara village. If we confirm the distribution of aftershocks, we can see that the aftershocks are on the Futagawa-Hinagu fault zone.

The strong ground motions of the 2016 Kumamoto earthquake sequence were observed by K-NET and KiK-net of NIED (The National Research Institute for Earthquake Science and Disaster Prevention) and also by JMA shindkei-network. These waveforms are published at the webpage of NIED or JMA, and are used for inversion analysis to estimate rupture process. According to the field survey report, we can see the damage of building due to ground deformation a lot. On the other hand, the damaged buildings caused by strong ground motions are also seen. It suggests the necessity of careful discussions to investigate the correlation of damaged buildings, strong ground motions, and ground deformations. Here, we perform spectral inversion analysis on the 2016 Kumamoto earthquake to investigate the properties of source spectra and site amplifications.

We selected the strong ground motions provided by K-NET, KiK-net, and JMA, based on the conditions of Nakano et al. (2015). The main conditions are; events with M_{JMA}4.5 or larger, sites within the hypocentral-distance of 200km, events with the hypocenter depth shallower than 30km in the case of crustal earthquake. We used the hypocenter locations estimated by the Hi-net and seismic moments M_0 estimated by the F-net. For more information on the analysis conditions, please see Nakano et al. (2015). As a result of the selection, we found 25 events usable from the 2016 Kumamoto earthquake sequence in total. From the separated source spectra, we evaluated that the corner frequency fc of the foreshock and the mainshock are 0.19Hz and 0.06Hz, respectively. We also estimated that the stress drop of the foreshock was about 2.2MPa, while that of the mainshock was about 1.8MPa. The stress drops of aftershocks are equal to or lower than the mainshock and the foreshock. This trend is consistent with the relationships of the mainshock-aftershock sequences presented in Nakano et al. (2015) for moderate-size earthquakes. We also calculate short-period levels A to find that the mainshock’s A is slightly lower than the average scaling law. Also the short-period levels A of the foreshock, the mainshock, and all the aftershocks are lower than the regression line of Dan et al. (2001) or Sato (2010). Instead, the short-period levels A of the aftershocks are consistent with the regression lines of Sato (2003) or Nakano et al. (2015). Further, the nonlinear site effects clearly seen in the site amplification factors for strong motions such as KMMH16, which are calculated by dividing the Fourier spectrum by the product of source characteristics and damping characteristics estimated in the linear region.

In short, it can be said that the 2016 Kumamoto earthquake is not extraordinary event considering the scaling law, since the stress drop of the mainshock and the foreshock are lower than the average of previous events with similar magnitude In the foreshock and the mainshock, pervasive emergence of non-linear effects can be found in the site amplification for strong motions such as KMMH16. Note that we used only strong ground motions equal to or lower than 200gal for spectral inversion analysis here to avoid nonlinear site effects. To account for site-specific near fault ground motions we need to consider both a complex rupture process on the fault and a three-dimensional nonlinear site response, which will be our future tasks.

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Keywords: Spectral inversion method, Source spectra, Nonlinear site factors