International Journal of Science and Engineering Applications
Volume 11-Issue 01, 27 - 30, 2022, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1101.1004

Freeze-Thaw Behavior of Stabilized Clayey Soil with Red Mud and Cement

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Abstract: The clayey soils in areas with seasonal frost are exposed to at least one freeze-thaw cycle every year and worsen their engineering properties. To prevent the engineering properties of clayey soils, it is necessary to improve the freeze-thaw resistance of them. In this study, the clayey soil was stabilized by using red mud and cement additive materials. Prepared samples of clayey soil and stabilized clayey soil were subjected to the unconfined compressive test. To investigate the effects of red mud and cement additive materials on the freeze-thaw resistance of clayey soil, the natural and stabilized expansive soil samples were exposed to the freeze-thaw cycles under laboratory conditions. The obtained results showed that the red mud and cement additive materials increased the freeze-thaw resistance of clayey soil. Consequently, it was concluded that red mud and cement additive materials can be successfully used to improve the freeze-thaw resistance of clayey soils.

Keywords: Clayey soil, red mud, cement, unconfined compression strength, freeze-thaw

1. INTRODUCTION

The clayey soils are generally classified as expansive soils and these soils are known to cause severe damage to structures resting on them. However, these soils 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 (Erguler and Ulusay, 2003; Harvey and Murray, 1997; Kayabali, 1997; Keith and Murray 1994; Murray, 2000; Sabtan, 2005; Kalkan and Akbulut, 2004; Kalkan et al., 2019; Indiramma et al., 2020; Yarbaşı and Kalkan, 2020).

The effects of freeze-thaw cycles on the geotechnical properties of clayey soils were studied (Lee et al., 1995; Eigenbrod, 1996; Konrad, 2000; Simonsen and Isacsson, 2001; Simonsen et al., 2002; Zhang et al., 2004; Kalkan, 2009). It was seen as a reason of such behavior in low freezing rate, pre-consolidation pressure developed during freezing, formation of new bonding between soil fabric units, and changes in free water (Broms and Yao, 1964; Yong et al., 1985; Eigenbrod, 1996; Yang et al., 2003; Kalkan, 2009). These changes are attributed to increased saturation with water caused by freezing and thawing, but much of the increase is attributed to changes in soil structure (Chamberlain et al., 1990; Porebska, 1994; Kalkan, 2009; Yarbaşı and Kalkan, 2021).

When the mechanical qualities of expansive soils are lower than those required, stabilization can be an option to improve performance, notably in enhancing its strength. Improvement of certain desired properties like bearing capacity, shear strength and permeability characteristics of soils can be undertaken by a variety of ground improvement techniques such as densification, reinforcement and stabilization (Kalkan, 2012; Lasaki et al., 2018). Soil improvement techniques can be classified in various ways, for example, mechanical, chemical, and physical stabilization (Ingles and Metcalf, 1977; Lambe and Whitman, 1979; Chen, 1988; Chu et al., 2009; Naeini and Mahdavi, 2009; Manar et al., 2015).

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 (Naeini and Sadjadi, 2008; Arab, 2019; Yarbaşı and Kalkan, 2019).

Soil improvement techniques 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 clayey soils (Puppala and Musenda, 1998). Many investigators have experienced on natural, fabricated, and by-product materials to use them as additive materials for the modification of clayey soils (Aitcin et al., 1984; Nelson and Miller, 1992; Sandra and Jeffrey, 1992; Asavasipit et al., 2001; Prabakar et al., 2003; Kalkan and Akbulut, 2004; Cetin et al., 2006; Kalkan, 2006; Kalkan, 2011; Kalkan et al., 2020).

The objectives of this research were to investigate the effects of red mud and red mud-cement mixtures on the unconfined compressive strength (UCS) values of clayey soil samples and to test the freeze-thaw resistance of stabilized clayey soil samples with red mud and red mud-cement mixtures. The unconfined compressive strength and freeze-thaw tests were carried out in accordance with related standard procedures to achieve these objectives.

2. MATERİLA and METHODS

2.1. Clayey Soil

The clayey soil has been supplied from the clay deposits of Oltu Oligocene sedimentary basin, Erzurum, NE Turkey. It is over-consolidated and it has clayey-rock characteristics in natural conditions. It is defined as a high plasticity soil (CH) according to the Unified Soil Classification System (Kalkan, 2003; Kalkan and Bayraktutan, 2008; Kalkan, 2018; Kalkan et al., 2019). The grain size distribution was given in Figure 1.

2.2. Red Mud

Red mud used in this study was provided from Etibank Seydişehir Aluminium Plant, Konya, Turkey. It had a density of 28.5 Mg/m3 and specific gravity of 3.05. The grain size distribution of red mud was given in Figure 1.

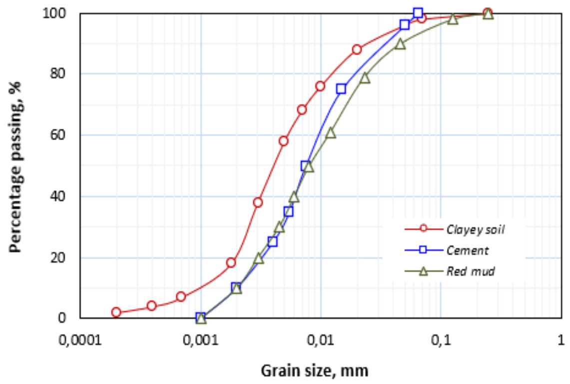

Figure 1. Grain size distribution of clayey soil, red mud and cement

2.3. Cement

Cement (PC42.5) used in this study was supplied from a local hardware store in Erzurum, NE Turkey. It had a specific gravity of Gs= 8.32 lb/ft3 (3.13 g/cm3), specific surface of s=1496 ft2/lb (3063 cm2/g), and compressive strength of σ = 59 MPa (590 kg/cm2) at 28 days. The grain size distribution of cement was given in Figure 1.

2.4. Sample Preparation

Firstly, clayey soil, red mud and cement were mixed at the required contents under dry condition. Then, amount of optimum water added to the mixtures and blended. The compacted samples were prepared in accordance with Standard Proctor procedure. The samples with 70 mm high and 35 mm diameter subjected to the un confined compression and freeze-thaw tests.

2.5. Unconfined Compressive Test

The unconfined compression tests were carried out in accordance with ASTM 2166. In this test, three cylindrical samples with a 70 mm length and 35 mm diameter were used. The samples were placed in a moist container to prevent from drying while waiting a turn at the compression machine. At least three samples were tested for each combination of variables at a deformation rate of 0.16 mm/min.

2.6. Freeze-Thaw Test

The freeze-thaw tests were performed in accordance with ASTM C 666. All samples were placed in the freezing apparatus and conditioned at −18 °C. After the freezing was completed, the samples were transferred from the freezing apparatus into a test room at +20 °C. The freeze-thaw cycle was repeated 20 times.

3. Results and Discussion

The effects red mud and cement on the clayey soil were illustrated in Figure 2. It is clearly seen that the red mud and cement played an important role and with the addition of these additives UCS values increased. The effect of the mixtures of red mud-cement on the increase of the UCS value was more than that of the red mud. The increase in the UCS values with the addition of red mud and cement was attributed to the changing composition of the clayey soil. With the addition of red mud and cement to the clayey soil, the particle origin, particle size distribution and surface area of the composite samples changed resulting the increasing in the UCS values (Pera et al., 1997; Attom and Al-Sharif, 1998; Kalkan and Akbulut, 2004; Kalkan, 2006).

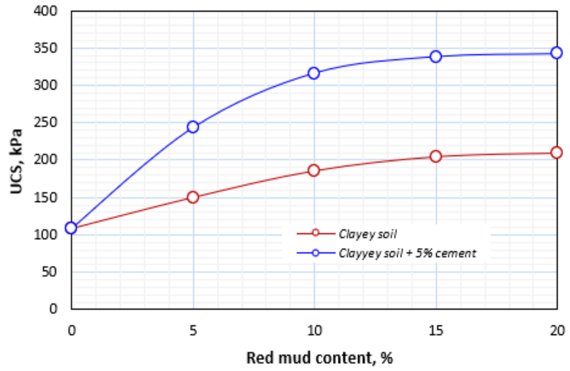

Figure 2. Variation of UCS values with the addition of red mud and cement

To investigate the effects of red mud and cement additive materials on the freeze-thaw resistance of stabilized clayey soil samples, the natural and stabilized clayey soil samples have been subjected to the freeze-thaw cycles. At the end of the freeze-thaw cycles, the natural and stabilized clayey soil samples were tested at the unconfined compression test apparatus under laboratory condition. The effects of the freeze-thaw cycles on the UCS of natural and stabilized fine-grained soil samples were shown in Figure 3.

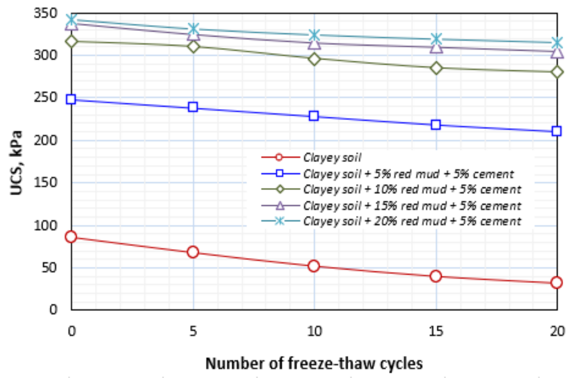

Figure 3. Variation of UCS values with the freeze-thaw cycles

The experimental results show that the red mud and cement additive materials plays a significant role on the freeze-thaw properties of clayey soils. The UCS values of natural and stabilized clayey soil samples are affected by increasing the number of freeze-thaw cycles. However, the red mud and cement additive materials improve the freeze-thaw durability of stabilized clayey soil samples as compared with natural clayey soil samples. The main mechanism governing the alteration of soil behavior caused by the freezing and thawing cycles is believed to be changes in the soil structures

(Eigenbrod et al., 1996; Viklander, 1997; Viklander and Eigenbrod, 2000; Kalkan, 2009).

3. CONCLUSIONS

In this study, the effect of red mud and cement additive materials on the freeze-thaw resistance of clayey soil was investigated. The results showed that the red mud and cement additive materials played an important role on the improving of UCS values of clayey soil. Also, the red mud and cement additive materials increased the freeze-thaw resistance of clayey soil against to the freeze-thaw cycles. As a result, it can be mentioned that red mud and cement additive materials can be successfully used to improve the freeze-thaw resistance of clayey soils.

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