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Effect of Natural Pozzolana and Scrap Tire Rubber Mixture on Compacted Clayey Soils

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Abstract: The properties of compacted clay soils are improved by adding some solid additives. Natural, waste and factory-made materials are generally used as additives. For this purpose, one of these materials can be used or a mixture of two or more materials can be used. In this study, improved compacted clay soil samples were obtained by compacting the clay soil material at optimum water content by adding different proportions of natural pozzolana and scrap tire rubber waste mixtures. The obtained unimproved and improved clay soil samples were subjected to compaction tests and the compaction parameters of the samples were obtained. The results of the experimental study showed that the mixtures of natural pozzolana and scrap tire rubber were effective in the improvement of clayey soils. Mixtures of natural pozzolana and scrap tire rubber increased unconfined compressive strength. Also, it was seen that the samples of clayey soil stabilized have high freeze-thaw durability as compared to unstabilized clayey soil samples. Consequently, it is concluded that the natural pozzolana and scrap tire rubber mixtures can be successfully used for the improvement of clayey soils in the geotechnical applications.

Keywords: clayey soil;soil improvement; natural pozzolana; scrap tire rubber; unconfined compressive strength

1. INTRODUCTION

Soil described as a heterogeneous, porous, and three-phase system is regarded as a combination of gravel, sand, silt and clay and generally has low tensile and shear strength (Davari et al. 2021; Nath et al., 2017). Soils containing clay and silt have considerable potential of distress, because of its loss of strength of the soil during rainy seasons and shrinkage during summer (Kumar and Kumar 2020). Especially, expansive soils are considered as problematic due to potential for swelling and shrinkage under changing moisture contents (Kalkan et al., 2019; Kalkan et al., 2020; Soundara and Selvakumar, 2019). The behaviors of expansive soils with the property of plasticity, compressibility and very low bearing capacity differ at the different locations in accordance with soil type and origin and cause structural deterioration (Nivetha et al. 2019; Petry and Little 2002; Vijayan and Parthiban 2020; Yarbaşı and Kalkan 2020; Kalkan et al., 2022).

It has been noted in the literature that the expansive soils may cause severe damage to overlying structures, particularly to single-family residential buildings and buried pipelines and cables and consequent distress to people (Erguler and Ulusay, 2003; Sabtan, 2005). However, they are very important in geology, construction, and for environmental applications, due to their wide usage as impermeable and containment barriers in landfill areas and other environmentally related applications (Keith and Murray, 1994; Harvey and Murray, 1997; Murray, 2000; Kalkan, 2009). Improvement of certain desired properties like bearing capacity, shear strength and permeability characteristics of soil can be undertaken by a variety of ground improvement techniques such as the use of soil stabilization (Abuel-Naga et al., 2006; Chu et al., 2006; Castro-Fresno et al., 2011).

Several stabilization methods are available for stabilizing expansive soils. These methods include stabilization with chemical additives, rewetting, soil replacement, compaction control, moisture control, surcharge loading, and thermal methods (Chen, 1988; Nelson and Miller, 1992). All these methods may have the disadvantages of being ineffective and expensive. Therefore, new methods are still being researched to increase the strength properties and to reduce the swell behaviors of expansive soils (Puppala and Musenda, 2002). Many investigators have experienced on natural, fabricated, and by-product materials to use them as stabilizers for the modification of clayey soil (CS) (Aitcin et al., 1984; Sandra and Jeffrey, 1992; Kayabali, 1997; Asavasipit et al., 2001; Prabakar et al., 2003; Kalkan and Akbulut, 2004; Cetin et al., 2006; Kalkan, 2006; Akbulut et al., 2007; Tozsin et al., 2014a; Tozsin et al., 2014b; Tozsin et al., 2015; Kalkan, 2020; Kalkan et al., 2020; Yarbaşı and Kalkan, 2020).

The use of different pozzolanic materials for soil improvement is increasing (Al-Naje et al., 2020). Such materials have gained popularity due to their cost-effectiveness. Good geotechnical properties of soils can be achieved by using different pozzolanic materials (Hussein, et al., 2021). The application of pozzolanic materials in problematic soils stabilization can solve the problems of these soils, on the one hand. It can solve some of the issues of the environment, on the other. The application of these materials was shown as stabilization agents for expansive soils (Harichane et al., 2011; Al-Kalili et al., 2022).

The concept of soil reinforcement with natural fiber materials originated in ancient times. Randomly distributed fiber reinforced soils have recently attracted increasing attention in geotechnical engineering (Yetimoglu and Salbas, 2003). The concept and principle of soil reinforcement was first developed by Vidal (1969). He demonstrated that the introduction of reinforcement elements in a soil mass increases the shear resistance of the medium. The primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity, and reduce settlements and lateral deformation. There are several researches investigating the utilizability of scrap tire rubber (STR) as low-cost additive material for the soil stabilization (Hausmann, 1990; Zhang and Shijie, 2001; Prabakar and Sridhar, 2002; Yetimoglu et al., 2005; Yarbaşı et al., 2007; Akbulut et al., 2007; Zaimoğlu, 2010; Zaimoğlu and Yetimoğlu, 2012; Kalkan, 2013; Yarbaşı and Kalkan, 2020).

The basic objectives of this study were to investigate the usability of NP and STR as additive material in stabilization of CS and determine their performance properties as a function of NP and STR addition. For purpose, a number of experimental works was carried out under laboratory condition and obtained findings were evaluated.

2. MATERIAL AND METHOD

2.1. CS

CS used in this study was supplied from the outcrop of sedimentary sequence at the western side of Oltu District (Erzurum, ND Turkey). The CS material is defined as a high plasticity soil (Kalkan, 2003; Kalkan, 2009). Some properties of CS were given in Table 1.

2.1. NP

The NP used in this study was collected from a quarry at Sarıkamış (Kars) in the East of Anatolia. The NP material was dried, ground and then sieved to use it in the experimental study. Some properties of NP were given in Table 1.

Table 1. Some properties of materials used in this study (Akbulut et al., 2007; Harichane et al., 2011; Yarbasi and Kalkan, 2020)

Properties	CS	NP	STR
Density, g/cm^3	2.63	-	1.153-1.189
Sand, %	2	-	-
Silty, %	66	-	-
Clay, %	32	-	-
Liquid limit, %	73	-	-
Plastic limit, %	35	-	-
Unit volume weight, g/cm^3	37	-	-
Porosity, %	-	-	-
Elastic modulus, MPa	-	-	1.97-22.96
Tensile strength, MPa	-	-	28.1
Specific surface area, m^2/kg	-	420	-

2.1. STR

The STR fiber materialwas supplied in Erzurum (NE, Turkey). The tire is shaved off into 150 mm and smaller strips using a sharp rotating disc. These strips are then ground into scrap rubber (Pierce and Blackwell, 2003; Akbulut et al., 2007). The STR fibers had length of 1.18 mm. Some properties of NP were given in Table 1.

2.1. Preparation of Mixtures

The CS, NP and MW were weighted in the required proportions and then blended together under dry conditions. The weights of the mixtures were determined according to the formula below;

$W_{MIX} = W_{CS} + W_{NP} + W_{STR}$(1)

where W_{MIX}, W_{CS}, W_{NP}, W_{STR} are the total dry weights of sample mixtures, CS, NP and STR, respectively.Combination of mixtures used in this study was given in Table 2.

Table 2. Combination of mixtures used in this study

No	Sample	Materials (%)			Total
		CS	NP	STR	(%)
1	MIX0	100	-	-	100
2	MIX2	80	10	10	100

2.5. Compaction Test

In this study, Standard Proctor test was carried out in accordance with ASTM D 698 to determine the optimum moisture content (OMC) and maximum dry unit weight (MDUW) of samples and to yield sample for the unconfined compression tests.

2.6. Unconfined Compression Test

Unconfined compression test is widely used as a quick and economical method of obtaining the approximate compressive strength of the cohesive soils. In this study, the UCS values of samples were determined from the unconfined compressive tests in accordance with ASTM D 2166.

3.4. Freeze-Thaw (F-T) Tests

All samples were subjected to F-T tests in accordance with ASTM C 666. The samples were placed in the freezing apparatus and conditioned at −18 °C for 2.30 h. After the freezing was completed, the samples were transferred from the freezing apparatus into a test room at +20 °C for 2.30 h. This F-T cycle was repeated 20 times and then these samples were subjected to the unconfined compression tests.

3. RESULTS AND DISCUSSION

3.1. Effect of NP and STR Mixtures on UCS

To determine the effect of NP and STR mixtures on UCS, unconfined compression test were carried out at the laboratory condition. Also, to test the effect of curing time on the UCS values of unstabilized and stabilized with NP and STR mixtures, all samples were subjected to the curing time of 1, 7 and 28 days. The test results were illustrated in Figure 1. The samples stabilized CS samples with NP and STR mixtures gave higher UCS values compared to unstabilized CS samples. Similar trends were obtained with the addition of additives to clayey soils (Ranjan et. al., 1996; Prabakar and Sridhar, 2002; Akbulut et al., 2007; Zaimoglu, 2010; Hejazi et al., 2012; Kalkan, 2013; Muntohar et al., 2013; Lv and Zhou, 2019; Benziane et al., 2019).

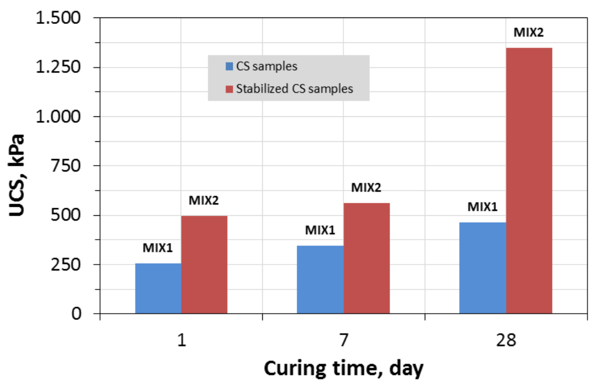

Figure. 1. Effect of NP and STR on the UCS of unexposed samples

The mixture of NP and STR was found to be effective on the UCS of CS and the UCS values of CS samples stabilized by adding NP and STR were higher. The improvement in the UCS values of CS samples stabilized with NP and STR mixture was attributed to changes in the composition of the material mass. The addition of NP and STR mixtures to the CS material caused a change in the composition of the stabilized CS. It is reported in the literature that the addition of additives changes the composition, mineralogy and grain size distribution of clayey soil (Gillot, 1968; Ola, 1978; Kalkan and Akbulut, 2004; Yarbasi and Kalkan, 2020; Yarbasi et al., 2023).

The STR fiber plays a major role in the increase in UCS values of CS stabilized with a mixture of NF and STR. The increase in UCS may be due to the bridging effect of the fiber, which can effectively prevent further development of fracture planes and deformations in the soil (Maher and Ho, 1994; Tang et al., 2007; Zaimoğlu and Yetimoğlu, 2012; Yarbasi and Kalkan, 2020).

3.2. Effect of NP and STR Mixtures on F-T Resistance of CS

To test the behavior of the mixture of NP and STR on the F-T resistance of CS, which shows a significant effect on the UCS values of CS; all samples were tested by exposing them to F-T cycles. The test results were illustrated in Figure 2.

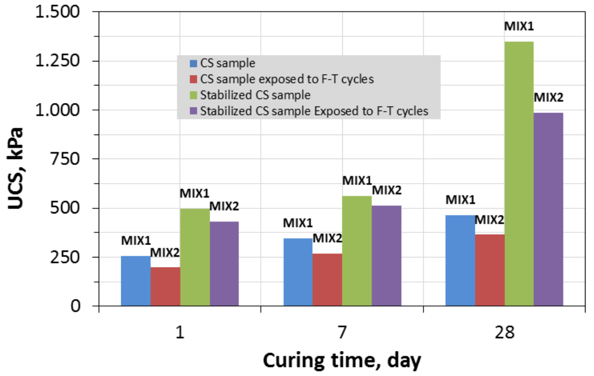

Figure. 2. Effect of NP and STR on the UCS of exposed samples

As shown in Figure 2, the mixture of NP and STR had a positive effect on the F-T resistance of stabilized CS. CS samples stabilized with a mixture of NP and STR became more resistant to F-T cycles.

All samples exposed to the F-T cycle were found to be negatively affected by the F-T cycle (Figure 2). This can be attributed to the freezing of the water in the pores of the soil samples, forming ice lenses in the pore space between the soil particles. Then, these ice lenses may have expanded in volume and pushed the soil particles and increased the gaps between the soil particles by acting as springs (Tunç, 2002; Işık et al., 2020; Yarbasi and Kalkan, 2020). However, the mixture of NP and STR showed its effect and the decrease in the UCS values of the CS samples stabilized with the mixture of NP and STR remained at a lower level than the unstabilized CS samples after freeze-thaw cycles (Figure 2). The higher UCS values of CS samples stabilized with a mixture of NP and STR resulted in greater F-T resistance to F-T cycles (Yarbasi and Kalkan, 2019; Yarbasi and Kalkan, 2020).

3. CONCLUSION

In this study, the effects of NP and STR blends on the UCS values and resistance of CS to F-T cycles were investigated. The experimental results showed a significant increase in the UCS values of CS samples stabilized with a mixture of NP and STR. At the same time, it was observed that CS specimens stabilized with NP and STR mixture had higher F-T resistance compared to unstabilized CS specimens. As a result, it was concluded that the mixture of NP and STR can be used to improve the strength properties of CS. The results also showed that the use of such blends can reduce the stabilization costs.

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