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RESEARCH ARTICLE

Strength performance of stabilized clayey soils with quartzite material

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INFORMATION

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ABSTRACT

Clayey soils contain clay minerals known as smectite. These soils present problems to geotechnical engineers due to their complex nature. Excessive compression, dispersive behavior, collapsing behavior, low shear strength, high swell potential and frost susceptibility are some of the undesirable properties of soils in geotechnical engineering. Soil properties such as those mentioned would cause severe distress to structures build on them. In this regard, it is necessary to reinforce and or stabilize the soil. In this study, clayey soils were stabilized by using additive geo-material to improve their engineering properties. For this purpose, quartzite known geological material was used as additive. In experimental study, the natural and stabilized clayey soil samples were subjected to the unconfined compression, the shear box, the odometer and the falling-head permeability tests after compaction at optimum moisture content. The test results indicated that quartzite enhanced both the unconfined compression strength and strength parameters. Consequently, it is concluded that the quartzite can be successfully used for the modifications of clayey soils in the geotechnical applications.

1. Introduction

Construction of buildings and other civil engineering structures on weak or soft soil is highly risky because such soil is susceptible to differential settlements due to its poor shear strength and high compressibility (Kalkan and Yarbaşı, 2013). Clayey soils containing smectite clay minerals absorb water and undergo large volume change as known swelling and shrinkage. The more water they absorb, the more their volume increases. This change in volume can generate forces on a building or other structure to cause damage. The cracked foundations, floors, and basement walls are typical types of damage done by expansive soils (Awwad et al., 2017).

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 soil can be undertaken by a variety of ground (Kalkan, 2012). The soil improvement techniques can be divided into four main categories These categories are soil improvement without admixtures, soil improvement with admixtures or inclusions, soil improvement using stabilization with additives and grouting methods and soil improvement using thermal methods (Chu et al., 2009; Manar et al., 2015).

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 (Ingles and Metcalf, 1977; Lambe and Whitman, 1979; Naeini and Mahdavi, 2009). 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).

Several soil stabilization methods are available for stabilization of expansive clayey soils. These methods include the use of chemical additives, rewetting, soil replacement, compaction control, moisture control, surcharge loading, and thermal methods (Chen, 1988; Nelson and Miller, 1992; Yong and Ouhadi, 2007). Many investigators have studied natural, fabricated, and by-product materials and their use as additives for the stabilization of 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 the expansive soils (Akbulut et al., 2007; Al-

Rawas et al., 2005; Asavasipit et al., 2001; Bell, 1996; Cetin et al., 2006; Guney et al., 2007; Kalkan and Akbulut, 2004; Kolias et al., 2005; Miller and Azad, 2000; Moavenian and Yasrobi, 2008; Prabakar et al., 2003; Puppala and Musenda, 2002; Senol et al., 2006; Sezer et al., 2006; Mohamedgread et al., 2019; Yarbaşı and Kalkan, 2019).

In the present study, geo-material quartzite was used as additive material to stabilize the expansive soils. The stabilized expansive soils were evaluated in an attempt to develop alternative stabilization material with high compressive strength for geotechnical applications. The obtained engineering properties of quartzite-stabilized expansive soil samples were presented and discussed.

2. Material and Method

2.1. Clayey soil

The soil material used in this study as expansive clayey soil was supplied from Oltu district of Erzurum, NE Turkey. This material belongs to the clay deposits of Oltu Oligocene sedimentary basin. Clay-rich sedimentary units of the basin were deposited in shallow marine and lagoonar mixed environments. Smectite group clay minerals are abundant in these units and they consist of montmorillonite and nontronite, while halloysite, palygorskite and hydrobiotite are also present. The expansive clayey soil material is defined as a high plasticity soil according to the Unified Soil Classification System (Akbulut, 1999; Kalkan, 2003; Kalkan and Bayraktutan, 2008; Kalkan, 2018). The ground clayey soil material and its grain-size distribution are shown in Fig. 1 and Fig. 2, respectively.

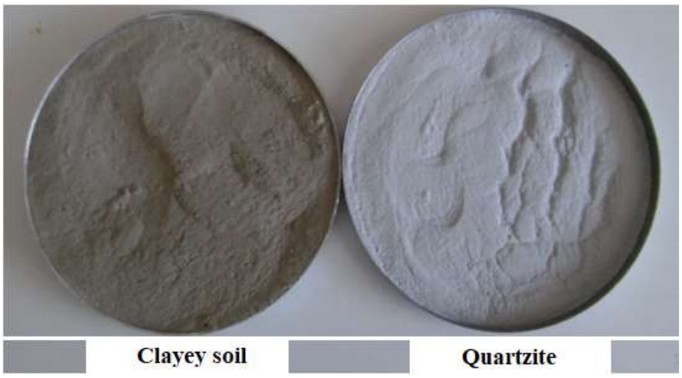

Fig. 1. The ground clayey soil and ground quartzite material

2.2. Quartzite

The quartzite material used in this study was supplied from Demirözü district of Bayburt, NE Turkey. The quartzite is a metamorphic rock composed mainly of quartz and sometime presents little crystals of mica. It is a metamorphic rock that results of a compaction and recrystallization of quartz sandstone. This quartzite, which has an ortho-quartzite formation, contains feldspar, mica, clay, magnetite, hematite, garnet rutile and limestone. There is more than 95% quartz in its composition. It usually has white to grey in color, but its impurity caused quartzite to yellow, orange and brown color. The ground quartzite material and its grain-size distribution are shown in Fig. 1 and Fig. 2, respectively.

2.3. Preparation of clayey soil-quartzite mixtures

The clayey soil and quartzite material were blended to prepare mixtures. The blending process was carried out under dry conditions. The amounts of quartzite material were selected to be 3%, 5%, 7% and 10% of the total dry weight of the clay soil-quartzite material mixtures. The dry mixtures were mixed with the required amount of water recognized to give the optimum moisture content (Kalkan, 2009). All mixing was done manually and proper care was taken to prepare homogeneous mixtures at each stage.

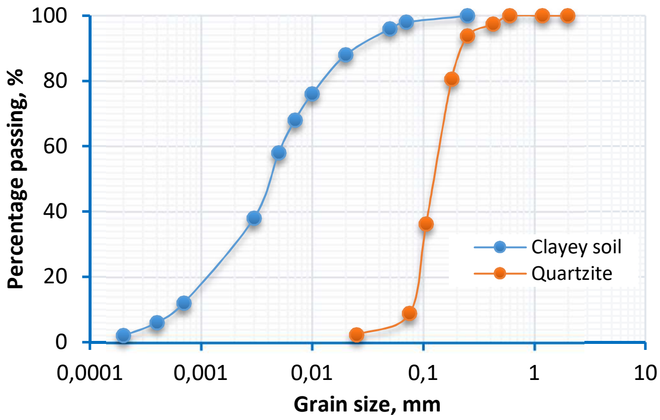

Fig. 2. The grain size distributions of clayey soil and quartzite material

2.4. 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). The natural clayey soil and the 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.

2.5. 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 ASTM 2166. The cylindrical test samples with a length (70 mm)/diameter (35 mm) ratio of 2 were prepared and used for the unconfined compression 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). At least three specimens were tested for each combination of variables at a deformation rate of 0.16 mm/min. The unconfined compressive strength (UCS) values were obtained from the results of this test.

2.6. Shear box test

In order to determine the shear strength parameters of samples, a series of shear box tests was carried out in accordance with ASTM D 3080. The samples were placed in the standard shear box apparatus with 60 mm in diameter and 35 mm in length (Kalkan and Yarbaşı, 2013). To obtain the shear strength parameters such as cohesion and internal friction angle, the values of shear stress versus the value of normal stress were plotted to construct a best fit straight line through the plotted points. The cohesion values were obtained from the intercept with the ordinate axis and the slops of the internal fraction angles from the slope.

3. Results and Discussion

3.1. Effects of quartzite on the compaction parameters

The effect of quartzite material on the compaction parameters of clayey soils maximum dry unit weight and optimum moisture content was illustrated in Fig. 3. The values of optimum moisture content and maximum dry unit weight determined from tests of unstabilized and stabilized samples were normalized equalizing these values of natural clayey soil samples to 1. These normalized values are depicted in Fig. 3.

The results show that in all cases the addition of quartzite material increased in the maximum dry unit weight and decreased in the optimum moisture content. Similar trends were obtained with the addition of additive to the soils (Oyediran and Kalejaiye, 2011; Nath et al., 2017). The addition of quartzite material to the clayey soil the maximum dry unit weight values increased. The maximum dry unit weight was obtained from the 10% quartzite-stabilized samples. On the other hand, the addition of quartzite material to the clayey soil the optimum moisture content values decreased. The 10% quartzite-stabilized samples had the lowest optimum water content values.

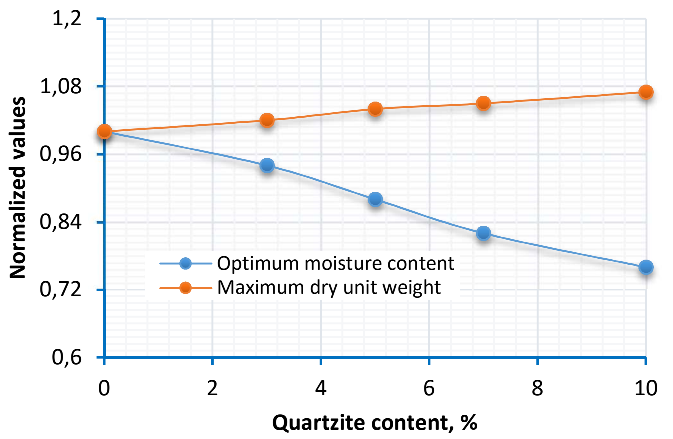

Fig. 3. Variations of optimum moisture content and maximum dry unit weight with quartzite

The significance of these changes depends upon the amount of quartzite material added and the chemical composition of the clay minerals. quartzite material, depending on its content, decreased the total particle surface of the mixture as compared with that of raw clayey soil samples. Therefore, the optimum water content decreased in the stabilized samples. Of course, depending on a decrease in optimum water content, maximum dry unit weight increased in the stabilized clayey soil samples gradually. This trend is similar to that found by Kaniraj and Havanagi (2001) and Nath et al., (2017) they described that the decrease in the maximum dry density is attributed to the agglomeration and flocculation of clay particles through cation exchange reaction.

3.3. Effects of quartzite on the shear strength parameters

The of shear strength parameters such as cohesion and internal friction angle of quartzite-stabilized clayey soil samples were obtained by shear box tests under laboratory condition. The test results showed that the addition of quartzite decreased the cohesion and increased in the internal friction angle of clayey soil samples.

These values of cohesion and internal friction angle determined from tests were normalized equalizing these values of natural clayey soil samples to 1. These normalized values are depicted in Fig. 4.

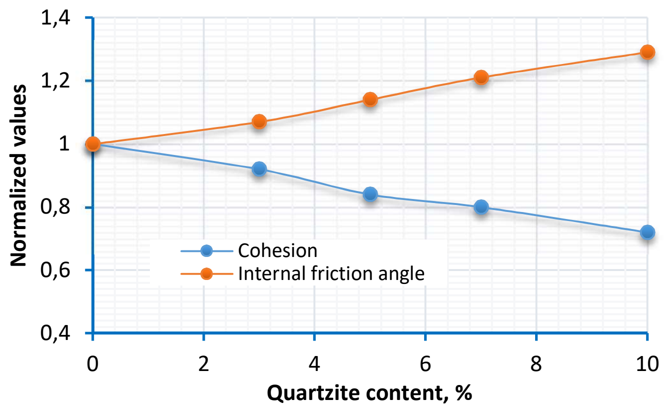

Fig. 4. Variations of cohesion and internal friction angle with quartzite

There is a considerable decrease in cohesion of samples containing 10% quartzite material. The decrease in cohesion with increasing quartzite content to be due to the bonding of particles into larger aggregates such that the soil behaved as a coarse-grained, strongly bonded, particulate material (Kalkan and Yarbaşı, 2013). There is an increase in the internal friction angle is probably due to the fact that the internal friction angle of the quartzite is more than that of the soil (Gay and Schad, 2000; Sezer et al., 2006; Okyay and Dias, 2010; Harichane et al., 2011).

3.4. Effects of quartzite on the UCS

The unconfined compression tests were conducted on the natural and quartzite-stabilized clayey soil samples at the 7th, 14th and 28th days. The effects of quartzite contents and length of curing time against the UCS for quartzite -stabilized clayey soil samples were presented in Fig. 5.

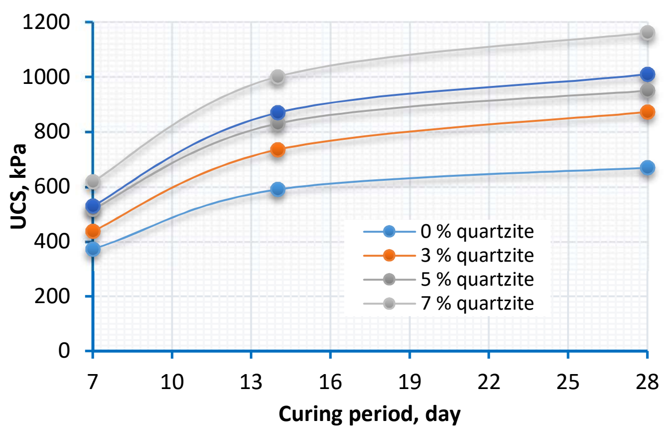

Fig. 5. The effect of quartzite material and curing time on the UCS of clayey soil samples

The UCS values of quartzite-stabilized clayey soil samples significantly increased with addition of more quartzite content up to 7% for the length of curing time 7th, 14th and 28th days. In more than 7% quartzite content, the UCS values of quartzite-stabilized clayey soil samples decreased for the length of curing time 7th, 14th and 28th days. The grain size distribution of quartzite-stabilized clayey soil samples changed with the addition of quartzite material. The UCS of quartzite-stabilized clayey soil samples increased due to due the coarser grains of quartzite-stabilized clayey soil samples.

It was noted in literature that the addition of additive changed the composition, mineralogy and particle size distribution of clayey soil (Gillot, 1968; Ola, 1978; Kalkan and Akbulut, 2004). On this account, the stabilized clayey soil samples have displayed higher UCS values. The increase in the UCS is attributed to the internal friction of quartzite material particles and chemical reaction between additive and clayey soil particles. The UCS values of quartzite-stabilized clayey soil samples increased with length of curing time was explained in terms of the action of cementing gel material produced following pozzolanic reactions which take place over a period of time (Thompson, 1968; Okagbue and Onyeobi, 1999; Kalkan and Yarbaşı, 2013).

4. Conclusion

In this study, clayey soils were stabilized by using quartzite as geological additive material. The quartzite-stabilized clayey soil samples were subjected to the compaction, shear box and unconfined compressive tests. The results obtained from these tests showed that the addition of quartzite material increased in the maximum dry unit weight and decreased in the optimum moisture content. The addition of quartzite decreased the cohesion and increased in the internal friction angle of quartzite-stabilized clayey soil samples. The UCS values of quartzite-stabilized clayey soil samples significantly increased with addition of more quartzite content up to 7% for the length of curing time 7th, 14th and 28th days. The maximum improvement occurred on the stabilized clayey soil samples with 7% quartzite material at the curing time of 28 days.

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