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Reinforce in Engineering Properties of Clayey Soils Using Cigarette Butts and Marble Dust

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ABSTRACT

In last decades, using of natural or synthetic materials in the field of soil reinforce especially for coarse or fine-grained soils with poor physical and mechanical properties becomes very common. It is considered as the main condition that these materials, generated as waste or residual, have economic, sustainable and environmental importance. In this study, cigarette butts and marble dust as waste materials have been used to reinforce clayey soils. Resistance values have been determined before and after the freeze-thawing process. The highest strength value has been obtained with the mixture of clayey soil including 5% cigarette butts and 5% marble dust before and after freezing-thawing process. It is concluded that this mixture can be used for clayey soil reinforce in the regions where temperature changes are frequently experienced.

Key words: Clayey soil, cigarette butts, marble dust, soil reinforce, mechanical properties justify

INTRODUCTION

In recent years, using of waste materials as additives in the field of soil reinforce is very popular in the economic and environmental sides. Direction of using waste materials in the field of construction industry will prevent irregular and fast consumption of natural resources, afford economic benefits and solve many environmental quandaries caused by wastes. Approximately 5.7 trillion cigarettes produced around the world [1], that means more than 1.2 million tons of cigarette butts (CBs) waste with toxic elements being dumped into the environment every year, without doubt this cause serious environmental problems. This equivalent to the common saying that CBs are one of the most common types of litter around the world last years. Also, this material encompasses the largest percentage of waste that collected globally during the coastal clean-ups each year (Table 1) [2].

Table -1 Top marine debris items collected, international coastal clean-up

Debris item	Number of debris item	Percentage of debris item
Cigarettes/cigarette filters	2.117.931	19
Food wrappers/containers	1.140.222	10
Beverage bottles (plastic)	1.065.171	10
Bags (plastic)	1.019.902	9
Caps, lids	958.893	9
Cups, plates, forks, knives, spoons	692.767	6
Straws, stirrers	611.048	6
Beverage bottles (glass)	521.730	5
Bags (paper)	298.332	3
Top 10 total debris items collected	8.765.871	80
Total debris items collected worldwide	10.957.338	100

This circumstance is predicted to increase by more than 50% by 2025, referring to a prediction [3]. Only in Turkey, more than 131 million 371 thousand cigarettes are smoked every day according to [4]. Most of cigarette filters are made of cellulose acetate, such materials break down slowly and can take between 1 to 24 months to break down under normal conditions [5-6]. In a recent study, it has been demonstrated that the slow degradation process of CBs comes true in a 2-

year experiment in a standard decomposing organic substrate [7]. CBs is a widespread source of pollution and has long-term effects and causes immeasurable environmental damages on our environment such as cities, parks, country areas, water sources, soil, beaches and seas. Over 4000 different chemicals [8], and their persistence in the environment and potential toxic effects [9], these toxic chemicals and heavy elements remained in the CBs can be leached, and can cause serious damage to the environment [10-12]. CBs accumulate in the environment mainly due to the poor biodegradability of the cellulose acetate filters. CBs release a range of toxic chemicals as they deteriorate [10, 13]. They are carried by storm water into watercourses and ultimately the ocean where the chemicals they contain pose a risk to the organisms of both freshwater and marine environments [12, 14].

Landfilling and incineration of CBs waste are not universally sustainable or economically feasible disposal methods. Even when correctly binned and sent to landfill far from natural waterways, CBs remain an environmental hazard [15]. In addition, landfilling of waste with high organic content and toxic substances is becoming increasingly costly and difficult [16-17]. Incineration of CBs is also a seemingly unsustainable solution as emissions from the burning of waste contain various hazardous substances [18]. Recycling CBs is not easy because there are no effortless mechanisms or procedures to ensure efficient and economical separation of the butts and appropriate treatment of the entrapped chemicals.

There are numerous studies experienced on by-product materials to use them as additive materials for the modification of clayey soils [19-28]. The alternative, which has been investigated throughout this study, is to incorporate CBs and marble dust (MD) into soil properties modification. Synthetic or natural materials also can be used as additive material. Attempts have been made to incorporate waste in the soil modifications; for instance, the use of rubber [29], limestone dust and wood sawdust [30], processed waste tea [31], fly ash [32-33], polystyrene [34], and sludge [35]. Recycling of such wastes by incorporating them into soil reinforce materials is a practical solution to the pollution problems.

This paper describes some of the procedures and results from a study on integrating CBs and MD into clayey soil reinforce. Physical and mechanical properties of several samples with different CBs and MD contents are presented and discussed.

MATERIAL AND METHODS

Materials

The Clayey soil material used in this experimental study was supplied from Oltu Oligocene sedimentary basin, Oltu (Erzurum), NE Turkey. This material has clayey-rock characteristics in natural conditions and overconsolidated and it defines as high plasticity soil (CH) according to the Unified Soil Classification System (USCS) [20, 36]. Geologically, this soil contains montmorillonite as clay mineral. The grain-size distribution, XRD pattern, chemical analysis, and index properties are given in (Fig. 1 and 2), (Table 1 and 2), respectively, and the SEM image of the clay soil shown in (Fig. 3).

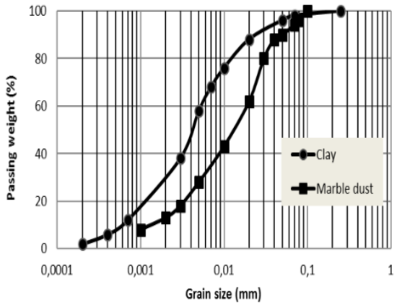
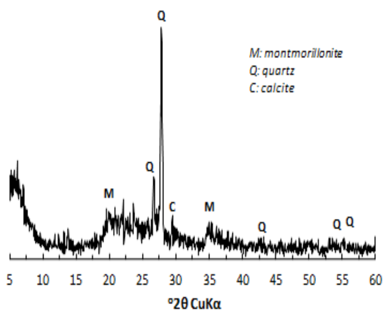


Fig. 1 The grain-size distributions of clayey soil and MD [36]



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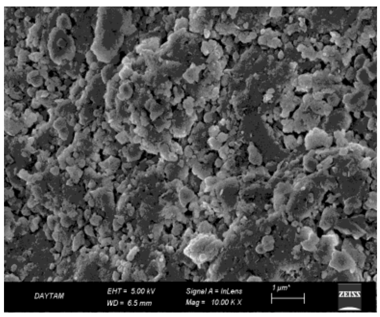

Fig. 3 SEM image of the clay soil

The CBs with different sizes used in this study were collected from the Ataturk University campus for two months (Fig. 4). After collecting, they have been kept in dry receptacles. The CBs were sterilized by heat at 105˚C for 24 h and then stored in sealed plastic bags. The SEM image of CBs is shown in (Fig. 5). CBs has been added to clayey soil and investigated the effects on the geotechnical properties. The percentages of CBs have been selected as 1%, 2.5% and 5%.

Table -2 Engineering properties of clayey soil [36]

Properties	Value
Specific Gravity, Gs	2.64
Sand (%)	10.0
Silty (%)	58.0
Clay (%)	32.0
Liquid Limit (%)	68
Plastic Limit (%)	28
Plasticity Index (%)	40
Optimum Water Content (%)	25.8
Max. Dry Unit Weight, (Kn/M^3)	14.1
Soil Class	CH

Fig. 4 CBs used in this study

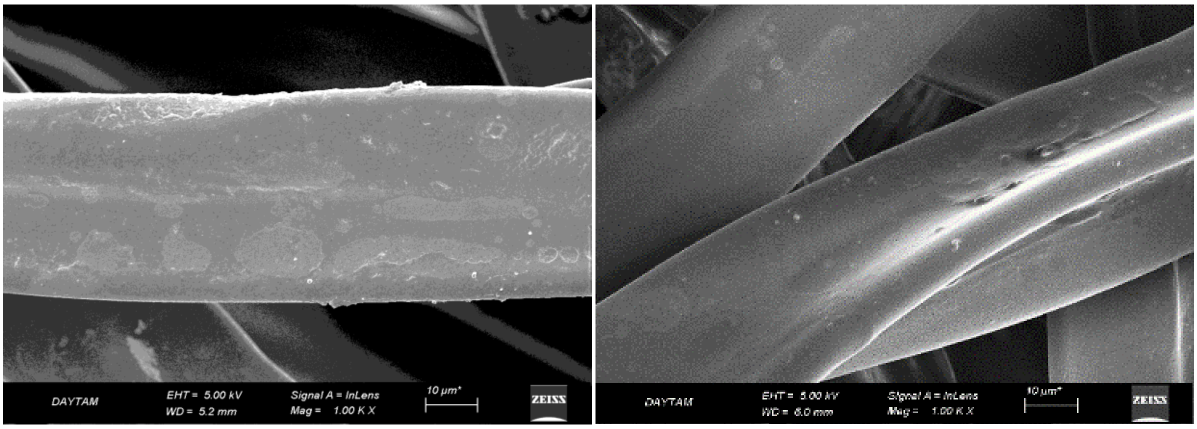

Fig. 5 SEM image of CBs

The MD used in this study is generated from cutting and polishing of marble stone. It is the powder of carbonate rocks known marble. The MD is the second component of this study after CBs and it has been supplied from Afyon (W Turkey). The dry MD was sieved by using 0.125 mm sieve to remove the coarse grains. The chemical properties were determined by Energy-Separated X-Ray Fluorescence spectroscopy method (ED-XRF) as shows in (Table 3). As shown in (Fig. 6), it contains calcite and quartz minerals. The SEM image of MD is shown in (Fig. 7) [37].

Table -3 Chemical properties of MD [36]

Compound	Value (%)
SiO_2	0.36
Al_2O_3	0.28
Fe_2O_3	0.04
CaO	54.98
MgO	0.62
Na_2O	0.03
K_2O	0.07
SO_3	0.06
CaO_2	43.56

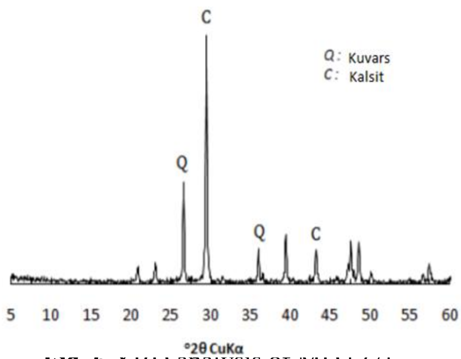

Fig. 6 XRD analysis of MD [37]

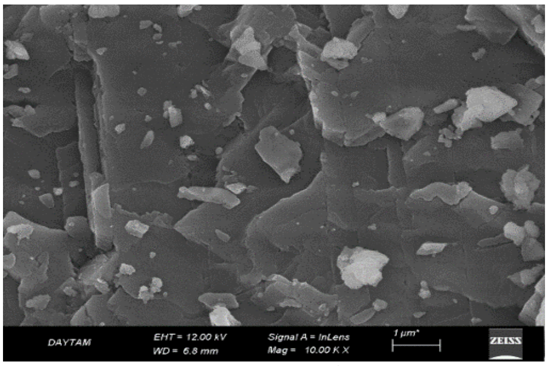

Fig. 7 SEM image of the MD

Preparation of samples

Clayey soil, CBs and MD were mixed together to obtain uniform and homogenous mixtures. The samples were prepared using different combination of these materials with different percentage. For each test, three sample using different proportions were used to investigate the effects of CBs and MD. In this study, the clay samples were mixed with three different percentages of CBs (1, 2.5, and 5%) respectively with 5, 10, and 15 % of MD respectively by weight of dry soil (Table 4). They were moulded at the optimum moisture content (25 wt. %) to achieve the targeted density. Each of the sample was cured naturally and free strength measurements taken at 1, 7, and 28 days, respectively. The standard compaction tests were carried out to determine the optimum water content and maximum dry unit weight. The samples were cylindrical with 38 mm diameter and 76 mm length. The free pressure strength values were determined using the digital free pressure device, loading speed was chosen as 0.8 mm/min. A deep freezer was used to accomplish the freeze test, and the temperature was set as - 21^{o} C. The thaw process was carried out at the laboratory temperature (+21^{o} C). The number of freeze-thaw cycles were 12 and the waiting time at each temperature was chosen as 24 hours (ASTM.D.698-78, ASTM.D.2166).

Table -4 Composite samples used in this study

Samples	Materials			Total
	Clayey Soil	CBs	MD	
CS	100.00	--	--	100
CS+CB1	99.00	1.00	--	100
CS+CB2	97.50	2.50	--	100
CS+CB3	95.00	5.00	--	100
CS+CB+MD1	94.00	1.00	5.00	100
CS+CB+MD2	92.50	2.50	5.00	100
CS+CB+MD3	90.00	5.00	5.00	100
CS+CB+MD4	89.00	1.00	10.00	100
CS+CB+MD5	87.50	2.50	10.00	100
CS+CB+MD6	85.00	5.00	10.00	100
CS+CB+MD7	84.00	1.00	15.00	100
CS+CB+MD8	82.50	2.50	15.00	100
CS+CB+MD9	80.00	5.00	15.00	100

CS: *Clayey soil,* ***CS+CB:*** *Clayey soil + CBs,* ***CS+CB+MD:*** *Clayey soil + CBs + MD*

RESULTS AND DISCUSSION

Changing in the strength before and after freezing

The change in free pressure strengths before and after freezing-thawing of the mixture by adding 1%, 2.5% and 5% of the CBs to the clay was investigated. At the end of the 28-day curing period, the highest strength values were obtained, before freezing-thawing, resistance rates increase of 5.19% in CS+CB1, % 20.12 in CS+CB2 and 106.91% in CS+CB3 samples, respectively. After freezing-thawing, CS+CB1 showed 14.84% drop in strength, while CS+CB2 had a strength increase of 2.58% and CS+CB3 had a strength increase of 24.81%. Therefore, the highest strength increase was obtained with CS+CB3 before and after freezing-thawing. The change in strength before and after freeze-thawing is shown in (Fig. 8), and change in the mixture structure shown SEM image in (Fig. 9).The changes in the free pressure strength of the clayey soil before and after the freeze-thawing were examined by adding 5%, 10% and 15% MD in addition to the fibers of the CBs as 1%, 2.5% and 5%.

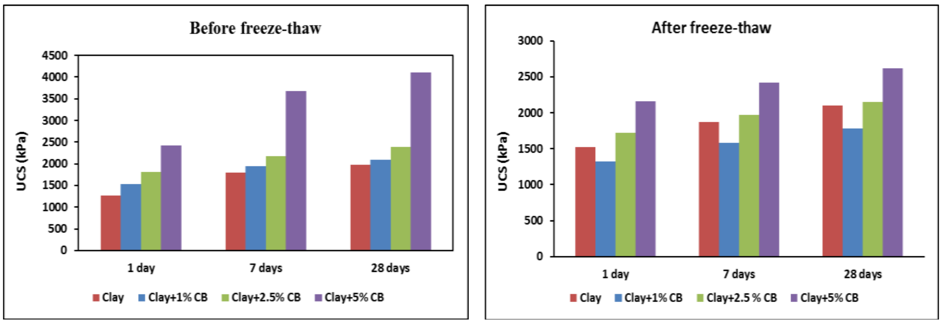

Fig. 8 Changes in the strength of the clayey soil + CBs before and after freeze and thaw

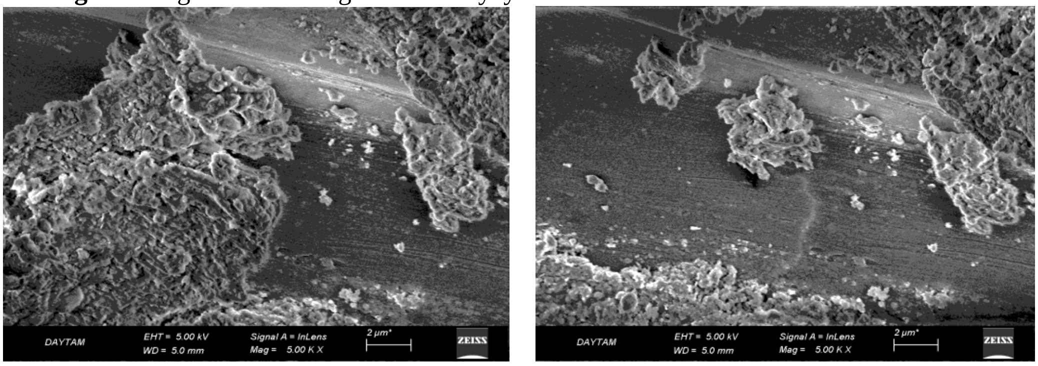

Fig. 9 SEM image before and after the freeze-thawing of the CS+CB3

The highest strength values were obtained at the end of the 28-day curing period, when we looking at the strength values before freezing-thawing. There was an increase of 3.73% in CS+CB+MD1, 21.53% in CS+CB+MD2 and 118.15% in CS+CB+MD3. The CS+CB+MD4 decreased by 1.66%, while CS+CB+MD5 increased by 30.11% and CS+CB+MD6 by 21.58%. There also an increase of 13.97% in CS+CB+MD7, 21.84% in CS+CB+MD8, and 46.65% in CS+CB+MD9.The highest strength values were obtained at the end of the 28-day curing period, when we looking at the strength values before freezing-thawing; there was an increase of 3.73% in CS+CB+MD1, 21.53% in CS+CB+MD2 and 118.15% in CS+CB+MD3, respectively. The CS+CB+MD4 decreased by 1.66%, while CS+CB+MD5 increased by 30.11% and CS+CB+MD6 by 21.58%, respectively. There also an increase of 13.97% in CS+CB+MD7, 21.84% in CS+CB+MD8, and 46.65% in CS+CB+MD9, respectively.

The strength after freezing-thawing, was increased of 2.77% in CS+CB+MD4, 6.97% in CS+CB+MD5 and 55.87% in CS+CB+MD6, respectively. Whereas CS+CB+MD4's strength increased by 12.60%, while CS+CB+MD5's decreased by 9.06%. There was an increase of 13.55% in CS+CB+MD6. While CS+CB+MD7 decreased by 2.91%, and CS+CB+MD8 increased by 5.25%, and CS+CB+MD9 increased by 23.57%, respectively. Therefore, the highest strength increase was obtained with CS+CB+MD3 before and after freezing-thawing. The changes in the strengths before and after the freeze-thaw are shown in (Figs. 10-11), and change in the mixture structure is shown SEM image in (Fig. 12).

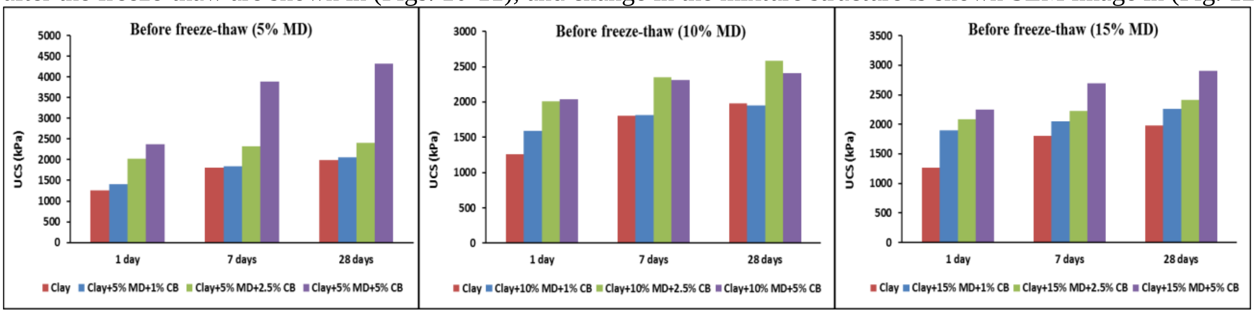

Fig. 10 Changes in strength of samples before freeze-thaw

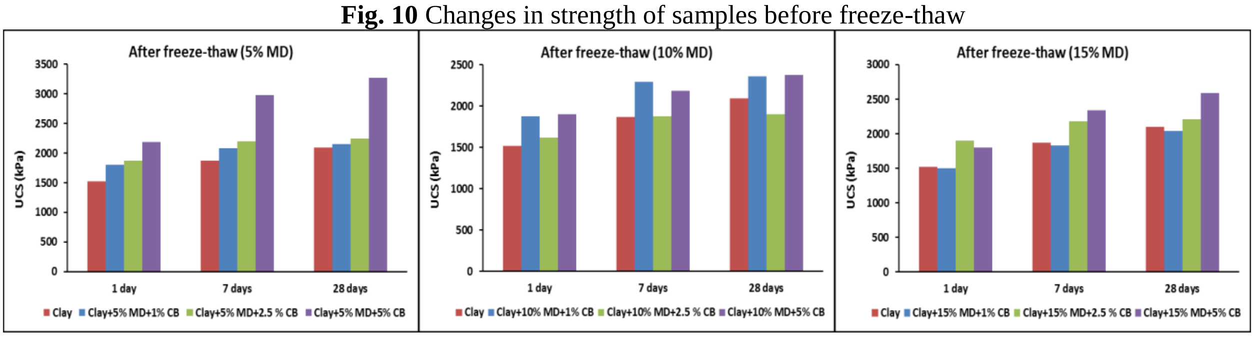

Fig. 11 Changes in strength of samples after freeze-thaw

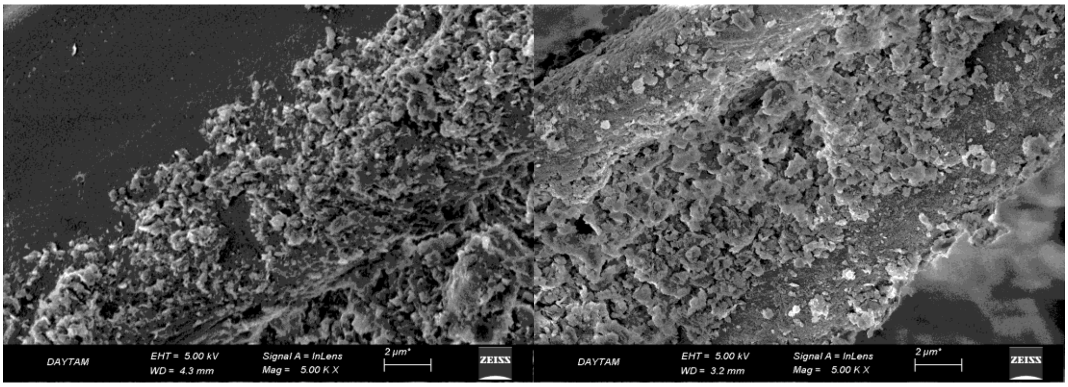

Fig. 12 SEM image of CS+CB+MD3 before and after the freeze-thaw

CONCLUSIONS

The effects of CBs and MD on the geotechnical properties of clayey soil was investigated and the results obtained this experimental study were given below. A significant change in free pressure strengths before and after freezing-thawing of the mixture strengthened by the addition of 1%, 2.5% and 5% CBs and 5%, 10% and 15% to the clay soil was observed. The highest strength values were obtained at the end of the 28-day curing period, before freezing-thawing cycle. The highest strength increase was obtained with CS+CB+MD3 samples before and after freezing-thawing cycle. From the data obtained, it was concluded that CS+CB+MD3 which is reinforced by joining CBs and MD into the clayey soil can be used for the soil improvement and it can be used as base and sub-base material of engineering structures in cold climate zones.

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