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Simulation of deformation followed by failure of unsaturated slope in a rainfall model test

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In recent years, there have been many collapses of slopes due to heavy rain. In most cases, to predict the collapses of slopes in heavy rainfall, seepage flow analysis and stability analysis are used together. However, it is insufficient to perform a stability analysis that judges whether a safety factor exceeds 1 or not, using the stress state determined from a seepage flow analysis. It is necessary to analyze slope behavior from deformation to failure caused by seepage. In addition, the failure phenomena are accompanied by acceleration motions even if the external force is rainfall. Therefore, it is necessary to take into consideration the inertial force. Furthermore, to simulate large deformation that leads to failure, it is essential to consider change in the geometry based on finite deformation theory.

With the above background in mind, a rainfall model test [1] was simulated using a soil-water-air coupled finite deformation analysis code considering inertia force [2] to elucidate the failure mechanism of unsaturated slope. The constitutive model for the soil skeleton is an elastoplastic constitutive model employing the unsaturated effect in the Super/subloading Yield Surface Cam-clay model (SYS Cam-clay model) [3,4].

As a result, we succeeded in simulating the rainfall-induced deformation behavior leading to failure accompanied by acceleration. The failure mechanism is explained as follows: 1) The entire unsaturated slope became a normally consolidated state caused by an increase in saturation degree (a decrease in suction), in addition to a rise in pore pressure and an increase of self-weight. 2) The stress state became located above the critical state line in mean skeleton stress p'–deviator stress q space especially near the slope toe where pore water gathered. Therefore, the soil element showed softening behavior with plastic volume expansion, which is a characteristic of the Cam-clay model. 3) A slip failure started to occur near the slope toe, and suddenly expanded to the upper part of slope with a significant acceleration.

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