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Laboratory evaluation of the behavior of a geotextile reinforced clay

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ABSTRACT

To evaluate the behavior of cohesive soil reinforced with a geotextile, 144 unconfined and 72 unconsolidated–undrained (UU) triaxial compression tests were conducted. The moisture content of soil during remolding, relative compaction, soil type, confining pressure, type and number of geotextile layers were all varied so that the behavior of the sample could be examined. The results provide evidence that as the moisture content increases, the peak strength of both the reinforced and unreinforced samples decreases and the axial strain at failure increases. Moreover, with increasing relative compaction the peak strength of the sample and axial strain at failure increases, whereas the peak strength ratio decreases. The peak strength ratio is the ratio of the peak strength of the reinforced samples to that of the unreinforced samples. For soils with low plasticity indices the main cause of the increase in the strength is the increase in the cohesion of the reinforced sample. However, in soils of higher plasticity index, as the number of geotextile layers increases, the internal friction angle of the reinforced samples increases.

1. Introduction

The main limitation to soil structure stability is the low strength of many cohesive soils. By reinforcing the soil with geosynthetics this problem is somewhat overcome. One of the most common geosynthetic materials used to reinforced soil is geotextiles. Several laboratorial and theoretical investigations have been conducted in this field, most of which are related to granular soils reinforced with geotextile, while limited studies have been made concerning cohesive soils reinforced with geotextiles.

Ingold (1979) used a triaxial apparatus to conduct research on reinforced cohesive soils. Ingold and Miller (1983) reported the results of undrained triaxial tests on Kaolin clay reinforced by aluminum plates and permeable plastic. Fabian and Fourie (1986) defined the effect of the permeability of the reinforcing material on the undrained strength of reinforced clay by conducting UU triaxial test on clay reinforced by materials with different values of permeability. Lafleur et al. (1987) used a series of direct shear tests on highly plastic cohesive soil to evaluate and compare the behavior of woven and non-woven geotextiles on the behavior of clay. Krishnaswamy and Srinivasula Reddy (1988) reported the influence of the distance between the reinforced materials as well as moisture content of the sample by using undrained triaxial experiments on silty clay reinforced with a geotextile. Srivastava et al. (1988) studied the behavior of silty soil reinforced with geotextiles by using unconfined and triaxial tests. By analyzing the confining pressure, the number of reinforcing layers and the ratio of height to the diameter of the sample were evaluated. Al-Omari et al. (1989) performed CU and CD triaxial tests in order to study the behavior of clay reinforced with geomesh. Indraratna et al. (1991) studied the behavior of reinforced and unreinforced soft silty clays through UU triaxial test. Non-woven and woven geotextiles were used in that study. The use of non-woven geotextiles for reinforcing a near-saturated silty clay was evaluated by Ling and Tatsuoka (1993) using a plane strain device. Zornberg and Mitchell (1994) gave a comprehensive review of the experimental and analytical studies which focused on the behavior of reinforced cohesive soil. The behavior of reinforced clay was examined in triaxial compression tests under both static and cyclic loading conditions by Unnikrishnan et al. (2002). Effects of the sand layer thickness, moisture content and reinforcement types were evaluated. Vinod et al. (2007) performed a series of undrained triaxial tests on clay specimens reinforced with sand–coir fiber cores. Influence of variables such as ratio of cross-sectional area of sand–coir fiber core to that of the triaxial test specimen, confining pressure, fiber content and fiber aspect ratio on the behavior of the composite soil specimen was studied. Other studies in this field were reported by Ingold and Miller (1982), Ingold (1983), Fourie and Fabian (1987), Miura et al. (1990), Li et al. (1995), Athanasopoulos (1996), Kolias et al. (2005), Lekha and Kavitha (2006), Tang et al. (2007), Sachan and Penumadu (2007), Wang et al. (2007), Prashant and Penumadu

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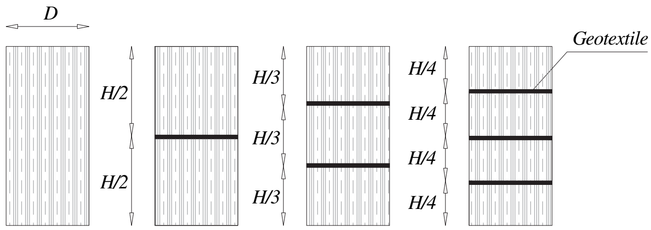

Fig. 1. The arrangement of geotextile in different samples.

(2007), Houston et al. (2008), Kim et al. (2008) and Subaida et al. (2009). In the present study, the mechanical and stress–strain behavior of cohesive soils reinforced with geotextile has been evaluated from a different perspective. Cohesive soils may have a wide range of plasticity indices. The behavior of such soils is also affected by the relative compaction. Although the previously mentioned research was conducted with cohesive soils, the two aforementioned parameters have not yet been evaluated for clays reinforced with geotextile layers.

2. Testing programme

To investigate the effects of varying soil parameters on the mechanical behavior of unreinforced and reinforced cohesive soils, a total of 114 unconfined and 72 triaxial compression tests were performed. Moreover, during the experiments, some of the tests were repeated to determine the accuracy of the results. The experiments were all conducted on a sample of diameter 38 mm and height 76 mm. The procedures for specimen preparation and testing were standardized to achieve repeatability in the test results. All the initial tests were repeated until consistent results were obtained. The different soil and geotextile parameters that were varied during the experiments are:

a. Two types of geotextiles.
b. The number of geotextile layers, illustrated in Fig. 1.
c. Three different moisture contents; two percent below the optimum moisture content, optimum moisture content and two percent above the optimum moisture content (at standard proctor compaction).
d. Three different relative compactions (90, 95 and 100% of the standard compaction).
e. Two types of soil with different plasticity index (Amol clay with plasticity index of 26 and Khalilshahr clay of 11).
f. Three different confining pressures (600, 800 and 1000 kPa).

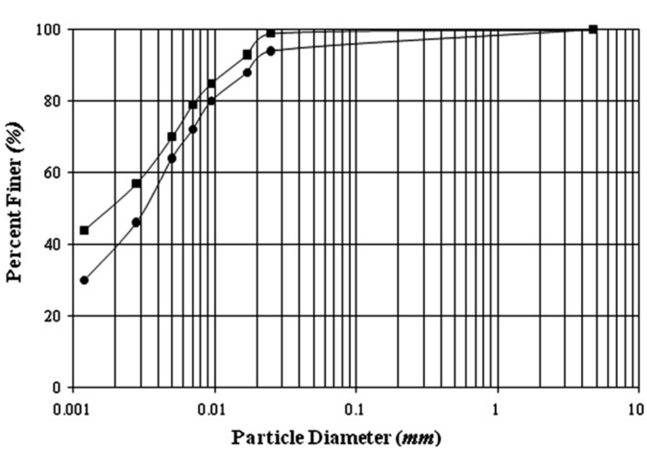

Fig. 2. Grain-size curves for Amol clay.

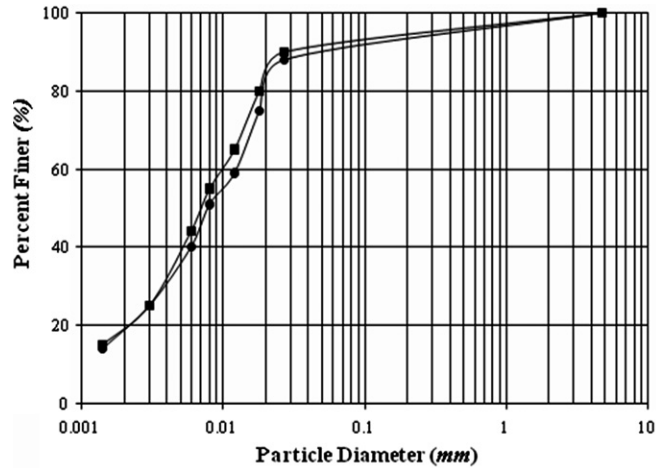

Fig. 3. Grain-size curves for Khalilshahr clay.

All testing was conducted with a strain-controlled rate of 1.5% per minute for the unconfined test and 1% per minute for the triaxial tests.

3. Materials used

Clay soils from Amol and Khalilshahr in the North Iran were used for the testing program. The standard test method for particle-size analysis was done for each soil type, provided in Figs. 2 and 3. The testing procedure was performed according to the ASTM D 422-63 (ASTM, 2003). Clay from Amol classifies as CH using the unified classification system, and clay from Khalilshahr is CL. The clay of Khalilshahr is referred to as type I and the clay of Amol as type II. The physical and compaction properties of the soils are provided in Table 1. All the soil properties were determined by testing as per relevant ASTM standards. Two types of geotextiles were also used in the testing program. The physical and mechanical properties of these geotextiles are provided in Table 2, which were provided by the producing companies, which will be named first type and second type geotextiles, respectively.

4. Preparation of the samples

The preparation of the soil sample is of great importance for laboratorial research. The preparation of the different specimens will be outlined in this section. Initially, the water content of the soils was determined so that the amount of additional water, needed to achieve the desired water content for testing, could be determined. The soils were mixed with water and placed within

Table 1
Physical and compaction properties of the experimented soil types.

Description	Type of soil	
	Type I	Type II
Unified soil classification system	CL	CH
Passing percent No. 200 sieve, %	92	98
Liquid limit, %	35	52
Plastic limit, %	24	26
Plasticity index, %	11	26
Specific gravity of solids, G_s	2.7	2.7
Maximum unit weight (at standard proctor compaction energy), kN/m^3	17.1	15.8
Optimum moisture content (standard proctor compaction), %	18	22