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Unsaturated soil–geotextile interface behavior

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ABSTRACT

The behavior of mechanically stabilized earth (MSE) structures under seasonal climatic variations, i.e. wetting and drying, is not well understood. Stability and serviceability of MSE walls and embankments can significantly depend on the soil-reinforcement (e.g., geosynthetics) interface shearing behavior in unsaturated conditions. This is especially true for reinforced soil slopes and embankments that have significant fines contents. This paper presents results of a laboratory study on the mechanical behavior of unsaturated soil-geotextile interfaces using a specially modified direct shear apparatus. Several suction-controlled laboratory tests were conducted to investigate the effect of soil suction on the soil-geotextile interface. Results of the study indicate that the peak shear strength of the soil-geotextile interface increases nonlinearly with the soil suction. On the other hand, while inconclusive, the effect of suction on the post-peak shear strength of the interface was negligible in some cases. An elastoplastic constitutive model was used to simulate the laboratory results. This study demonstrates that the constitutive model is capable of capturing the mechanical behavior of the unsaturated soil-geotextile interface subjected to constant suction. Both shearing and volume change responses were reasonably simulated by the model.

1. Introduction and background

Construction of mechanically stabilized earth (MSE) walls and reinforced soil slopes (RSS) has increased significantly worldwide and specifically in the United States. For instance, on average more than 850 000 m^2 of MSE and 190 000 m^2 of RSS are constructed annually in the United States (Berg et al., 2009). Therefore, it is crucial to understand the behavior of these structures recognizing that their design is influenced by the shear strength of the interface between reinforcement layers and soil. Although coarse-grained soils are recommended as backfills in MSE walls in North America (Elias et al., 2001, AASHTO, 2002), some industry design guides (NCMA, 2002) allow for the use of up to 35% fine-grained soils, provided that a properly designed drainage system is present. The British Standard (BS8006, 1995) also allows cohesive-frictional soils (i.e., soils with greater than 15% passing 63 μm sieve) to be used for wall backfill materials. Backfills with up to 50% fine-grained soils (i.e., passing sieve #200) are allowed in some guidelines for the construction of reinforced embankments and slopes (Elias et al., 2001). In many projects (e.g., Powel et al., 1999; Musser and Denning, 2005) low quality backfill soils have been used in slopes and highways due to scarcity and high cost of good backfill soils in local areas. Since fine contents as low as 6–10% can significantly reduce the permeability of soils (BS8006, 1995, Elias et al., 2001; Koerner, 2005) and since these structures are built under unsaturated conditions, a main concern in their stability analysis and design is the reduction of the soil-reinforcement interface shear strength as a result of wetting. Factors such as seasonal precipitation and variation of the ground water table can significantly alter the soil moisture condition and suction, and thus the interface behavior. For example, some case studies of failure or large deformations of MSE walls have been reported (e.g., Mitchell and Zornberg, 1995; Christopher et al., 1998; Koerner, 2005; Sandri, 2005; Lawson, 2005; Stulgis, 2005) where backfill soils were compacted wet of optimum or where the structures under construction were subjected to heavy rainfalls resulting in increase of pore water pressure, decrease in matric suction, and thus reduction in shear strength and excessive deformations. Matric suction in the soil is defined as $u_a – u_w$, where u_a and u_w denote the pore air pressure and pore water pressure, respectively (e.g., Fredlund and Rahardjo, 1993; Lu and Likos, 2004).

Current laboratory techniques to determine the soil-geosynthetic interface strength include interface shear tests (ASTM, 2009; D5321) and pullout tests (ASTM D6706) on soil-geosynthetic specimens. Soil specimens are generally compacted at optimum moisture content and 95% of maximum dry density (e.g. as

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