Modelling of unsaturated decomposed granite subjected to finite deformation

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ABSTRACT

Generally speaking, most of geomaterials in surface ground are in unsaturated state. The mechanical and hydraulic properties of unsaturated soil are much more complicated than those of saturated soil. To rationally describe these properties, it is important to model properly the stress-strain relation of the unsaturated soil considering its water retention characteristics using rational state variables. In this paper, systematic triaxial compression tests on decomposed granite under various conditions were conducted. Based on the test results, a modified constitutive model was proposed to build an incremental relation between degree of saturation and suction that considers the influence of finite deformation. The modified model was utilized to simulate the corresponding laboratory tests. It is found that the modified constitutive model has satisfactory accuracy to describe the mechanical and hydraulic properties of unsaturated decomposed granite, which verified the reasonability of the assumption adopted in this paper. The test results are also helpful for the understanding of the moisture characteristics of the decomposed granite under constant-degree-of-saturation condition.

Keywords: unsaturated soil; triaxial test; finite deformation; constitutive model; degree of saturation; skeleton stress

1 INTRODUCTION

In order to properly describe the mechanical and hydraulic properties of saturated/unsaturated soil, both laboratory tests and numerical modelling is necessary. Especially it is absolutely necessary to propose a constitutive model that can rationally describe the soils under saturated/unsaturated states in unified way. In this paper, a decomposed granite, called as Masado with high permeability, was tested with systematic triaxial compression tests. Based on the test results, an existing constitutive model (Zhang and Ikariya, 2011) was modified to describe the influence of finite deformation on water retention curve (WRC). The modified model was verified with the oedometer and triaxial compression tests under constant-degree-of-saturation (CDS) conditions.

2 LABORATORY TESTS

Masado was selected as the test material for the unsaturated tests under constant-suction (CS) and CDS conditions.

2.1 Test apparatuses

In the element tests of the Masado, axis-translation method is adopted to control the suction. The main feature of the triaxial apparatus is that both the porous stone (pore air pressure) and the ceramic disks (pore water pressure) are embedded both in up and lower axial caps, and the test time can be shortened to one fourth under double-end-face drainage condition.

2.2 Test methods

The specimens for the triaxial compression tests have the same initial moisture content \(w_0=15\%\), and were 10.0 cm in height and 5.0 cm in diameter. The specimens were prepared by static compaction method for three layers and the target void ratio was 0.65. Then, specimens were consolidation under different suction.

For the tests under CS condition, the suction was kept as constant during the shear stage. For the tests under CDS condition, PVC was utilized to keep the degree of saturation constantly during the shear stage by the method proposed by Burton et al. (2016). The confining stress \(\sigma_{conf}\) was kept constant during the shear stage.

2.3 Test results

Figs. 1 shows the test results of triaxial compression tests under CS condition. As shown in Fig. 1, the degree of saturation decreased gradually during the shear stage, which means that finite deformation has influence on
WRC under CS condition.
Figs. 2 shows the test results of triaxial compression tests under CDS condition. It is known from Fig. 2(b) that the suction changed during the shearing stage. The variation of the suction is quite different in different case, which means that the suction variation under CDS condition cannot be described by existing model (Zhang and Ikariya, 2011).

3 MODIFIED Constitutive MODEL

As shown in Fig.3, three kinds of scanning curves should be considered: ① $dS \neq 0, ds \neq 0$; ② $ds = 0$; ③ $dS_s = 0$. It is natural to define that the incremental saturation is composed of two parts, $dS_i^s$ and $dS_r^s$, in which $dS_i^s$ is attributed to the incremental suction $dS_s^e = k_i^s ds$ and $dS_r^s$ is attributed to the change of void ratio $de$ and the change of gravimetric water content $dw$, which is defined as:

$$dS_r^s = -c_i^s \frac{S_i de}{e}$$ (1)

For simplicity, the following relation is assumed,

$$ds = -k^s ds^e = k_{id} c_i^s \frac{S_i de}{e}$$ (2)

By adopting parameters $c_i^s$ and $k_{id}$, the scanning curves of WRC under CS and CDS conditions, taking into consideration of the finite deformation, can be described.

4 PERFORMANCE OF MODIFIED MODEL

The triaxial compression tests under CS and CDS conditions were simulated by parameters determined by the triaxial compression tests and the water retention tests with try-and-error fitting. By comparing the test and calculated results, it is found that by choosing suitable state variables and adding some new parameters, the modified constitutive model has satisfactory accuracy to describe the mechanical and hydraulic properties of the unsaturated Masado. The rationality of the assumption considering the influence of the finite deformation on WRC was confirmed quantitatively.

5 CONCLUSIONS

Based on the test results of Masado, a modified constitutive model was proposed to describe the influence of finite deformation on the relation between saturation and suction. By choosing suitable state variables and adding some new parameters, the modified constitutive model can describe the mechanical and hydraulic properties of unsaturated Masado with satisfactory accuracy.

REFERENCES
