Long-period strong ground motions near the source fault of the 2016 Kumamoto earthquake

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Introduction

The 2016 Kumamoto earthquake with Mw 7.0 occurred at 01:25JST on April 16, 2016 along the Futagawa fault zone and the northern part of the Hinagu fault zone. Surface breaks caused by the mainshock were found associated with Futagawa-Hinagu fault system by field surveys. Near-field strong ground motions with high accuracy during the 2016 Mw 7.0 Kumamoto earthquake were recorded by the NIED strong motion network (K-NET and KiK-net) and the JMA and local-government seismic-intensity network. In particular, two stations at Mashiki Town-Hall (MTH) and Nishihara Village-Hall (NVH) were located within 2 km of the surface traces along the Futagawa fault zone. The ground motions of the 2016 Kumamoto earthquake were well simulated using a characterized source model consisting of strong motion generation areas (SMGAs) based on the empirical Green's function (EGF) method except the very-near-field ground motions at MTH and NVH. We attempt to simulate the very-near-field ground motions with fling steps taking long-period generation areas (LMGAs) above the SMGAs into account.

SMGA model for simulating strong ground motions of the 2016 Kumamoto earthquake

Many studies of slip distributions obtained from the waveform inversion of the strong-motion data for this event have so far been published (e.g., Asano and Iwata 2016; Kubo et al. 2016; Yoshida et al. 2016). The rupture area and asperity area were determined based on the slip distributions obtained from the waveform inversions of the strong motion observations. Irikura et al. (2017) found that the relationship between the rupture area and the seismic moment for this event follows the second-stage scaling relation within one standard deviation developed by Irikura and Miyake (2001). Characterized source models with the SMGAs are estimated, based on the slip distribution models of Yoshida et al. (2016) and Kubo et al. (2016). There are found two best-fit source models, both of which show a good agreement between synthetic and observed motions (Irikura et al., 2017). One is Model A with three SMGAs from Yoshida et al. (2016) and the other is Model B with a single SMGA from Kubo et al. (2016). The SMGA of Model B is located around a center of the three SMGAs of Model A. The combined area of three SMGAs of Model A is nearly equal to the area of the single SMGA of Model B. The ratio of the SMGA area to the total rupture area is 0.22–0.24. Then, the stress parameter of each SMGA is about 14 MPa.

Long-period ground motions at very-near surface-fault stations

The ground motions at MTH and NVH show clearly the fling steps as shown in near-field ground

motions during the 1992 Landers earthquake (Hisada and Bielak, 2003). The fling effects are dominant in the slip direction only in the vicinity of the surface fault and are negligible for buried faults, because the near-field terms of the Green's functions attenuates rapidly with distance from the fault, r, as the order of $(1/r^2)$. Therefore, the effects might have a strong influence on the ground motions at MTH and NVH, whereas less on those at KMMH16 and KMM006. We estimate the ground motions at MTH and NVH putting a long-period motion generation area (LMGA) between surface fault and the top of the seismogenic zone above the SMGA. We assume a long-period (about 3 s) modified-ramp-functions as slip velocity time functions on the LMGA, because the slip velocity time functions from the inversion results are expressed to be a bell shape near the surface fault, while they are Kostrov-type on deeper SMGAs, as shown in Kubo et al. (2016). The location of the LMGA is put near large slip from the inversion results. The area of the LMGA and the peak velocity of the slip velocity time function were determined through comparison between the synthetic and observed long-period motions. The synthetic ground motions as a sum of ground motions from the SMGA and those from the LMGA agree well with the observed motions with fling steps.

Keywords:
2016 Kumamoto earthquake, strong ground motion, near-field ground motions, lomg-period strong ground motions, fling steps