A MICRO-MECHANICAL STUDY OF THE RESPONSE OF UNSATURATED PENDULAR STATE GRANULAR SOILS

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ABSTRACT

A significant portion of natural and man made civil systems comprises soils in an unsaturated condition, such as compacted roadway embankments, earth dams, slopes along with others. Unsaturated soils are three-phase mixtures consisting of a skeleton of mineral particles, pore liquid (generally water), and pore gas (generally air). The response of unsaturated granular soils is strongly affected by the interaction of solid-particles with pore-water. Prediction of the static and dynamic responses of these soils is essential for the design of new systems as well as health-assessment and rehabilitation of existing ones.

In this study, a micro-mechanical model is developed to analyze the state of stresses and response of unsaturated soils in a pendular state. Both static and cyclic load conditions were considered. The discrete element method was used to idealize the soil skeleton. Bridge suction forces were used to model the effects of pendular water bridges. These bridges develop at interparticle contacts as well as the contact of particles with surfaces of structural elements or boundaries. Explicit relationships were developed to compute water bridge suction forces as a function of water content, particle dimensions and interparticle separation distance. These relationships were implemented within a discrete code. Numerical simulations were conducted to asses the impact of pendular water bridges on the stress condition of unsaturated soils. These simulations were used along with analytical derivations to develop an expression providing the effective and suction stresses within these soils. Suction stress was found to be a direct function of porosity, water content, water bridge coordination number, and water bridge fabric tensor. Simulations were also conducted to investigate the impact of moisture content on the sedimentation process and dynamic response of level and sloping ground unsaturated deposits. The outcome of these simulations was in agreement with observations of densification mechanisms of unsaturated soils, and provided valuable insight into the response mechanisms of this type of soils. The proposed micro-mechanical model was shown to be an effective tool to investigate the state of stress and response of unsaturated (pendular state) granular soil systems when subjected to static and cyclic load conditions.