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# The Stabilization of Sandy Soils by Using the Plastic Bottle Waste

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**Abstract —** *The soil improvement methods recently became an attractive topic for geotechnical engineers. Because they do not have any control over the process of soil and some soil mass may not be suitable for supporting the desired facilities. When the mechanical qualities of these soils are lower than those required, stabilization can be an option to improve performance, notably in enhancing its strength. The solid waste materials are preferred as additive materials in soil improvement processes because they are more economical than factory product additive materials. As a result, researches in this direction show an increase. One of the solid waste materials is plastic bottles and produced using the Polyethylene Terephthalate. This study reports the properties of sandy soils when waste of the plastic bottles is used in fiber form as additive material in reinforced sandy soils. In this study, straight and irregular recycled polyethylene fibers were used. The percentages of recycled plastic fibers added in the concrete mix were 0.1%, 0.2%, and 0.3% respectively. The strength values show that the stabilized sandy soil samples with the waste of the plastic bottle fibers have high strength when compare with the unstabilized sandy soil samples. The results show that the reinforced sandy soil samples with the waste of the plastic bottle fibers have high strength when compare with the unreinforced sandy soil samples. Consequently, it is concluded that the waste of the plastic bottles materials can be successfully used for the reinforce of sandy soils in the geotechnical applications.*

***Keywords****-sandy soil; plastic bottle; waste material; soil improvement; freeze-thaw*

## I. INTRODUCTION

The sand is usually easily destroyed due to its low strength and cohesion and most of natural sand needs to be reinforced to meet the engineering requirements in the application of geotechnical engineering [1]. In order to enhance properties of weak soil formations such as loose sand deposits a wide range of ground improvement techniques have been introduced over the past decades. Majority of these ground improvement techniques utilize mechanical energy and fabricated binder materials. Nowadays, there is a high demand for new sustainable methods to improve soils. The extensive research has been undertaken to find alternative soil binders to replace high cost materials for soil improvement. The engineering properties of the soils are important not only in foundation materials for the projects, but also as materials for construction in embankments, dams, and other works.

The improvement of soil properties is necessary to solve many engineering problems. Soil improvement techniques can be classified in various ways, for example, mechanical, chemical, and physical stabilization [2-4]. In the mechanical stabilization, the soil density is increased by the application of mechanical forces in the case of surface layer compaction. Chemical stabilization includes incorporation of additives such as natural soils, industrial by-products or waste materials, and cementitious and other chemicals. Physical stabilization includes changing the physical conditions of a soil by means of heating or freezing [5-7].

There are several soil stabilization methods to improve the engineering properties of sandy soils. These methods include stabilization with chemical additives, rewetting, soil replacement, compaction control, moisture control, surcharge loading, and thermal methods [8-9]. All these methods may have the disadvantages of being ineffective and expensive. Therefore, new methods are still being researched to increase the strength properties [10-12].

The effects of different types of fibers on soil properties have been studied in the past decades. Environmental and economic issues have attracted the interest of many researchers to develop alternative materials that can fulfil design specifications. Experimental researches have shown that compressive strength, failure strain, ductility and shear strength of samples is increased when discrete fibers are mixed with the soil. These investigations indicate that strength properties of fiber-stabilized soils consisting of randomly distributed fibers are a function of fiber content and fiber-surface friction along with the soil and fiber strength characteristics [13-26].

The amount of plastic consumed annually had been increasing steadily. Polyethylene terephthalate is one of the most common consumer plastics used in the world especially for manufacturing beverage containers and other consumer goods [26-27]. The polyethylene terephthalate bottles are usually thrown away every day after every single use as beverage containers and most of them are discarded into landfills. Unfortunately, this is becoming a serious problem as plastic waste is not degradable and may cause environmental disturbance. The problems concerned with the management of numerous different types of waste, the scarcity of space for landfills and ever-increasing production costs as led to the search for alternative solutions such as the use of waste in concrete mixes [28-32].

In this study, the plastic bottle waste (PBW) fiber was used as additive material to stabilize the grained soils. The main objectives of this research were to produce different utilization areas for PBW fiber in geotechnical applications. In this study, the effects of PBW fiber on the mechanical properties of sandy soils was investigated under laboratory conditions. To accomplish these objectives, natural sandy soil was stabilized by using PBW fiber with different contents and the mechanical properties of sandy soils were determined in laboratory tests.

## II. MATERIALS

### 2.1. Sandy Soil

Soil is called sandy soil when the percentage of sand is high in a specific soil. Sandy soil is also known as light soil. The sandy soil generally composed of- 33,20 gravel, 62,40% sand and 4,40% silt and clay. In sandy soil, most of the soil particulars are bigger than 2mm in diameter and it has the largest particle among different soil particles. The sandy soil material used in this experimental study was supplied from Oltu Quaternary sedimentary basin, Oltu (Erzurum), NE Turkey. This material is classified as poorly graded Sand (SP) according to the Unified Soil Classification system (USCS). The photo of sandy soil material was given in the Fig. 1 and its grain size distribution was given in the Fig. 2.


*Fig. 1. Photos of sandy soil and PBW fiber*

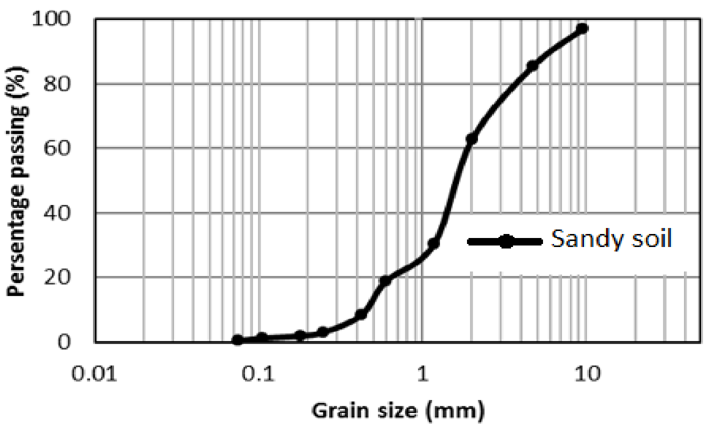



*Fig. 2. Grain size distribution of sandy soil*

### 2.2. PBW Fiber

The PBW fibers used in this study were obtained from Ertona Tekstil (Bursa, W Turkey) which provides raw materials to the textile market. The photo of PBW fiber material used in this study was given in the Fig. 1. The PBW fiber has a length of 20 mm, diameter of 0.035 mm. It has some physical properties such as specific gravity of 0.91, melting point of 265 °C and burning point of 590 °C.

## III. EXPERIMENTAL PROCEDURE

The sandy soil was dried in an oven at approximately 105 °C and then ground before using in the mixtures. First, the required amounts of sandy soil and PBW fiber were blended together under dry conditions. As the fiber tended to lump together, considerable care and time were spent to get a homogeneous distribution of the fibers in the mixtures. Then the sandy soil-fiber mixtures were mixed with the required amount of water according to the optimum moisture content. The contents of PBW fiber were selected as 0.1%, 0.2%, and 0.3% by the total weight of stabilized samples. The proportion of dry weight of sand is considered as the percentage of fiber and denoted as below.

$$P_{PBW} = \frac{W_{PBW}}{W_{SS}} x100\% \quad (1)$$

where $P_{PBW}$ is percentage of PBW fiber, $W_{PBW}$ is of PBW fiber and $W_{SS}$ is weight of dry sandy soil.

For unconfined compression test and freeze-thaw test, samples were prepared with static compaction method based on ASTM standards. Three-layered compaction was adopted to keep the uniformity of test samples with the 35 mm diameter and 70 mm height.

The unconfined compression tests were performed to obtain the unconfined compressive strength (UCS) values of tested samples were in accordance with ASTM D 2166. This test is widely used as a quick and economical method of obtaining the approximate UCS of the soils. The unconfined compression tests were carried out at the loading rate of 0,8 mm/min until samples failed.

This tests were performed by a programmable freeze-thaw apparatus. The samples with an age of 28 days were subjected to freeze-thaw tests in accordance with ASTM C 666. In the freeze-thaw apparatus, the samples were conditioned at -20 °C for 2.30 h. After freeze-thaw process, they were transferred into a test room at 20 °C to thaw for 2.30 h. This process was repeated 10 times.

## IV. RESULT and DISCUSSION

### 3.1. Effects of PBW on the UCS of Samples Unexposed to the Freeze-Thaw

The unconfined compression tests were performed to investigate the effect of PBW fiber on the UCS values of the samples unexposed freeze-thaw process and obtained test results were illustrated on the Fig. 3. The test results showed that the PBW fiber improved the UCS values of sandy soil samples. The sandy soil has low cohesion between the soil particles resulting in its loose structure. The fiber reinforcement mechanism in sand mainly includes that the fiber and sand particles constrain each other to produce interface force. This interface force is mainly caused by the extrusion pressure and in the form of cohesion and friction [1]. The maximum values of the UCS were obtained from stabilized samples of sandy soil including 0.3 % PBW fiber and 28 days of curing time. The same results were obtained from some experimental studies carried out in the past [11, 16, 33-36]. The highest strength values were obtained after 28 days curing time. The proportions of increase were 18,42%, 31,58% and 57,89% for the stabilized samples including 0,1%, 0,2% and 0,3% fiber, respectively. This increase in strength was proportional to the increase in curing time and fiber additive ratio.

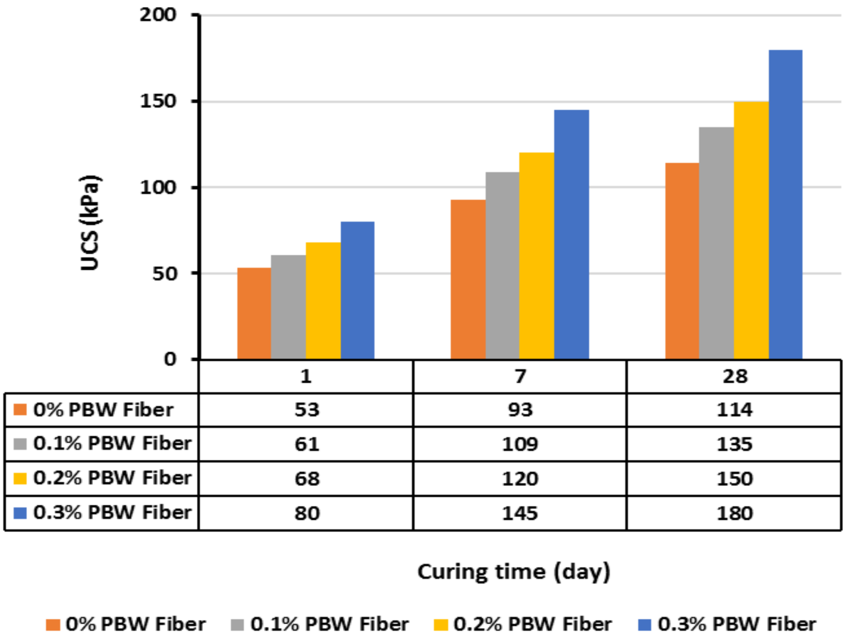
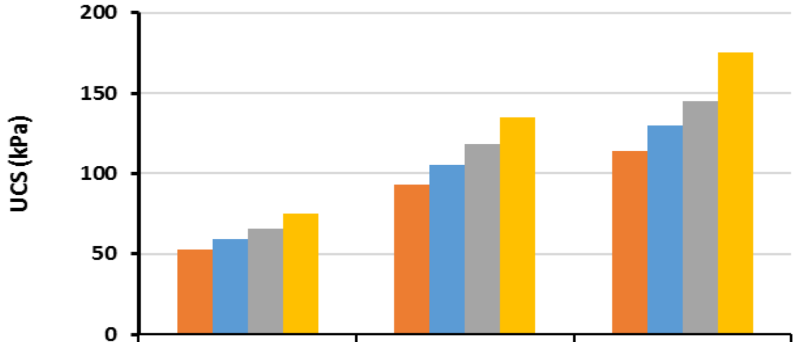



*Fig. 3. The effect of PBW fiber on the UCS of samples unexposed to the freeze-thaw*

### 3.2. Effects of PBW on the UCS of Samples Unexposed to the Freeze-Thaw

In this experimental study, all samples were subjected to the freeze-thaw tests to investigate the resistance of PBW fiber-stabilized sandy soil samples against to the freeze-thaw cycles. For this purpose, all samples were exposed to the freeze-thaw cycles and then these samples were subjected to the unconfined compression tests. The unconfined compression tests results showed that PBW fiber improved the freeze-thaw resistance of the sandy soil samples. After the freeze-thaw cycles, decrease in the UCS values of unstabilized sandy soil samples was highest level compared to the PBW fiber-stabilized sandy soil samples. It is thinking that the freeze-thaw cycles caused the decrease in the UCS values of samples because of water lenses accumulated in the pores. These water lenses reduced the friction between the grains and reduced the strength of the mixture. The highest strength values for samples exposed to the freeze-thaw cycle were obtained end of the 28 days curing time (Fig. 4). The rates of increase in the strength were 9,65%, 27,19% and 53,51% for the stabilized samples including 0,1%, 0,2% and 0,3% fiber, respectively.




| | 1 | 7 | 28 |
|---|---|---|---|
| 0% PBW Fiber | 53 | 93 | 114 |
| 0.1% PBW Fiber | 59 | 105 | 130 |
| 0.2% PBW Fiber | 66 | 118 | 145 |
| 0.3% PBW Fiber | 75 | 135 | 175 |

Curing time (day)

0% PBW Fiber   0.1% PBW Fiber   0.2% PBW Fiber   0.3% PBW Fiber

*Fig. 4. The effect of PBW fiber on the UCS of samples exposed to the freeze-thaw*

## V. CONCLUSION

The sandy soils have low strength behavior and most of natural sandy soils need to be stabilized to meet the engineering requirements in the application of geotechnical engineering. In this study, sandy soil with poor strength were stabilized by using PBW fiber and obtained results were discussed. According to the test results, PBW fiber improved the strength properties of sandy soil samples. Also, PBW fiber-stabilized sandy soil samples had more resistance of the freeze-thaw cycles compared with the unstabilized sandy soil samples. As a result, PBW fiber can use as an alternative waste material for the stabilization of the sandy soils.

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