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Effects of Quartzite on the Desiccation Cracks of Clayey Soils Exposed to Wetting-Drying Cycles

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Abstract: The compacted clayey soils crack on drying because of their high swelling potential, and their hydraulic conductivities increase. To solve this problem, it is essential to stabilize the clayey soils using additive materials. The aim of this study is to examine the suitability of quartzite as a stabilization material to reduce the development of desiccation cracks in compacted clayey liner and cover systems. Experimental study was conducted to investigate the effect of wetting-drying cycles on the initiation and evolution of cracks in compacted clayey soils. For experimental studies, seven samples were prepared stabilized by using 0%, 2.5%, 5%, 7,5%, 10%, 12,5% and 15% quartzite and then they were subjected to four subsequent wetting-drying cycles. The results show that quartzite decreases the development of desiccation cracks on the surface of compacted samples. It is concluded that quartzite as a geological material can be successfully used to reduce the development of desiccation cracks in compacted clayey liner and cover systems exposed wetting-drying cycles.

Keywords: Clayey soil, quartzite, soil stabilization, desiccation cracks, wetting-drying cycles

1. INTRODUCTION

The clayey soils generally classified as expansive soils tend to expand as they absorb water and will shrink as water is drawn away. They contain clay minerals that have the potential for swelling and shrinkage under changing moisture contents. Clay minerals could originate from the weathering of shale, slate, sandstone, and limestone. Another source is the diversification of volcanic ash deposited under marine conditions during geologic times, settled alone or mixed with shale or limestone (Grim 1968; Kalkan and Bayraktutan, 2008).

Expansive 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). Safe and economic designs of foundations on clayey soils and performance of compacted clayey soils for geotechnical purposes require the knowledge of swelling characteristics such as swelling pressure, swelling potential and swelling index. Cyclic drying and wetting phenomena can cause progressive deformation of expansive clayey soils, which may affect building foundations, drainage channels, buffers in radioactive waste disposals, etc. (Guney et al., 2007; Nowamooz and Masrouri, 2008; Rao et al., 2001; Kalkan, 2011; Kalkan et al., 2020).

The formation of desiccation cracks on soil surface due to loss of water is a common phenomenon in nature. This behavior significantly affects the performance of soil in various geotechnical, geological and environmental applications. Generally, the presence of cracks in soil would increase the compressible and reduce the overall mechanical strength (Morris et al., 1992). The hydraulic properties of soil are directly influenced by crack networks in soil (Chertkov, 2000). There are numerous laboratory experiments conducted to investigate the initiation and propagation of desiccation crack in soils (Miller et al., 1998; Nahlawi and Kodikara, 2006; Tang et al., 2008; Tang et al., 2011; Tang et al., 2016; Kalkan, 2020; Yarbaşı and Kalkan, 2020).

The main requirements of liners are the minimization of pollutant migration, low swelling and shrinkage and resistance to shearing (Brandl, 1992; Kayabali, 1997; Cazaux and Didier, 2000). Some recent applications include those for environmental purpose, such as impermeable layers in landfills, which act as horizontal or vertical contaminant barriers. The close proximity of compacted clayey soil systems to the atmosphere leaves a compacted clayey layer unprotected, and prone to damage from desiccation. Compacted clayey layers in earthen covers undergo seasonal changes in water content, even at significant depths, due to seasonal variations in precipitation and evapotranspiration (Daniel andWu,1993; Sharma and Levis,1994; Khire et al., 1997; Albrecht and Benson, 2001; Mal et al., 2008).

The swelling potential of expansive soils can be controlled by different methods including soil improvement by chemical additives, treatment by electroosmosis application, compaction control, moisture control, rewetting, and thermal methods (Kalkan, 2011; Goodarzi et al. 2016; Kalkan et al., 2019; Kherad et al. 2020). The application of both the traditional and non-traditional additives in treatment of expansive soils has been widely studied by various researchers from different parts of the world (Pooni et al. 2019; Goodarzi et al. 2015; Seco et al. 2011). Lime, cement, and gypsum are considered as traditional additives and are known as appropriate additives for reducing the swelling potential and increasing the strength of soils (Shahsavani et al., 2020). In the chemical stabilization, some additives such as lime, cement, fly ash, silica fume etc., are added, which physically interacts with the soil and change the index properties (Chen, 1988; Çokça, 2001; Kalkan and Akbulut, 2004; Kalkan, 2009; Kalkan, 2011; Jamsawang et al., 2017; Chittoori et al., 2018; Kalkan et al., 2019).

The basic objective of this research is to investigate the effects of quartzite on the desiccation cracks of clayey soils exposed to wetting-drying cycles. For this purpose, clayey soil was stabilized by using quartzite as geological material at different content.

2. MATERİLA and METHODS

2.1. Clayey Soil

The clayey soil was supplied from the clay deposits of Oltu Oligocene sedimentary basin, Erzurum, NE Turkey. This soil was placed in plastic bags and transported to a soil mechanics laboratory. This clayey soil is over-consolidated and it has clayey-rock characteristics in natural conditions. It is defined as a high plasticity soil according to the Unified Soil Classification System (Kalkan, 2003; Kalkan and Bayraktutan, 2008). Its granulometry curve was given in Figure 1.

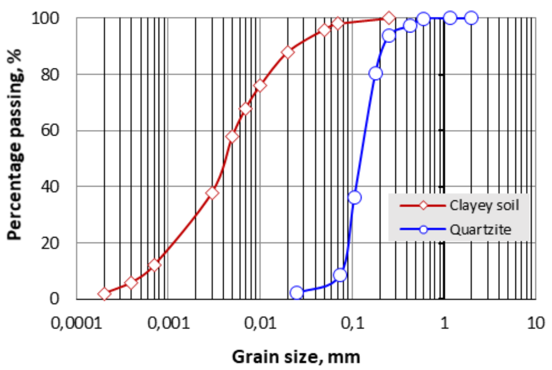

Figure 1. Grain size distribution of clayey soil, red mud and cement

2.2. Quartzite

In this experimental study, the quartzite was used as additive material. It was supplied from Demirözü district of Bayburt, NE Turkey. It is a metamorphic rock formed by 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 (Kalkan et al., 2019). Its granulometry curve was given in Figure 1.

2.3. Experimental Procedure

The clayey soil and quartzite-clayey soil mixtures were compacted at the optimum moisture content in cylindrical mold with 50 mm diameter and 30 mm height. The compacted samples were subjected to four drying-wetting cycles under room temperature (20 ± 2 °C). After 7 days drying period, the samples were saturated with water. After saturation, the samples were exposed a new drying process. They were dried for 7 days. Each end of wetting-drying cycles, the samples were imaged.

3. Results and Discussion

To investigate the effects of quartzite on the desiccation cracks, the compacted clayey soil samples and quartzite stabilized-clayey soil samples were exposed to wetting-drying cycles. The observations showed that the quartzite improved the clayey soil. At the end of first drying cycle, the cracking effect decreased in stabilized clayey soil samples with increasing quartzite contents. In the stabilized clayey soil samples with 10%, 12,5% and 15% quartzite content, no cracks developed (Figures 2-5).

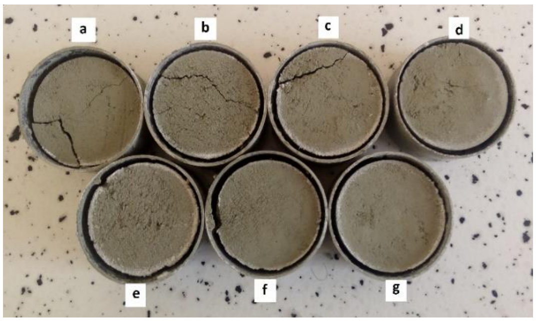

Figure 2. Typical crack patterns captured at first drying process (a: 0%, b: 2.5%, c: 5%, d: 7,5%, e: 10%, f: 12,5% and g: 15% quartzite)

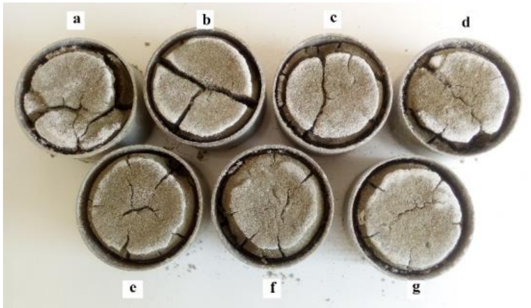

Figure 3. Typical crack patterns captured at second drying process (a: 0%, b: 2.5%, c: 5%, d: 7,5%, e: 10%, f: 12,5% and g: 15% quartzite)

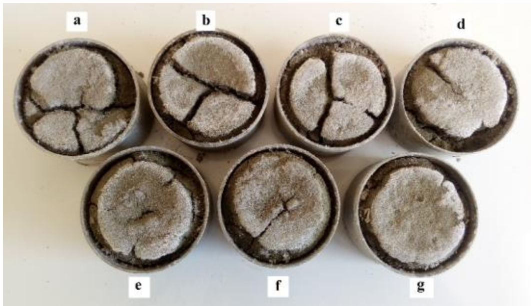

Figure 4. Typical crack patterns captured at third drying process (a: 0%, b: 2.5%, c: 5%, d: 7,5%, e: 10%, f: 12,5% and g: 15% quartzite)

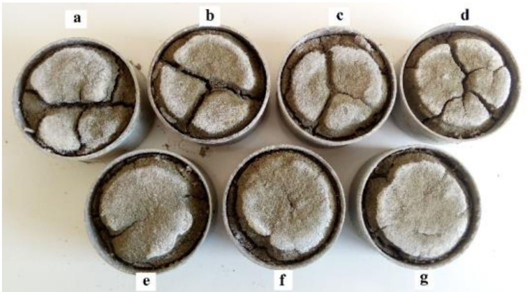

Figure 5. Typical crack patterns captured at fourth drying process (a: 0%, b: 2.5%, c: 5%, d: 7,5%, e: 10%, f: 12,5% and g: 15% quartzite)

In the stabilized clayey soil samples with 10%, 12,5% and 15% quartzite content, very small cracks occurred or no cracks developed. The improve in the resistance of clayey soil samples against to desiccation crack development under wetting-drying cycles was attributed to the addition of low-plastic material to the clayey soil material (Attom and Al-Sharif, 1998; Di Maio et al., 2004; Kalkan and Akbulut, 2004; Kalkan, 2009; Kalkan et al., 2020).

In Figures 2-5, it is interesting to found that the cracks initiated at the boundaries are almost perpendicular to the tangent direction, pointing to the centre of the soil sample. This is attributed to the boundary effect. The soil shrinkage during the drying process results in a separation away from the vertical walls of the mold and creates cracks along the boundary direction (Tang et al., 2011, Cui et al., 2014; Cheng et al., 2021).

3. CONCLUSIONS

In this study, the effect of quartzite geological material on the desiccation crack behaviors for clayey soils exposed to the wetting-drying cycles. It was seen that quartzite decreased the development of desiccation cracks on the surface of clayey soil-quartzite mixture samples under wetting-drying cycles. As a result, it can be stated that quartzite as a natural material can be used to minimize the development of desiccation cracks under wetting-drying cycles. Also, it can potentially reduce stabilization costs by utilizing wastes in a cost-effective manner.

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