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A constitutive model for unsaturated soil-structure interfaces

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Abstract

In geotechnical engineering structures, there may be a thin layer of soil between soil and structure through which, load transferring occurs. This layer is called soil-structure interface and the mechanical response of geostructures depends strongly on the behavior of this layer. If the soil mass is in unsaturated state, then the interface is technically called unsaturated interface. In this paper, a constitutive model for unsaturated soil-structure interfaces is introduced. The soil-water characteristic curve and the concept of modified effective stress are adopted to create an appropriate hydro-mechanical coupling. The model predictive capacity is evaluated by comparing its predictions with the existing experimental data.

Keywords: Constitutive model, Matrice suction, Critical state, Unsaturated interface.

1. INTRODUCTION

To understand the behavior of most geotechnical constructions such as deep foundations, retaining walls, soil-nailing, off-shore, and underground structures, knowledge on the mechanical behavior of their interfaces with soil is essential. Early experimental researches into soil-structure interfaces have performed by means of direct shear [1-2], ring shear [3], simple shear [4-5] devices and particle image velocimetry [6] technique. According to these studies, behavior of soil-structure interfaces depends on various factors including stress path, density, normal stress, normal stiffness, structure roughness, mineralogy and degree of saturation.

Modeling of soil-structure interfaces is a young area in geotechnical engineering. For instance Clough and Duncan [8] developed an interface model based on the hyperbolic elasticity. Ghionna and Mortara [1], Shahrour and Rezaie [9], Fakharian and Evgin [10] among others, introduced constitutive models for soil-structure interfaces in the framework of elastoplasticity theory. De Gennaro and Frank [11] developed a constitutive model which can simulate normal dilatancy in soil-structure interface behavior. Recently, Lashkari [12-15] using the framework of bounding surface plasticity and critical state soil mechanics, proposed a constitutive model to simulate the behavior of sand-structure interfaces. The most important advantage of this model is to predict the mechanical response of interfaces in wide ranges of densities and applied normal stresses, using a unique set of parameters. Recently, Lashkari [16], used this model to predict the shaft resistance of non-displacement piles in sand.

In practical problems, often, we deal with partially saturated soils, whereas, most researches on soil-structure interfaces have done considering fully saturated or dry states. The first attempts to understand the behavior of unsaturated interfaces are those of Miller & Hamid [17], Hamid and Miller [18] and Khoury et al.[19]. By using the framework of two independent stress variables, Hamid and Miller [20] introduced the first constitutive model for unsatureted soil-structure interfaces. The biggest weakness of this model is that, for wide ranges of states and suction, it needs several sets of parameters to predict the behavior of interfaces. Recently, based on the critical state soil mechanics and two independent stress variable concept, Lashkari [22] introduced an extension to his previous interface model (e.g., [12-16]) for simulation of unsaturated interfaces. This model is capable of predicting the behavior of unsaturated sand-structure interfaces for different ranges of density, normal stresses, and suctions values by using a unique set of parameters.

Recent studies revealed that the framework of two independent stress variables responds to describe the behavior of unsaturated soils, only when, one of the variables is kept constant [23]. Furthermore, this framework is unable to appropriately simulate the hydro-mechanical coupling. Regarding these issues, Houlsby [24] demonstrated that two sets of stress-strain (like) variables are necessary to describe