Procedia Engineering
Volume 143, 2016, Pages 146–152
Advances in Transportation Geotechnics 3 . The 3rd International Conference on Transportation Geotechnics (ICTG 2016)

Effect of Grain Shape and Size on the Mechanical Behavior of Reinforced Sand

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Abstract
The effect of sand grain shape and size on the mechanical behavior of geotextile-reinforced sands is investigated in the present research, based on the results of triaxial compression tests. Six clean uniform sands differing in grain shape (subangular or rounded grains) and/or grain size as well as one non-woven and three woven geotextiles with or without apertures, were used in this experimental investigation. Triaxial compression tests were conducted on specimens with a diameter of 70 mm and a height of 144 mm, consisting of dry and dense sands reinforced with 3, 5 and 7 horizontal geotextile disks. The geotextile-reinforced sands present higher strength and axial strain at failure than the unreinforced sands. The strength of reinforced sands increases with decreasing sand grain size, with increasing number of geotextile layers and is affected by the grain shape of sand, since it was observed that reinforced sands with subangular grains attain higher strength values than the reinforced sands with rounded grains. The triaxial compression tests yielded bilinear failure envelopes for all geotextile-reinforced sands.

Keywords: reinforced sands, geotextiles, mechanical behavior, shear strength, triaxial compression tests

1 Introduction

Reinforced soil structures, such as reinforced slopes, embankments and retaining walls, are frequently part of transportation infrastructure projects. Also, geotextiles are used as reinforcement for the cost-effective construction of roads, airfields and railroads. The safe and economical design of reinforced soil structures requires the knowledge of the mechanical behavior of the composite material. As free draining granular materials, e.g. sands, are specified as backfill material for reinforced soil structures, the mechanical behavior of sand – geotextile composites has been investigated in the past by conducting triaxial compression tests on sand specimens reinforced with sheets of geotextiles (e.g. Gray et al., 1982; Gray and Al-Refeai, 1986; Chandrasekaran et al., 1989; Baykal et al., 1992; Ashmawy and Bourdeau, 1998; Haeri et al., 2000; Wu et al., 2002; Madhavi Latha

[*] Supervised the research reported in this paper and prepared this document

 Selection and peer-review under responsibility of the Scientific Programme Committee of ICTG 2016

doi:10.1016/j.proeng.2016.06.019

and Murthy, 2007; Nguyen et al., 2013). Although the results of these investigations have provided valuable information on the effects of several important parameters, the effect of sand grain shape and size on the mechanical behavior of geotextile-reinforced sand needs further experimental documentation. This need is enhanced by the fact that the results of triaxial compression tests are also used for the understanding of the behavior of granular columns reinforced with horizontal reinforcement layers and used for the improvement of weak or soft soils (Wu and Hong, 2008; Hong and Wu, 2013).

It is, therefore, of merit to investigate the effect of sand characteristics (grain shape and size) on the mechanical behavior of the composite material. Toward this end, an experimental investigation was conducted on a variety of sands reinforced with different geotextiles and the results obtained, are reported herein. The 131 triaxial compression tests on geotextile-reinforced sands, required for the present study, were conducted using conventional testing equipment.

2 Materials and Procedures

Conventional laboratory triaxial compression equipment without modifications was used to conduct tests on geotextile reinforced sands in order to investigate the mechanical behavior of the composite material. The tests were conducted using six clean uniform sands in dry and dense condition with grain sizes limited between ASTM sieve sizes Nos. 4 and 10, 16 and 20, 20 and 30, 30 and 40, and 40 and 100. From the properties of sands presented in Table 1, it can be seen that the sands also differ in grain shape since three of them (designated as S 4-10, S 16-20 and S 20-30) consist of subangular grains while the other three (designated as R 20-30, R 30-40 and R 40-100) are standard Ottawa quartz sands with rounded grains. The values of angle of internal friction, φ, of the sands in dry and dense condition are also shown in Table 1, together with the average relative density values of the specimens tested in triaxial compression for the determination of them.

Sand	Grain shape	Grain sizes (mm)			Void ratios		Shear strength characteristics	
		D_{max}	D_{50}	D_{min}	e_{max}	e_{min}	Friction angle φ (°)	Rel. density D_r (%)
S 4-10	Subangular	4.75	3.00	2.00	0.81	0.51	45.0	76
S 16-20	Subangular	1.18	1.00	0.85	0.92	0.58	48.5	92
S 20-30	Subangular	0.85	0.71	0.60	0.96	0.62	47.0	83
R 20-30	Rounded	0.85	0.71	0.60	0.77	0.46	36.0	82
R 30-40	Rounded	0.60	0.51	0.43	0.85	0.52	35.0	92
R 40-100	Rounded	0.43	0.25	0.15	0.79	0.52	37.0	90

Table 1: Soil properties

Four different commercially available geotextiles were used during this investigation. These geotextiles were selected in order to test non-woven and woven products with or without apertures. More specifically, one thermally bonded non-woven polypropylene geotextile (TYPAR SF 56), one standard grade woven polypropylene geotextile without apertures (BONAR SG 80/80), one woven polyethylene geotextile with apertures (NICOLON 66447) and one woven polyester with PVC coating geotextile with apertures (HUESKER HaTe 50.145), were tested. These geotextiles are designated as SF 56, SG 80/80, N 66447 and H 50.145, respectively. Pertinent geotextile properties, according to the manufacturers, are presented in Table 2.

Triaxial compression tests were conducted using samples with a diameter of 70 mm and an overall height of 144 mm. A schematic representation of the reinforced sand samples with 3, 5 and 7 horizontal geotextile layers is shown in Figure 1. The geotextile reinforcement discs had a diameter equal to the diameter of the sample and were placed at equal distances perpendicular to the axis of the