AN ELASTOPLASTIC MODEL FOR UNSATURATED GRANULAR MATERIALS WITH MICROSTRUCTURAL CONSIDERATION

PIERRE-YVES HICHER* AND CHING S. CHANG**

* Research Institute in Civil and Mechanical Engineering, UMR CNRS 6183
Ecole Centrale Nantes, France
pierre-yves.hicher@ec-nantes.fr

** Department of Civil and Environmental Engineering
University of Massachusetts
Amherst, MA 01002, USA

Microstructural models for stress-strain behavior of granular material can be derived from properties of inter-particle contacts. Considering the mean behavior of all contacts in each orientation, the overall stress strain behavior can be obtained as an average of the contact behavior for all orientations. The basic idea is to view the packing as represented by a set of micro systems. The inelastic behavior of each micro-system is characterized and the overall stress-strain relationship of the packing is obtained from an average of the behaviors of micro-systems. In this paper, the micro-systems are regarded as inter-particle planes, or mobilized planes, which requires to describe only a simple relation between the vectors of forces and relative displacements on a contact plane. The stress and strain tensors are obtained by integration over all spatial orientations. In the model, a simple elastic-plastic behavior was assumed on each contact plane. The elastic part is based on the Hertz-Mindlin's contact formulation, while the plastic part is based on a Mohr-Coulomb friction law with an isotropic hardening assumption and a non associated flow rule. For the whole packing, a critical state behavior is assumed at large deformations and the friction angle on each plane is related to the actual void ratio compared to the critical void ratio at the same state of stress.

For the non-saturated state, capillary forces at the grain contacts are added to the contact forces created by an external load. They are calculated as a function of the degree of saturation, depending on the grain size distribution and on the void ratio of the granular assembly.

The model predictions are compared to experimental results on saturated and unsaturated samples of silty sands under undrained triaxial loading condition. This comparison shows that the model is able to account for the influence of capillary forces on the stress-strain response of the granular materials and therefore, to reproduce the overall mechanical behavior of unsaturated granular materials under various stress and water content conditions.. The numerical simulations include constant water content triaxial tests at a given degree of saturation and various net confining pressure, constant water content triaxial tests at a given net confining pressure and various degrees of saturation, and a wetting test at constant deviatoric stress and constant net mean stress. For constant water content triaxial tests, the results show an increase in the mechanical properties whenever the degree of saturation decreases. The results also demonstrate that the collapse of an unsaturated specimen can be obtained during wetting, provided that a sufficiently high stress ratio is applied during the whole process.

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