Geotextiles and Geomembranes xxx (2016) 1–13

Contents lists available at ScienceDirect

Geotextiles and Geomembranes

journal homepage: www.elsevier.com/locate/geotexmem

Influence of particle shape on the shear strength and dilation of sand-woven geotextile interfaces

Aliyeh Afzali-Nejad, Ali Lashkari*, Piltan Tabatabaie Shourijeh

Department of Civil & Environmental Engineering, Shiraz University of Technology, P.O. Box 71555-313, Shiraz, Iran

ARTICLE INFO

Article history:
Received 17 January 2016
Received in revised form
26 May 2016
Accepted 1 July 2016
Available online xxx

Keywords:
Geosynthetics
Sand-geotextile interface
Direct shear
Dilation
Roughness
Density

ABSTRACT

The influence of particle shape on the mechanical behavior of sand-woven geotextile interfaces over a wide domain of soil density and normal stress is studied. A uniformly graded angular fine sand, and a blend of well rounded glass beads with identical particle size distributions, were selected as granular material. Experiments revealed the impact of particle shape on peak and residual friction angles as well as the maximum dilation angle of interfaces between both granular media and woven geotextile. It was observed that the residual friction angles of interfaces between angular sand/glass-beads and woven geotextile are very similar to the residual friction angles of angular sand and glass-beads in soil–soil direct shear test. It is understood that the peak friction angle and maximum dilation angle of angular sand-woven geotextile were slightly lower than corresponding values for angular sand in soil–soil direct shear test. While the peak friction angle and maximum dilation angle of angular sand-woven geotextile interface decrease with the increase in normal stress, experiments showed that these factors are insensitive to normal stress for glass beads-woven geotextile interfaces, at least for the range studied herein. All interfaces with woven geotextile as the contact surface exhibit an abrupt loss of shear strength in the post-peak regime of behavior. Finally, a unified stress-dilation law for the angular sand-woven geotextile, glass beads-woven geotextile, and angular sand-roughened steel interfaces is obtained.

1. Introduction

Interfaces between soil and reinforcement have a great influence on the performance of geosynthetic reinforced structures such as retaining walls, slopes, and embankments (e.g., Madhavi Latha and Murthy, 2007; Woon and Kim, 2007; Palmeira, 2009; Portelinha et al., 2014). On this subject, Krieger and Thamm (1991) showed that the mobilized friction angle between soil and geotextile is a key factor in assessment of failure in reinforced soil walls. Moreover, Finite Element Modeling and recently, Discrete Element Method simulations carried out by Karpurapu and Bathurst (1995), Rowe and Ho (1996), Desai and El-Hoseiny (2005), Basudhar et al. (2008), Bhandari et al. (2008), Ferellec and McDowell (2012), Wang et al. (2014, 2016) [among others] have revealed that soil-geotextile interaction plays a significant contribution in the stability, serviceability, and bearing capacity of earth structures. Goodhue et al. (2001) reported that the peak friction angle of sand–geotextile interfaces is about 65–75% of the sand peak friction angle. Jewell (1996) suggested that for a wide variety of interfaces between woven and non-woven geotextiles and soil, the interface friction angle may vary from 65 up to 100% of the soil friction angle. In the absence of detailed information, it is recommended assuming soil-geotextile interface friction angle limited to 65% of the soil friction angle (e.g., Look, 2007; Das, 2016). Therefore, accurate estimation of the soil-geotextile interface behavior by means of laboratory and numerical methods still deserves consideration.

The mechanical behavior of soil-geotextile interfaces depends on the physical soil properties (e.g., mineralogy, particle shape and size distribution, particle mean size, density, and degree of saturation), as well as the geotextile characteristics (e.g., material type, fabric, texture, tensile strength, failure strain, and water permeability) (Giroud et al., 1985; Athanasopoulos, 1993; Lee and Manjunath, 2000; Goodhue et al., 2001; Khoury et al., 2011; Anubhav and Basudhar, 2013; Esmaili et al., 2014; Hatami and Esmaili, 2015; Ferreira et al., 2015; Vangla and Latha, 2015; Vieira et al., 2015; Prasad and Ramana, 2016; Vangla and Gali, 2016). Among various experimental techniques developed for the investigation of soil-geosynthetic interaction, pullout and direct shear

* Corresponding author. Fax: +98 71 3727 7656.
E-mail addresses: afzali.aliye@sutech.ac.ir (A. Afzali-Nejad), lashkari@sutech.ac.ir, lashkari_ali@hamyar.net (A. Lashkari), piltan@sutech.ac.ir (P.T. Shourijeh).

http://dx.doi.org/10.1016/j.geotexmem.2016.07.005
0266-1144/

Nomenclature

A	corrected shear area
C_c	coefficient of curvature
C_u	coefficient of uniformity
d_{50}	mean particle size
Dr	relative density [$=100 \times (e_{max} - e)/(e_{max} - e_{min})$]
e	void ratio
e_0	initial void ratio
e_{max}	maximum void ratio
e_{min}	minimum void ratio
G_s	$=\rho_s/\rho_w$
h	height of soil specimen within the shear box
m_s	mass of soil specimen within the shear box
R_{max}	maximum peak-to-valley distance of surface asperities
R	roundness
R_n	normalized roughness [$=R_{max}(L=d_{50})/d_{50}$]
S	sphericity
u	horizontal displacement in direct shear test
v	vertical displacement in direct shear test
ϕ	mobilized internal friction angle [$=\tan^{-1}(\tau/\sigma_n)$]
ϕ_{res}	residual friction angle
ϕ_p	peak friction angle
ρ_s	average density of solid phase
ρ_w	density of water ($=1000$ kg/m^3)
σ_n	normal stress
σ_{n0}	initial normal stress
τ	shear stress
τ_p	peak shear stress
τ_{res}	residual shear stress
ψ	dilation angle [$=\tan^{-1}(\delta v/\delta u)$]
ψ_{max}	maximum dilation angle

tests are the most common ones. However, it is suggested that soil-reinforcement interaction can be better characterized by direct shear test when sliding at the soil-geosynthetic interface is likely to occur (e.g., Palmeira, 2009; Lopes, 2012; Vieira et al., 2013; Ferreira et al., 2015). Such a condition may happen at the toe of reinforced soil slopes. Hitherto, the direct shear test has been applied by many researchers to study the mobilization of frictional shear strength at soil-geotextile interfaces (e.g., Athanasopoulos, 1993; Lee and Manjunath, 2000; Goodhue et al., 2001; Khoury et al., 2011; Anubhav and Basudhar, 2013; Vieira et al., 2013; Esmaili et al., 2014; Ferreira et al., 2015; Hatami and Esmaili, 2015; Vangla and Latha, 2015; Vieira et al., 2015; Vangla and Gali, 2016). While some researches have employed large size direct shear boxes to study the mechanical behavior of soil-geotextile interfaces (e.g. Lee and Manjunath, 2000; Goodhue et al., 2001; Ferreira et al., 2015; Vangla and Latha, 2015; Vangla and Gali, 2016), standard box direct shear test has also been applied by many researchers to the same purpose (Khoury et al., 2011; Anubhav and Basudhar, 2013; Deb and Konai, 2014; Esmaili et al., 2014; Hatami and Esmaili, 2015). Vieira et al. (2015) reported that in general, the maximum and residual shear strengths obtained from large size and traditional direct shear devices are relatively close; however, it should be noted that the peak shear stress is usually achieved in lower horizontal displacements in large scale shear tests.

Constitutive modeling of soil-structure interfaces is a relatively young matter. Clough and Duncan (1971) introduced a hyperbolic model for soil-structure interfaces. De Gennaro and Frank (2002) proposed a plasticity model for sand–steel interfaces taking into account phase transformation. Later, Liu et al. (2006) and Lashkari (2013) suggested versatile state-dependent interface models capable of simulating the mechanical behavior of interfaces in a wide domain of density and normal stress values using a single set of parameters. For sand–geotextile interfaces, Anubhav and Basudhar (2010), Huang et al. (2014), and Anubhav and Wu (2015) proposed modified hyperbolic elastic models. Recently, Khoury et al. (2011) and Lashkari and Kadivar (2016) applied advanced constitutive models to simulate the mechanical behavior of partially saturated soil-geotextile interfaces. The influence of particle shape on the mechanical behavior of granular soils has been addressed in the literature (e.g., Cho et al., 2006; Rousé et al., 2008; Lashkari, 2014; Vahidi-Nia et al., 2015; Vangla and Latha, 2015). This paper reports result of a study on the effects of particle shape on the mechanical behavior of soil-woven geotextile interfaces. To this purpose, mobilization of shear strength and volume change response of interfaces between woven geotextile and fine angular sand and glass-beads were studied. The testing program covers a rather wide range of normal stress and initial void ratio values. For the sake of comparison, the behavior of interfaces between similar granular materials and a serrated steel block was also presented. The outcome of this study may be useful in development of novel constitutive models for sand–geotextile interfaces.

2. Interface materials

2.1. Granular materials

A graded sand and a blend of glass beads with physical properties given in Table 1 were, respectively, selected as angular and well rounded granular materials in this study. Scanning Electron Microscope (SEM) images for sand particles and glass beads are presented in Fig. 1. As plotted in Fig. 2, nearly identical particle size distributions were used for sand and glass beads specimens and thus, particle size is not considered as a variable here. In accordance with the Unified Soil Classification System, both granular media are categorized as fine poorly graded sand (SP).

2.2. Structural materials

A multifilament woven geotextile and a serrated steel block are used as structural materials. Table 2 presents general properties of the woven geotextile used is this study. The texture and filaments of the woven geotextile as observed in SEM photographs before and after six interface tests [with angular sand] are, respectively, presented through parts “a” and “b” of Fig. 3. It is worth noting that in experiments reported here, geotextiles were renewed after two tests. Photograph of the serrated steel block (100 mm in dimension and 11 mm in height) surface asperities is illustrated in Fig. 3(c).

Using a profilometer, longitudinal profiles of the serrated steel block and woven geotextile asperities are digitalized and typical samples are plotted in Fig. 4. Uesugi and Kishida (1986) introduced the concept of normalized roughness, R_n, as a unified index quantifying combined effects of surface roughness and particle size on the behavior of sand–structure interfaces:

$$R_n = \frac{R_{max}(L = d_{50})}{d_{50}} \quad (1)$$

Please cite this article in press as: Afzali-Nejad, A., et al., Influence of particle shape on the shear strength and dilation of sand-woven geotextile interfaces, Geotextiles and Geomembranes (2016), http://dx.doi.org/10.1016/j.geotexmem.2016.07.005