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Micromechanical modeling for behavior of silty sand with influence of fine content

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ABSTRACT

Silty sand is a soil mixture with coarse grains and fine grains. Experimental observations have shown that small amount of fines may reduce the undrained shear strength significantly. The purpose of this paper is to propose a micromechanical model for the stress–strain behavior of silty sand influenced by fines under drained and undrained conditions. The micromechanical stress–strain model accounts for the influence of fines on the density state of the soil mixture, thus consequently affect the critical state friction angle and the amount of sliding between particles. The present model is examined by simulating typical drained and undrained tests in conventional triaxial conditions. The simulated stress–strain curves are compared with the measured results on samples made of Ottawa sand and Foundry sand with various amounts of fines. The predictive ability of the present model for simulating the behavior of silty sand is discussed.

1. Introduction

The stress–strain behavior of silty sand has been experimentally studied by many investigators, e.g., Kuerbis et al. (1998), Pitman et al. (1994), Zlatovic and Ishihara (1995), Lade and Yamamuro (1997), Thevanayagam (1998), Thevanayagam and Mohan (2000), Salgado et al. (2000), Thevanayagam et al. (2002), Ni et al. (2004), and Murthy et al. (2007). Depending on the amount of fines content, the microstructure of a granular mix can be constituted with different ways of packing arrangements, which leads to different stress–strain responses. Among many variations, Thevanayagam et al. (2002) gave three extreme limiting categories of microstructure (see Fig. 1): (*case i*) coarse grains skeleton, (*case ii*) fine grains skeleton with coarse grains dispersed in the fine grain matrix, and (*case iii*) a layered system where the coarse grain layers have no fines confined in them and vice versa. Within *case i* there are three subsets: (1) the fines are confined within the void spaces between the coarse grains with little contribution to supporting the coarse grain skeleton; (2) they partially support the coarse grain skeleton; (3) or they partially separate the coarse grains. For silty sand with less than 25% fines, which is commonly found in natural environment, the microstructure can be best described by *case i*. It has been demonstrated in the experimental results that a small amount of non-plastic fines contents can significantly reduce the undrained shear strength of silty sand. Thus, soil with less than 25% of fines may have a very low strength that causes liquefaction problems during earthquake or instability problems of embankments/levees due to flooding. In this paper, we focus on modeling the stress–strain behavior of silty-sand with less than 25% fines.

Very little effort has been devoted to the modeling work of silty-sand. Yamamuro and Lade (1999) had made modifications to the shape of the yield surface in their single hardening model which enables predictions of the behavior pattern of Nevada sand with 20% fines. This type of approach may be cumbersome for applications to silty sand with different amounts of fines, because the yield surface may be of different shapes for different amounts of fines content. In order to overcome the difficulties, we propose a new model for the behavior of silty sand.

Since we aim to model soil with fines content below 25%, the soil behavior is primarily dominated by the coarse grain skeleton. In order to model the deformation of coarse grain skeleton with the effect of various amounts of fines content, we propose a model based on a micromechanics approach similar to that utilized by Chang and Hicher (2005).

In what follows, special considerations required for modeling silty sand using a micromechanics approach are first discussed. The density characteristics for the soil mixture are significantly affected by the amount of fines. To model this effect, an equation is derived to determine the void ratio change due to the presence of fines. A micromechanical model for silty sand is described that accounts for the influence of fines, through which, the deformation of an assembly can be obtained by integrating the movement of the inter-particle contacts in all orientations. Experimental results on

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