Compressive Strength of Clayey Soil Stabilized with Rock Dust and Cement

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DOI: https://doi.org/10.51583/IJLTEMAS.2024.130103

Received: 18 December 2023; Revised: 03 January 2024; Accepted: 08 January 2024; Published: 03 February 2024

Abstract: Building structures on weak soils with low strength and high compressibility carries great risks. When poor quality soil is available at the construction site, the best option is to modify the properties of the soil.In this study carried out under laboratory conditions, clayey soil material was stabilized by using a mixture of rock dust and cement. Compaction and free compressive strength tests were carried out with the mixtures prepared for this purpose. Natural and modified clay soil samples were subjected to unconfined compressive tests after compaction at optimum moisture content. The results of the experimental investigation showed that the mixture of rock dust and cement increased the unconfined compressive strength. As a result, it was concluded that the rock dust and cement mixture additive can be successfully used to stabilize clayey soils in geotechnical applications.

Keywords: Clayey soil, rock dust, cement, stabilization, unconfined compressive strength

I. Introduction

The construction of buildings and other civil engineering structures on weak or soft ground is highly risky because such soils are susceptible to differential settlement due to poor shear strength and high compressibility. Expansive clays are dominated by clay minerals with crystalline swelling potential, such as smectite group minerals. These are recognized to have very small particles even among clay minerals (Meunier, 2006; Fityus and Buzzi, 2009). Expansive soils are highly plastic and typically contain clay minerals such as montmorillonite that attract and absorb water. If clayey soils contain montmorillonite or a certain type of illite, they will have the potential to swell significantly when wet and tend to affect their engineering behavior (Shi et al. 2002; Sabtan 2005). The response of an expansive soil to changing environmental conditions is to swell or exert great pressure against non-flowing structures; but it can also exhibit a high degree of shrink-swell reversibility with changes in moisture content, which can lead to deformation and damage to buildings (Popescu 1979; Mohan et al. 1973; Mitchell 1993; Bell and Maud 1995; Du et al. 1999; Abdullah and Al-Abadi, 2010; Kalkan, 2012; Kalkan and Yarbaşı, 2013).

As stated in the literature, expansive soils change their behavior with changing environmental conditions and cause serious damage to the structures on them. Single-story light dwellings and buried structures such as pipelines and underground cables are significantly affected.(Erguler and Ulusay, 2003; Sabtan, 2005; Pooni et al., 2019; Yarbaşı et al., 2007; Kalkan, 2009a; Kalkan, 2013; Indiramma et al., 2020; Kalkan, 2020; Kalkan et al., 2022). 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, 2009b). 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).

Soil is defined as a mixture of minerals, organic matter, gases, liquids, and countless organisms together supporting life on Earth. It continually undergoes development by way of numerous physical, chemical and biological processes, which include evaporation which in turn results into increased plastic limit of soil. The soil does not always meet the desired features. For this reason, it is necessary to intervene the soil to gain needed properties (Afrin, 2017). Geotechnical properties of soils are improved by using various methods. Soil stabilization is one of the most important issue in geotechnical engineering practices. For this purpose, cement-based materials have been widely used for various soil improvement strategies because of their benefits such as safety, workability and affordability (Achal et al., 2010; Choi et al., 2016). The process of improving the engineering properties of soils is called soil stabilization. By soil stabilization, the soil becomes more stable by the reduction in the permeability and compressibility and by the increase in shear strength (Andavan and Kumar, 2020; Kalkan, 2020; Kalkan et al., 2022; Yarbaşı et al., 2023; Kalkan, 2023a).

Many investigators have studied natural, fabricated, and by-product materials and their use as additives for the stabilization of coarse or clayey soils. 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 potential of expansive soils (Asavasipit et al., 2001; Puppala and Musenda, 2002; Prabakar et al., 2003; Kalkan, 2003; Yetimoglu and Salbas, 2003; Kalkan and Akbulut, 2004; Al-Rawas et al., 2005; Kolias et al., 2005; Cetin et al., 2006; Senol et al., 2006; Sezer et al., 2006; Akbulut et al., 2007; Guney et al., 2007; Moavenian and Yasrobi, 2008; Kalkan, 2011; Kalkan, 2012; Mohamedgread et. al., 2019; Yarbaşı and Kalkan, 2019a; Yarbaşı and Kalkan, 2019b; Yarbaşı and Kalkan, 2020).

In this study, rock dust and cement mixtures were used as additive material to stabilize the clayey soils. The results obtained experimental study showed that the mixtures of rock dust and cement can be used as additive material for stabilization of clayey soils.

II. Material And Method

2.1. Clayey Soil

The clayey used in this experimental study was supplied from the clay deposits of Oltu Oligocene sedimentary basin, Erzurum, NE Turkey. This soil with green color and high plasticity 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 Akbulut, 2004; Kalkan and Bayraktutan 2008).The grain size distribution curve of clayey soil material is given in Fig. 1.

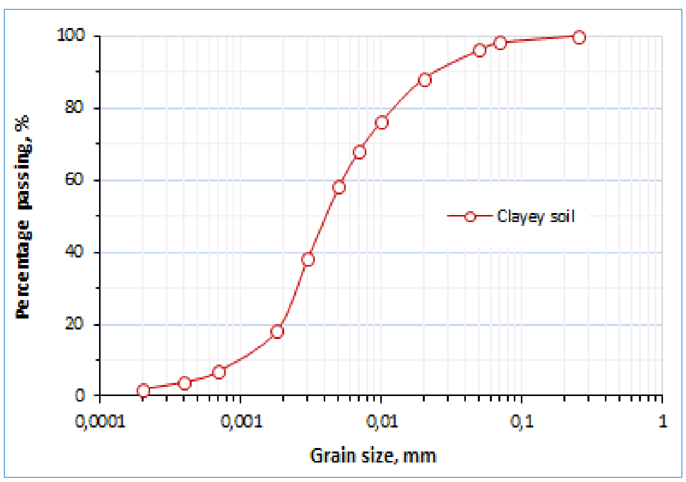

Fig. 1. Particle size distribution curve of clayey soil material

2.2. Rock Dust

Rock dust is the waste material resulting from the crushing of stone. Although it is a waste product, rock dust is nowadays used for agricultural and landscaping purposes and is often used in paving projects such as driveways, terraces and footpaths (Kumar and Bhavannarayana, 2022).The rock dust material used in this study was obtained from limestone and crystallized limestone primary rocks were supplied from the Stone Quarry Facility of Makimsan Company in Erzurum, NE Turkey.

2.3. Cement

Cement as a binder is a chemical substance used for construction that hardens, cures and adheres to other materials to bind them together. It is most commonly used in the production of concrete. The cement used in this study was obtained from a cement factory in Erzurum (NE Turkey).

2.3. Preparation of Sample

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIII, Issue I, January 2024

Firstly, the clayey soil material was dried in an oven at approximately 65 °C and then ground before using the mixtures. The required amounts of clayey soil and mixtures of rock dust and cement were prepared and then blended together under dry conditions. The weights of the mixtures were determined according to the formula below;

$$W_{MIX} = W_{CS} + W_{RD} + W_{C} \qquad (1)$$

where W_{MIX}, W_{CS}, W_{RD}, $W_{C}$are the total dry weights of mixture, clayey soil, rock dust and cement, respectively. The component of the samples used in the experimental studies is summarized in Table 1.

Table 1. Ratios of clayey soil, rock dust and cement

No	Sample	Materials (%)			Total
		Clayey soil	Rock dust	Cement	(%)
1	MIX1	100	-	-	100
2	MIX2	92.5	5	2,5	100
3	MIX3	85,0	10	5,0	100
4	MIX4	77.5	15	7,5	100

2.3. Compaction Test

For experimental studies, the Standard Proctor tests were carried out in accordance with ASTM D 698. The compaction curves were plotted and the values of optimum water content and maximum dry unit weight were determined from the compaction curves (Kalkan, 2011; Kalkan et al., 2022; Yarbasi et al., 2023). The natural clayey soil and the rock dust and cement mixtures were compacted at the optimum water content to prepare the compacted samples for related tests. The samples compacted using the Standard Proctor tests were cylindrical with a 35 mm diameter and 70 mm length. The samples compacted at optimum water content were extruded from the mold using a hydraulic jack. At least three samples were prepared for each combination of variables for these tests.

2.3. Unconfined Compression Test

The unconfined compression test, widely used as a quick, economical way of obtaining the approximate compressive strength of cohesive soils, was performed according to STM 2166. The cylindrical test samples with a length (70 mm)/diameter (35 mm) ratio of 2 were prepared and used for this test. The samples were placed in a moist container to prevent from drying while waiting a turn at the compression machine (Kalkan and Akbulut, 2004; Kalkan et al., 2022; Kalkan, 2023a). At least three specimens were tested for each combination of variables at a deformation rate of 0.16 mm/min.

III. Results And Dıscussıon

3.1. Effect of Rock Dust and Cement Mixture on Compaction Parameters

The effect of rock dust and cement mixture on the compaction parameters OMC and MDUW of clayey soil material is shown in Fig. 2 and Fig. 3, respectively.With the increasing addition of rock dust and cement mixture to the clayey soil material, OMC values decreased while MDUW values increased. This change in OMC and MDUW values of rock dust and cement mixture is attributed to the different properties of the new mix materials obtained by the addition of additives to the clayey soil.These results were similar to those obtained by some other researchers using additive stabilized soils (Okagbue and Onyeobi, 1999; Kaniraj and Havanagi, 2001; Guney et al., 2007; Oyediran and Kalejaiye, 2011; Jafari and Esna-ashari, 2012; Kalkan and Yarbasi, 2013; Nath et al., 2017; Kalkan et al., 2019; Oliga, 2021).

Rock dust and cement mixtures used as additives for stabilization of clayey soil materials changed the properties of soils such as soil type, composition, mineralogy, particle size distribution, particle shape and others (Gillot, 1968; Ola, 1978; Basma and Tuncer, 1991; Kalkan and Akbulut, 2004; Al-Mukhtar et al., 2012; Kalkan and Yarbaşı, 2013; Kalkan et al., 2022).

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIII, Issue I, January 2024

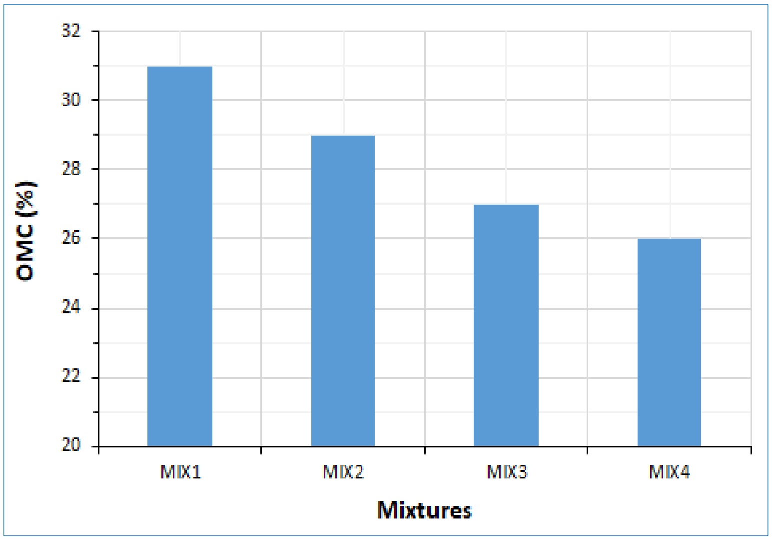

Fig. 2. Effect of rock dust and cement mixtures on OMC

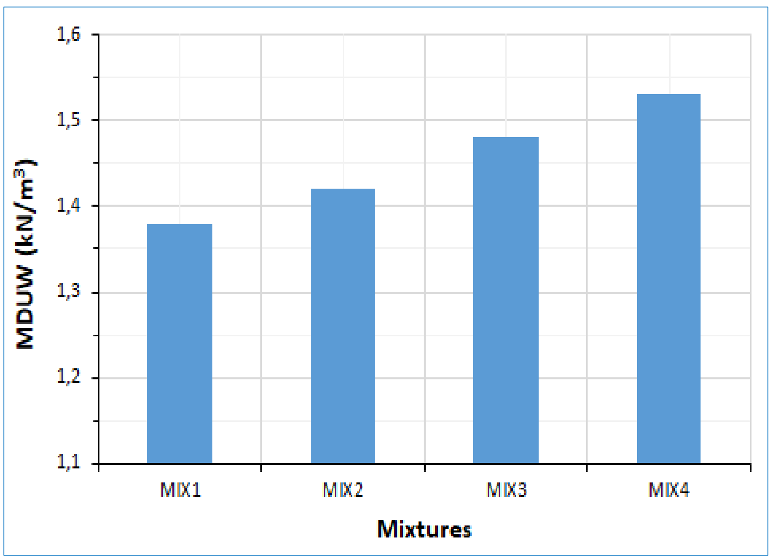

Fig. 3. Effect of rock dust and cement mixtures on MDUW

3.2. Effect of Rock Dust and Cement Mixture on UCS

Unconfined compression tests were performed to determine the effect of rock dust and cement mixture on the UCS values of clayey soils. The test result showed that rock dust and cement mixtures caused changes in the UCS values of the stabilized clay soil samples.This change is clearly seen in Fig. 4.

As can be seen in Fig. 4, it was determined that the UCS values of the stabilized clay soil samples increased with increasing rock dust and cement mixture ratios and UCS values decreased after a certain ratio.The maximum improvement in the UCS values of the clay soil samples was obtained in MIX3 mixture.While the UCS value of the unstabilized clayey soil samples was 223 kPa, it was obtained as 264 kPa in MIX3, the mixture with the best improvement.

Previous scientific studies indicate that the addition of additives to clayey soils changes the composition, mineralogy, and grain size distribution of the clayey soil(Gillot, 1968; Ola, 1978; Kalkan and Akbulut, 2004; Kalkan and Yarbasi, 2013; Kalkanet al., 2022; Kalkan, 2023a; Kalkan, 2023b; Yarbaşı et al., 2023). Therefore, the stabilized clay soil samples gained higher UCS values.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIII, Issue I, January 2024

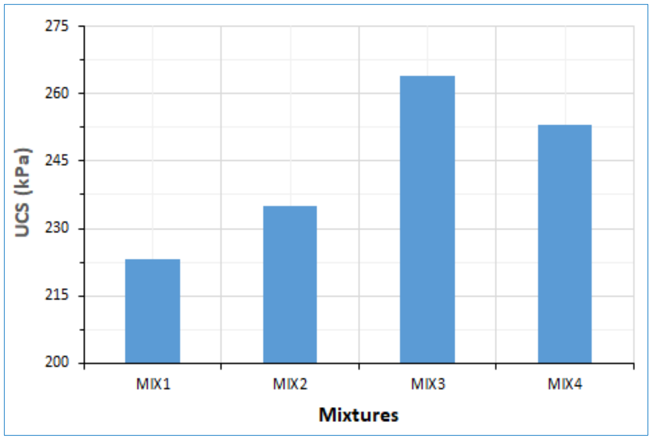

Fig. 4. Effect of rock dust and cement mixtures on UCS

IV. Conclusıon

The results showed that rock dust and cement mixtures decreased OMC values and increased MDUW values of compacted clay soil samples. In addition, the UCS values of the clay soil material increased at first and decreased after a certain ratio with the addition of rock dust and cement mixtures to the clay soil material. The optimum improvement in UCS values of clayey soil samples was obtained in MIX3 samples.It is concluded that rock dust and cement mixtures can be used to improve the geotechnical properties of clayey soils in earthwork applications.

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