Special issue of the 2nd International Conference on Computational and Experimental Science and Engineering (ICCESEN 2015)

Use of Basalt Fibers for Soil Improvement

C.P. Ndepete[a] and S. Sert[b,*]

[a]Sakarya University, Institute of Natural Sciences, Sakarya, Turkey

[b]Sakarya University, Civil Engineering Department, Sakarya, Turkey

Soil reinforcement with natural and man-made fibers is one of the techniques to improve a number of mechanical and physical properties of soils. Although basalt originated fibers are currently being used for concrete, it is not an easy task to find a source in literature concerning the use of basalt fibers for soil improvement. In this study, basalt fibers have been used for this new aim. This study is an investigation into evaluation of the increase in soil strength, which is reinforced, in different percentages, by basalt chopped fibers. A silty soil sample has been chosen for this study and has been mixed, with 6, 12, and 24 mm long basalt fiber at varying contents. The unconsolidated undrained triaxial tests show that the addition of 24 mm long fibers into soil gives the maximum improvement in strength and the optimum fiber content (by dry weight of soil) is 1.5%.

DOI: 10.12693/APhysPolA.130.355

PACS/topics: 83.80.Nb

1. Introduction

Soil reinforcement is widely adopted to improve several mechanical and physical properties of soils. Natural and man-made fibers have been used for centuries as reinforcement materials. The idea behind the reinforcement is to randomly add fibers to the soils and improve their engineering characteristics, such as shear strength and compressibility.

Nowadays, because there is a clear need for environmentally friendly materials, numerous efforts have been dedicated to an effect of use of natural and composite fibers on strength behaviour of soils. While coconut fibers, sisal, palm fibers, jute, flax, barely straw, bamboo and cane are natural fibers, many studies were carried out by mixing synthetic (man-made) fibers, including polypropylene (PP), polyester (PET), polyethylene (PE), glass, nylon, steel, polyvinyl alcohol (PVA) with soil [1–5].

Basalt is a type of volcanic rock and a natural material. It can be used in civil engineering for many purposes, such as crushed rock in highway engineering or siding and flooring materials in buildings. In addition to glass, carbon and aramid fibers, basalt originated fibers were also used in concrete as an alternative reinforcement material, after being subjected to a melting and spinning procedure [6]. On the other hand, researches on the use of basalt fibers for soil improvement are rarely reported.

Glass fibers offer an economical balance between cost and expected strength properties for concrete; this makes them preferable to carbon and aramid. In recent years, basalt fibers have emerged as an alternative to glass fibers [7]. Basalt fibers are environmentally safe, nontoxic, and possess high stability and insulating characteristics [8]. In addition to the above mentioned properties, basalt fibers have better tensile strength than the E-glass fibers, greater failure strain in comparison with carbon fibers and provide good resistance against chemical corrosion, impact load and fire with less poisonous fumes [9, 10].

2. Materials and methods

In this study, the effect of basalt fiber inclusion on strength of a silty soil was investigated. The soil was reinforced by inclusion of fibers of various lengths at three levels of fiber content: 1%, 1.5%, and 2%. For every fiber content, the fiber lengths considered are 6, 12, and 24 mm. This study comprises the results of 40 unconsolidated-undrained (UU) triaxial tests.

The soil used in this study was classified as low plasticity silt (ML) according to Unified Soil Classification System (USCS). The soil was taken from the depth of 3–4 m, in Yenigün District, Adapazarı, Turkey. Table I shows the index properties of the soil.

TABLE I

Index properties of the soil.

Property	Value
fines content [%]	92
liquid limit [%]	34
plastic limit [%]	27
plasticity index [%]	7
optimum moisture content [%]	21
maximum dry unit weight [kN/m^3]	15.8
USCS and TS classification	ML

The diameter and the average weight of a single basalt fiber are given as 14 ± 2 μm and 13.44×10^{-6} g, respectively. The 24 mm long basalt fibers were found to increase the tensile strength at bending and compression strength, for C30 concrete, at about 30% and 2%, respectively [11].

After determining the optimum moisture content and maximum dry unit weight of original silty soil with standard compaction (Proctor) energy, 1%, 1.5% and 2%

*corresponding author; e-mail: sert@sakarya.edu.tr

basalt fiber added mixtures were prepared with optimum moisture content and compacted with the same energy. After compaction, four samples were taken from every compacted soil sample and unconsolidated undrained triaxial (UU) tests were conducted on these samples by changing the confining pressure (σ_3) from 100 kPa to 400 kPa. Figure 1 shows the basalt fibers, the soil mixed with basalt fibers and tested samples.

Fig. 1. Basalt fibers, the soil mixed with basalt fibers and tested samples.

3. Experimental results

The unconsolidated undrained triaxial (UU) tests results of prepared soil specimens are shown in Table II and Fig. 2.

TABLE II

Maximum deviator stress results of UU tests.

		6 mm fiber			12 mm fiber			24 mm fiber		
σ_3 [kPa]	Silt	1%	1.5%	2%	1%	1.5%	2%	1%	1.5%	2%
100	173	213	314	290	270	363	327	264	450	384
200	257	321	439	346	369	492	426	425	536	433
300	369	429	574	496	487	582	526	529	640	569
400	450	476	734	633	519	746	655	637	819	695

With fiber addition, undrained shear strength of all samples are observed to be increased. These are expected results regarding the studies on the other fiber types. It is shown from the results that the use of 1.5% fiber addition (by weight of soil) yields the maximum strength increase for all fiber lengths (Fig. 2a, b, and c). The increase in the compression strength can be caused by the bridge effect of fiber and this increase is not significant for a fiber content greater than 1.5%. Figure 2d shows that for 1.5% fiber content, the specimens with 24 mm fibers have larger undrained shear strength compared to other fiber length.

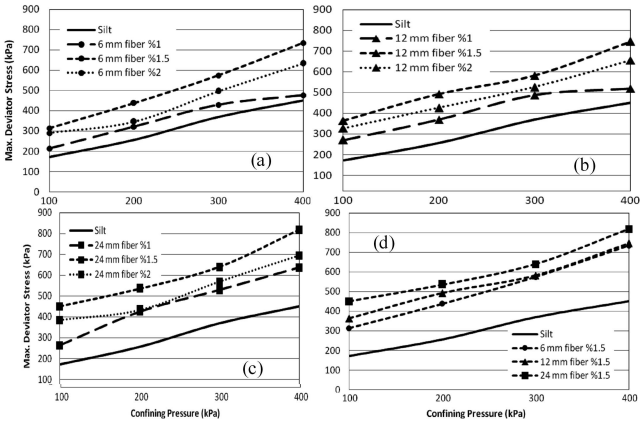

Fig. 2. UU test results for (a) 6 mm, (b) 12 mm, (c) 24 mm fiber added specimens, (d) UU test results for 1.5% fiber added specimens.

4. Conclusion

Based on the experimental results, it is concluded that undrained shear strength of silty soils increases with the inclusion of basalt fibers. The optimum fiber content (by weight of soil) corresponding to maximum improvement in strength is found to be 1.5%. The additional gain in strength is not observed when the fiber content is increased further to 2%. It is also concluded that fiber length has a significant effect on undrained shear strength of silty soils and 24 mm fibers added samples give higher strengths related to 6 mm and 12 mm fiber added samples.

References

[1] M.H. Maher, Y.C. Ho, *J. Geotechn. Eng. ASCE* **120**, 1381 (1994).

[2] G.L. Sivakumar Babu, A.K. Vasudevan, S. Haldar, *Geotextil. Geomembr.* **26**, 181 (2008).

[3] A. Zaimoglu, T. Yetimoglu, *Geotechn. Geolog. Eng.* **30**, 197 (2012).

[4] S. Akbulut, S. Arasan, E. Kalkan, *Appl. Clay Sci.* **38**, 23 (2007).

[5] S.M. Hejazi, M. Sheikhzadeh, S.M. Abtahi, A. Zadhoush, *Construct. Build. Mater.* **30**, 100 (2012).

[6] A. Ross, *Basalt Fibers: Alternative to Glass?*, *Composites World*, retrieved October 28, 2015 (2006).

[7] A. Nanni, A. De Luca, H.J. Zadeh, *Reinforced Concrete with FRP Bars: Mechanics and Design*, CRC Press, Taylor & Francis Group, 2014.

[8] C. High, H.M. Seliem, A. El-Safty, S.H. Rizkalla, *Construct. Build. Mater.* **96**, 37 (2015).

[9] N. Kabay, *Construct. Build. Mater.* **50**, 95 (2014).

[10] J. Sim, C. Park, D.Y. Moon, *Composites Part B* **36**, 504 (2005).

[11] `www.spintex.com`, retrieved October 28, 2015.