Measurement 59 (2015) 372–381

Contents lists available at ScienceDirect

Measurement

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

Effects of coir fibers on tensile and compressive strength of lime treated soft soil

Vivi Anggraini [a,*], Afshin Asadi [b], Bujang B.K. Huat [a], Haslinda Nahazanan [a]

[a] Civil Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia
[b] Housing Research Centre, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia

ARTICLE INFO

Article history:
Received 18 March 2014
Received in revised form 15 September 2014
Accepted 19 September 2014
Available online 28 September 2014

Keywords:
Coir fiber
Lime
Indirect tensile strength
Tension cracks
Compressive strength
Soft soil

ABSTRACT

The purpose of this study is mainly to investigate the tensile and compression strengths of natural and treated soft soil. The tensile strengths and compression strengths of compacted specimens of natural soil, lime and coir fiber treated soil were obtained using the indirect tensile test and unconfined compressive test. The results revealed that both tensile and compressive strengths increased with the addition of lime, coir fiber and the increasing of the curing time. From the test results, the relationship of the unconfined compressive strength of the soft soil was predicted by the correlation agreed with the indirect tensile strength. It was indicated that lime and fiber reinforced soils took on the strain-hardening ductile failure characteristic. The load causing this failure was the highest obtained during the test, and the outer fractures occurred subsequent to the central fracture.

1. Introduction

The significance of tensile strength of cohesive soils in the design of pavement and earth structures reveals the complexity of the tensile behaviour of soils. Furthermore, the importance of the study related to the tensile strength of cohesive soils was emphasised by the fact the tension cracks often occurs in earth slopes were reported by Win [1] and Vanicek [2]. Tensile test of brittle materials such as rock and concrete has been extensively conducted in both engineering research and practices [3,4]. Conventional tests such as compression and shear tests of soils were not very useful to accurately assess the cracking phenomena in such structures. However, the study of tensile strength characteristics of cohesive soils has not been taken up extensively mainly due to the lack of a simple laboratory test to determine the tensile strength of soils. The indirect (Brazilian) test is used more frequently in rock mechanics as the sample is easily prepared from the obtained core drill; moreover, the load transfer is less difficult. Although the published studies of indirect tensile strengths on soils are limited, there have been some results published with respect to soil samples [5–8]. Several laboratory studies have been conducted to evaluate the effect of the inclusion of randomly distributed fibers with and/or without additives treated soil mass. A summary of the materials investigated in some previous studies are presented in Table 1.

However, all of the previous studies have shown that the addition of fiber reinforcement caused significant improvement in the strength as well as the decreased stiffness of the soil. Generally, the high tensile strength and the extendibility of the added fibers effectively help in reducing the compressibility and brittleness of the host soil, which is generally superior to traditional soil improvement approaches such as using cement and/or lime [4,7,9,10,14,15]. Recently, Fatahi et al. [11] employed fiber mixed with cement treatment technique to improve dynamic properties of soft soil.

* Corresponding author. Tel.: +60 12 2442058.
E-mail addresses: vianggraini@gmail.com (V. Anggraini), afshin.asadi@yahoo.com (A. Asadi), bujang@eng.upm.edu.my (B.B.K. Huat), n_nahazanan@upm.edu.my (H. Nahazanan).

http://dx.doi.org/10.1016/j.measurement.2014.09.059
0263-2241/

However more works are necessary to comprehend the influence of fiber inclusion on the mechanical behaviour of cemented and uncemented soils, especially the interfacial interactions between fiber surface and reinforced soil matrix. At the same time, there have been a growing environmental consciousness and understanding of the need for sustainable development in recent years, which have raised interests in using natural fibers as reinforcements in soil. The reinforcement of soils with natural fibers such as roots, sisal, coir and palm has recently received a great deal of attention [13,17,21].

This paper aims to investigate the effect of coir fiber content and curing time on the tensile strength and compressive strength of soft soil treated by lime as a possible material to be used for land-based structures. A number of untreated and treated soil specimens were subjected to indirect tensile test and unconfined compressive strength test. The tensile strength of soil as determined by the indirect tensile strength test was correlated with the values obtained from unconfined compression strength test. Also, to understand the underlying mechanisms of coir fibers treated soil, Scanning Electron Microscopy (SEM) test was conducted.

2. Materials and methods

2.1. Materials

The soil used herein was soft soil; a typically clay-based soil extensively distributed in Klang, Selangor Malaysia. The basic properties of the soil such as grain size analysis, specific gravity of the soil and Atterberg limits (liquid limit and plastic limit) were determined according to classification tests of British Standard (BS1377-2). This soil can be classified as inorganic class with high plasticity (CH). Basic properties of the used soil are presented in Table 2.

Coir fibers used in this investigation were light, elastic, have high initial strength, a low light resistance and a high durability. They were obtained from a factory in Batu Pahat, South Malaysia. The physical and mechanical properties of coir fiber are shown in Table 3.

A photograph of the short coir fiber is given in Fig. 1.

Table 2
Basic properties of the soft soil was used for this study.

Basic properties	Values
Natural moisture content (%)	98–103
Unit weight (gr/cm^3)	1.3–1.6
Specific gravity	2.55–2.67
Grain size analysis	
Sand (%)	5–20
Silt (%)	20–35
Clay (%)	35–70
Consistency limit	
Plastic limit (%)	35–49
Liquid limit (%)	61.5–80
Plasticity index	26–30
Salinity	1.3–1.7
Organic content (%)	5–6
Activity	0.875–1.25

Table 3
The physical and mechanical properties of coir fiber were used in this study.

Basic properties	Values
Length (mm)	5–15
Density (g/cm^3)	1.40
Breaking elongation (%)	25–34
Diameter (mm)	0.2–0.3
Tensile strength (MPa)	76–102

In this research hydrated lime product from *Limetreat*, Selangor Malaysia was used as an active additive. The lime was kept in an airtight container to preserve its originality. The chemical contents of hydrated lime used in this study are given in Table 4.

2.2. Sample preparation

Two series of the soil mixtures, with and without additives, were thoroughly mixed with various moisture contents. The soft soil and coir fibers were initially mixed thoroughly in a mechanical blender for about 10 min with the water being added, and then the moist mixture was mixed with lime. Different percentages of coir fiber rang-

Table 1
Materials investigated in some previous studies.

Fiber	Soil	Additive	Tests	References
Polypropylene glass	Kaolinite clay	–	UCS, TPB, HC, ITS	[7]
Polypropylene	Silty sand	–	ITS	[8]
Polypropylene carpet (0.1%, 0.2% and 0.5%)	Kaolinite bentonite	Cement (10–50%)	ST, UCS	[9–11]
Polypropylene	Sand	Cement (2%)	UCS	[12]
Coir fiber (1, 1.5, 2, 2.5%)	Black cotton	–	CU	[13]
Polypropylene (0.05%, 0.15% and 0.25%)	Clay	Lime (2–8%)	UCS	[14]
Polypropylene (0.05%, 0.15% and 0.25%)	Clay	Cement (5–8%)	UCS	[15]
Polyethylene terephthalate (PET)	Sand	Cement (1%)	UCS, STS, CD	[16]
Sisal	Clay	–	CU	[17]
Polypropylene	Sand		UCS	[18]
Sisal	Clay	–	UCS	[19]
Pulp	Kaolinite		UU, CU, CD	[20]

Notes: UCS = Unconfined Compressive Strength; TPB = Three-Point Bending; HC = Hydraulic Conductivity; UU,CU,CD = Unconsolidated Undrained, Consolidated Undrained, Consolidated Drained Triaxial Compressive Strength; ITS = Indirect Tensile Strength; ST = Shrinkage Test.