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Estimations of Strong Ground Motions in Downtown Mashiki during the Mainshock of 2016 Kumamoto Earthquake Using the Nonlinear Analysis Method

〇Jikai SUN, Hiroshi KAWASE, Kiyoshi FUKUTAKE, Fumiaki NAGASHIMA, Shinichi MATSUSHIMA

Several sites located between the local Road No.28 and Akitsu river in Mashiki were found being liquefied after the mainshock of 2016 Kumamoto earthquake, which were reported by several researchers [1,2]. Equivalent linear analyses (ELA) of the subsurface structures of KiK-net KMMH16 [3–5] and Mashiki Townhall [6] were carried out in previous studies, while the effects of soil liquefaction to the ground motions were not understood clearly. Moreover, the distribution of all the visible and invisible liquefaction sites in Mashiki during the mainshock was not studied. Thus, it is necessary to understand the soil liquefaction effects on site response and delineate the distribution of liquefaction sites in Mashiki by the nonlinear analysis (NA). The Ramberg–Osgood (RO) relationship and Bowl model [7] were applied to perform the NA in Mashiki. 592 one–dimensional (1D) velocity structures inverted from microtremors and the input ground motions on the seismological bedrock (with V_s = 3.4 km/s) were obtained from our previous studies [4,8]. Water table depth of each site were investigated based on the ground surface elevation (Geospatial Information Authority of Japan, 2020) and water table elevation [9] distributions of Mashiki. Then, 592 sites were classified into four categories, whose soil nonlinear properties were obtained from four sets of borehole experimental data. Rayleigh damping of each soil column was obtained from the eigenvalue analysis. The estimated ground motions were similar to the observed ones at KMMH16 in both EW and NS directions (Figure 1). Soil liquefactions were found mostly at sites near the river (Figure 2), which were distributed in the similar area to the field survey results of Ministry of Land, Infrastructure, Transport and Tourism [2] and Wakamatsu et al. [1]. The estimated NA–PGAs showed the similar distribution to the ELA–PGAs. PGAs between the Road No. 28 and Akitsu river were smaller than the northern areas in both EW and NS directions. Furthermore, NA–PGVs (Figure 3) also presented the similar distribution to the ELA–PGVs, on which the large PGVs were concentrated between the Road No. 28 and Akitsu river. Also, both the PGAs and PGVs of NA were smaller than the ELA results, which indicated the soil liquefaction effects to strong ground motions during the mainshock. Associating with the building damage distribution in Mashiki of AIJ [10], the NA–PGVs may explain the building damage in Mashiki.

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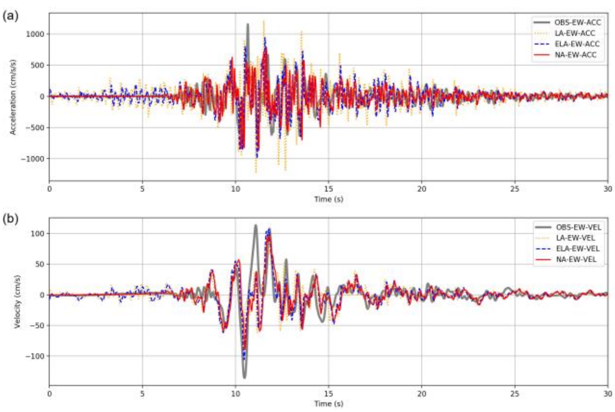

Figure 1. Comparisons of estimated accelerations (a) and velocities (b) with observed ones at KMMH16 in the EW direction. Orange, blue, red, and heavy grey lines denote the estimated ground motions by linear analysis (LA), ELA, NA, and the observed ground motions at KMMH16.

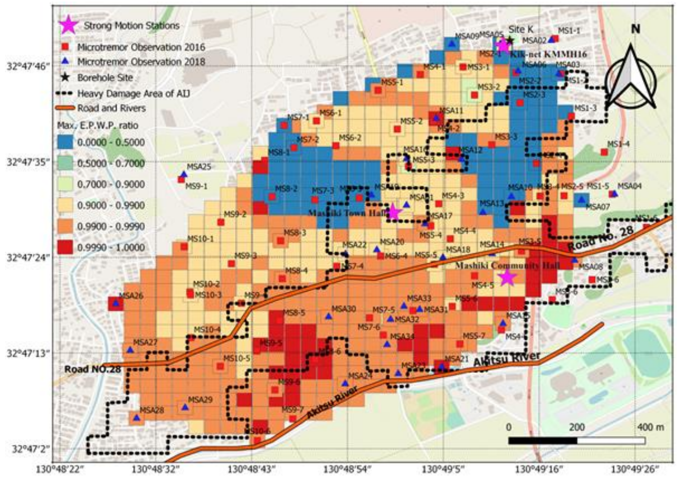

Figure 2. Distribution of soil liquefaction site in Mashiki estimated by the NA.

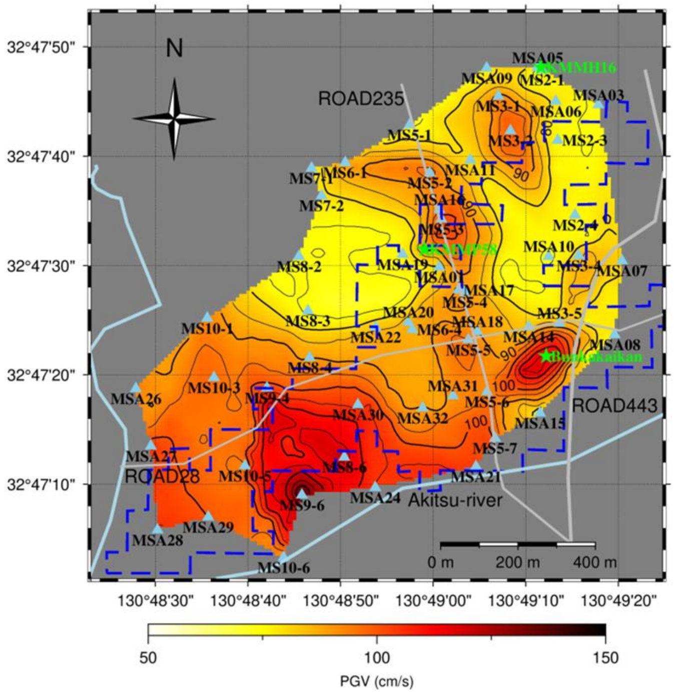

Figure 3. Estimated PGV distribution in the EW direction by the NA.