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Numerical elucidation of the graben crack damage that formed in the Aso caldera due to the 2016 Kumamoto earthquake

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In the 2016 Kumamoto earthquake, graben crack damage occurred in the northwest part of Aso Caldera. It was thought that the Futagawa fault zone did not reach to the Aso Caldera, and no causal relationship has been identified between the graben damage and the fault zone. Therefore, various causes have been considered, such as collapse of underground cavities, surface seismic faults, liquefaction-induced horizontal movement in deeper ground, etc. However, the definite cause of graben cracks have not been identified yet. Yasuda et al. [1] revealed that most of the grabens appeared at the location above the old lake which existed about 9,000 years ago. In addition, they have confirmed that the lake sediments have the property that the shear rigidity decreased sharply with strong repeated shear stress from the laboratory testing.

The aim of this study is to elucidate the mechanism of graben cracks formed in the Aso Caldera in terms of "stratum irregularity" formed by the old lake basin in the Aso Caldera, the "presence of soft clayey soil" of the old lake deposit and the "two consecutive earthquakes" that characterize the Kumamoto earthquakes. Therefore, 2-dimensional seismic response analysis was conducted to elucidate these effects on the subsurface damage. The analysis code was the soil-water coupled finite deformation analysis [2], which incorporates an elasto-plastic constitutive model that allows description of mechanical behavior of soils ranging from sand through intermediate soils to clay within the same theoretical framework [3]. The following conclusions were obtained.

(1) By considering the effect of stratum irregularity, (a) the focal phenomena of the body waves, (b) the excitation of the surface waves and (c) these amplification interference ("edge effect") were numerically reproduced. Therefore, the wave propagation became intricated and the oscillation became larger at a specific point near the ground surface.
(2) The clayey lake deposit was in a soft condition. Therefore, the effective stress was easily decreased by seismic motions, which causes further increase in natural period of the ground.
(3) As mentioned in (2), natural period of the ground was increased by foreshock. The continuous occurrence of main shocks significantly amplified long-period oscillations. This long-period and large shaking caused graben damage at the surface.

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