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Studies on Application of Numerical Models for Unsaturated Soils to Slope Stability

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1. Introduction

The relationship between suction and water content in an unsaturated soil is called the soil water characteristic curve (SWCC). The SWCC of such soils is hysteretic in nature. In this research, an ink bottle model for hysteresis, to simulate the main and scanning curves of the SWCC in an unsaturated sandy soil, has been proposed based from the KITA-ARA model and the KITA-SAKO model by considering the maximum and minimum degree of saturation which can be derived from compaction tests in addition to the basic soil properties such as soil particle density, void ratio, grain size distribution, and surface tension of pore-water based on some probabilistic and mechanical considerations on the soil particle scale.

In this study also, a slope stability analysis using the KITA-SAKO and KITA-YAMA models combined with Janbu's generalized method has been applied to a Shirasu slope under unsaturated conditions considering pseudo-static and pseudo-dynamic earthquake forces and also considering seepage force generated by a hydraulic gradient due to infiltration of rainfall.

2. Results and Discussions

In this research, the proposed KITA-CALO model has been applied to Shirasu and Toyoura sandy soils and the results are quite promising but other types of soils are needed to further validate the proposed model. In view of this, a field monitoring system has been established in Cebu, Philippines to validate the KITA-CALO model for the local soils in such area.

For the slope stability analysis considering change in apparent cohesion which has been applied to Shirasu soil slopes, it has been found that the change in slope stability with the change in water content can be quantitatively estimated by using only the soil particle density, void ratio, and grain size distribution.

For the slope stability analysis considering pseudo -static and pseudo-dynamic earthquake forces, the factor of safety is found to decrease significantly with increase in horizontal seismic acceleration, however the effect of vertical seismic acceleration is found to be marginal. Seismic stability of Shirasu slopes decreases with increase in slip depth of the failure plane but increases with increasing apparent cohesion due to unsaturation of Shirasu soil. The natural period or the period of earthquake shaking has a substantial effect on the factor of safety of Shirasu slopes.

For the slope stability analysis considering seepage forces under unsaturated conditions, it has been found out that the factor of safety decreases with time as an effect of the infiltration of rainfall. The reduction in the factor of safety is lesser as the inherent cohesion of the natural slope due to physical and chemical action is increased.

3. Conclusions

In this study, the KITA-CALO model for hysteresis of SWCC in an unsaturated soil has been proposed. Finally, a slope stability analysis due to change in apparent cohesion has been done using Janbu's generalized method considering earthquake forces and seepage forces with self-weight.

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