A simplified source model to explain damaging near-source ground motions during the 2016 Kumamoto earthquake

*Atsushi Nozu[1], Yosuke Nagasaka[1]

1. Port and Airport Research Institute

A simplified source model was developed for the main shock of the 2016 Kumamoto earthquake (April 16, 2016, 1:25 JST, M_J7.3) for the purpose of estimating strong ground motions at the sites of significant damage. The first priority was to reproduce strong ground motions in the region extending from Mashiki Town to Minami-Aso Village where significant damage to highway bridges was found. Corrected EGF method (Kowada et al., 1998; Nozu and Sugano, 2008; Nozu et al., 2009) was used for the simulation. Details of the source model and the simulation can be found at http://www.pari.go.jp/bsh/jbn-kzo/jbn-bsi/taisin/sourcemodel/somodel_2016kumamoto.html. The digital data of the source model can also be found at the same website.
The near-source region of the earthquake is shown in the top-right panel of the figure. The rectangle in the map indicates the surface projection of the fault plane (length:40 km; width:20 km; strike=232 degrees; dip=84 degrees) that was used for the waveform inversion (Nozu and Nagasaka, 2017). According to the waveform inversion (bottom-right panel of the figure), a region of significantly large slip and slip velocity (hereafter referred to as “Asperity 3” in this article) existed around 15 km northeast of the hypocenter (indicated by a star). In Mashiki Town (KMMH16), a large-amplitude pulse-like ground motion with a predominant period of 1 s was observed, which resulted in significant damage. However, if we consider the fact that Mashiki Town is located between the hypocenter and Asperity 3, the damaging ground motions in Mashiki Town cannot be attributed to the rupture of Asperity 3. On the other hand, in the region northeast of Mashiki Town, the effect of the rupture of Asperity 3 should have been predominant. Thus, the near-source strong ground motions could have been dependent on the relative locations of the site and the asperities.
Site amplification factors evaluated in a conventional study (Nozu and Nagao, 2005) was used except for two stations. At KMM006, a newly evaluated site amplification factor (http://www.pari.go.jp/bsh/jbn-kzo/jbn-bsi/taisin/research_jpn/research_jpn_2016/jr_48.html) was used, because the site was relocated after the evaluation of the conventional site amplification factors. At KMMH16, a newly evaluated site amplification factor was used to include recently obtained data. However, the site amplification factors at these sites did not differ significantly from the old ones. At Komori, Nishihara Village and Kawayo, Minami-Aso Village, the site amplification factors were evaluated based on weak motion records obtained by Osaka University. The phase characteristics of the Green’s functions were evaluated using weak motion records that occurred in the source region.
The simplified source model is shown in the bottom-right panel of the figure. Three asperities were modeled referring to the results of waveform inversion, namely, Asperity 1 and Asperity 2 at approximately 5 km northeast of the hypocenter and Asperity 3 at approximately 15 km northeast of the hypocenter. The rupture of each asperity was assumed to start from the individual rupture staring point indicated by the open star and to propagate radially. The rise time of each asperity was determined based on the relation by Kataoka et al. (2003) except for the Asperity 3, for which a slightly larger rise time was assigned to reproduce observed ground motions at Komori, Nishihara Village. The Q value for the region proposed by Katoh (2001) ($Q=104\ f^{0.63}$) was used. Multiple nonlinear effects were considered in the simulation (Nozu and Morikawa, 2003; Nozu and Sugano, 2008). Among the two parameters to consider the multiple nonlinear effects, ν_1 was determined based on the ratio of peak frequencies between the strong and weak motion records. ν_2 was determined to appropriately reproduce the amplitude of the later phases.

The left panel of the figure compares the observed and synthetic velocity waveforms. The main features of the velocity waveforms including the large-amplitude pulse at KMMH16 were successfully reproduced. The Fourier spectra at near-source stations were also successfully reproduced.

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