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Investigation of Wet-Dry Cycle Effect on Swelling Behavior of Stabilized Expansive Soils

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Abstract: Expansive soils pose a significant hazard to civil engineering structures due to its high swelling and shrinkage potential. Cyclic wetting–drying phenomena can cause progressive deformation of expansive soils, which may affect building foundations, drainage channels, and liner and cover systems in waste containment facilities. Therefore, it is essential to modify these soils by stabilization techniques at the geotechnical applications. In this study, expansive soil samples were stabilized by using pine tree sawdust waste material and the effects of wetting and drying cycles on swelling behavior of stabilized expansive soils were investigated under laboratory conditions. The results indicated that conducting consecutive drying and wetting causes a considerable reduction in the swelling potential of soil samples prepared with different qualities of pore water. Consequently, it was concluded that pine tree sawdust can be successfully used to improve the swelling behaviors against the wet-dry cycle.

Keywords: Expansive soil; pine tree sawdust; soil stabilization; swelling pressure, swelling potential

1. INTRODUCTION

Expansive soils are considered a worldwide problem because they cause extreme damage to civil engineering structures such as embankment dams, water conveyance structures, irrigation and drainage channels, retaining walls, small buildings, tunnels, highways, roads and pavements (Nelson and Miller, 1992). These soils are prone to large volume changes (swelling and shrinkage) which are directly related to changes in water content. Expansive soils are found in many parts of the world particularly in arid and semi-arid regions (Gourley et al.,1993) and can be identified assoils which form deep cracks in drier seasonss (Soltani and Estabragh, 2015).

Despite being classified as a problematic and destructive soil, expansive soils are widely utilized for civil engineering projects and landfilling of municipal, industrial and radioactive wastes (Komine and Ogata,1994; Pusch, 2001; Siddiqua et al., 2011). Many researchers have proposed that cyclic drying and wetting conducted on expansive soils will likely cause reduction in swelling potential and hence, can be adopted as a simple and economic method to reduce the damage caused by swelling in arid and semi-arid regions (Ahmadi et al., 2012; Soltani and Estabragh, 2015).

Seasonal changes cause moisture variations of soil water, increasing in the wet season and decreasing in the dry season. Evaporation of soil water during drying period causes volume shrinkage and desiccation cracks to occur. Swelling and shrinkage are the most important parameters in the investigation of volume change properties of expansive soils. Several factors affect shrinkage and cracking such as clay mineralogy, clay content, compaction conditions, temperature changes, cyclic wetting and drying, soil particle orientation, moisture and density conditions. Temperature changes have great impact on the behavior of compacted soil, mainly when landfill barrier materials are subjected to elevated temperatures due to bio-chemical reactions of the waste contained (Öncü and Bilsel, 2020).

Recently, there have been many researchers investigating the influence of cyclic wetting and drying on the swelling behavior of natural clayey soils. Some researchers found out that swelling potential decreases when expansive clayey soils are repeatedly subjected to swell then allowed to dry to their initial water content (Al-Homoud et al., 1995; Basma et al., 1996; Day, 1994; Dif and Bluemel, 1991; Osipov et al., 1987; Rao et al., 2000; Rao and Revanasiddappa, 2006). On the other hand, several researchers have examined the influence of cyclic wetting and drying on the swelling behavior of expansive soils modified by lime. It is observed that the swelling potential of expansive soils modified by lime increases when it is subjected to the cyclic wetting and drying (Guney et al., 2007; Rao et al., 2001; Yong and Ouhadi, 2007).

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 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; Kalkan et al., 2019; Mohamedgread et al., 2019; Yarbaşı and Kalkan, 2019; Kalkan, 2020; Kalkan et al., 2020).

In this study, the pine tree sawdust as an additive waste material was used to stabilize the expansive soils in terms of swelling behavior. The expansive soil samples stabilized with pine tree sawdust were exposed to the wetting-drying cycles and then tested their swelling behaviors. Also, obtained results of stabilized expansive soil samples with pine tree sawdust were presented and discussed.

2. MATERİLA and METHODS

2.1. Expansive Soil

The clayey soil material was supplied from the clayey soil deposits of Oltu-Narman sedimentary basin, Erzurum, NE Turkey. The clayey soil samples were taken 0,75 m deep. According to the United Soil Classification System, clayey soil are inorganic clays of high plasticity (CH). These soils have high expansion potential as a result of over consolidation, high-very high plasticity and montmorillonite content (Kalkan, 2003; Kalkan and Bayraktutan, 2008). The grain-size distribution of clayey soil was given in Figure 1.

2.2. Pine Tree Sawdust

Wood cutting factories, generates a by-product known as sawdust. The pine tree sawdust waste material was obtained from the carpenters in the industrial zone of Oltu (Erzurum), NE Turkey. The pine tree sawdust is an organic waste resulting from the mechanical milling or processing of timber (wood) into various standard shapes and useable sizes. Consisting of soil-like particulate materials that are lighter than soil, sawdust inexpensive and environmentally safe (Rao et al., 2012; Oyedepo et al., 2014). The grain-size distribution of pine tree sawdust was illustrated in the Figure 1.

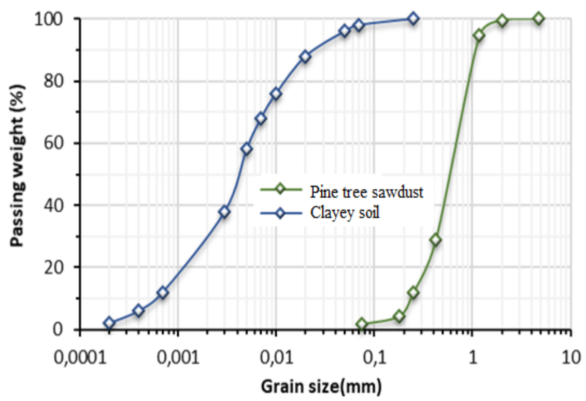

Figure 1. The grain-size distributions of clayey soil and pine tree sawdust

2.3. Preparation of the Samples

Under dry condition, expansive soil and pine tree sawdust materials were mixed to prepare mixtures of expansive soil-pine tree sawdust. The amounts of pine tree sawdust were selected to be 0,5%, 1% and 1,5 % of the total dry weight of the mixtures (Table 1). The dry mixtures were mixed with the required amount of water recognized to give the optimum water content. All mixing was done manually and proper care was taken to prepare homogeneous mixtures at each stage.

Table 1. Expansive soil and pine tree rates of samples

Samples	Expansive soil	Pine tree sawdust	Total
MIX0	100	-	100
MIX1	99,5	0,5	100
MIX2	99,0	1,0	100
MIX3	98,5	1,5	100

2.4. Swelling Pressure Test

This test was performed in the standard one-dimensional oedometer apparatus in accordance with ASTM D 4546. The sample was confined in the consolidation ring of 74 mm diameter and 20 mm high, and water was allowed to flow into the sample. The samples were submerged in water. The deflection of the dial gauge was set to zero. As a result, when the samples showed no further tendency to swell, the maximum surcharge load, P_{MS}, at that point was used for the calculation of the swelling pressure. The swelling pressure can be expressed as;

$$S_{PR} = P_{MS} / A \qquad (1)$$

where S_{PR} is the swelling pressure in kPa, P_{MS} is the maximum surcharge load on the sample in kN, and A is the area of sample in m^2.

2.5. Swelling Pressure Test

This test was carried out in a similar way as swelling pressure test. However, the sample was allowed to swell under a small load. The samples were loaded to a static pressure of 0.7 kPa. The samples were submerged in pure water. The samples were allowed to swell under the initial seating load. The dial gauge readings were recorded periodically until there were no further changes in swelling. The swelling percentage can be expressed as;

$$S_{PT} = H_{MS} / H_{OT} \qquad (2)$$

where S_{PT} is the swelling percentage, H_{MS} is the axial expansion in mm, and H_{OT} is the original thickness of the sample in mm.

2.6. Wet-Dry Cycle Test

In this test, all samples were submerged in tap water allowing the samples to swell fully over 48 h. Water was then drained and the consolidation cell with wetted samples were transferred from the odometer apparatus in to a test room. The wetted samples were then allowed to air-dry to their initial water contents at 22 °C. The drying of the samples required about five days. After all dried samples were carefully weighed, the dried natural and stabilized samples within the consolidation cells were again placed in the odometer apparatus and these samples were wetted by allowing them to swell for 48 h. A wet-dry cycle test was completed with the saturation of samples within the consolidation cell and their drying in an air-dry environment. In these tests, the natural and stabilized samples within consolidation cells were subjected to 5 cycles of alternate wetting and drying.

3. Results and Discussion

3.1 Change in Swelling Pressure and Swelling Potential with Pine Tree Sawdust

The change in the swelling pressure and swelling potential values with the pine tree sawdust additive material in the stabilized expansive soil samples were presented in Figures 2 and 3. The swelling pressure and swelling potential steadily decreased with increasing pine tree sawdust content in the expansive soil material. The decrease in the swelling pressure and swelling potential of the stabilized samples was attributed to the addition of low-plastic materials and the interaction between clay and pine tree sawdust particles (Kalkan, 2006). The maximum values for the swelling pressure and swelling potential were obtained from the samples of MIX2 and MIX3. It is known from literature that the engineering properties of expansive soils are controlled by the CEC, SSA and pH (Eades, 1962; Erzin and Erol, 2007). With the addition of pine tree sawdust, these parameters of expansive soil changed

(Churchman and Burke, 1991; Locat et al., 1984; Ohtsubo et al., 1983; Sridharan et al., 1988).

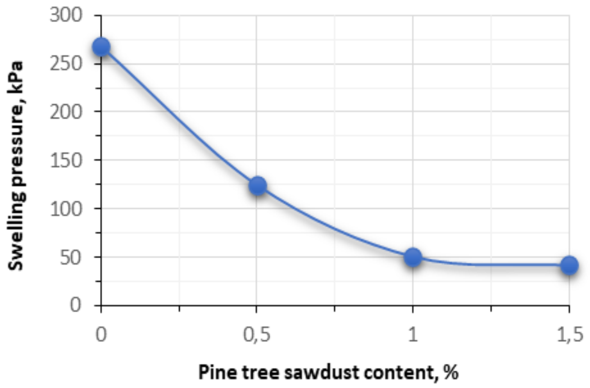

Figure 2. Change in swelling pressure with pine tree sawdust

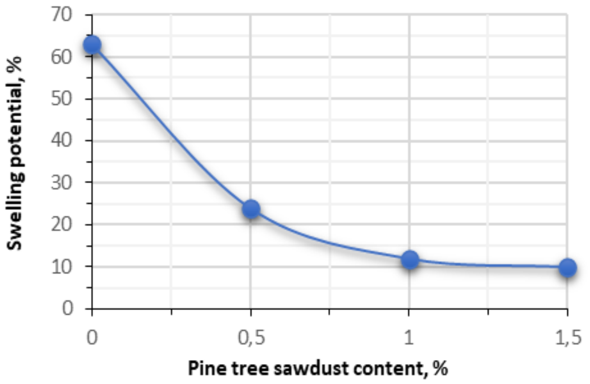

Figure 3. Change in swelling potential with pine tree sawdust

3.2 Change in Swelling Pressure and Swelling Potential with Wet-Dry Cycle

The change in the swelling pressure and swelling potential with wet-dry cycles in the stabilized expansive soil with pine tree sawdust were determined by the wet-dry cycle tests. The results of wet-dry cycle tests were presented in Figures 4 and 5. It was seen from the experimental test results that both the swelling pressure and swelling potential decrease with increasing wet-dry cycles. The most reduction in the swelling pressure and swelling potential values were observed within the first 3 wet-dry cycles.

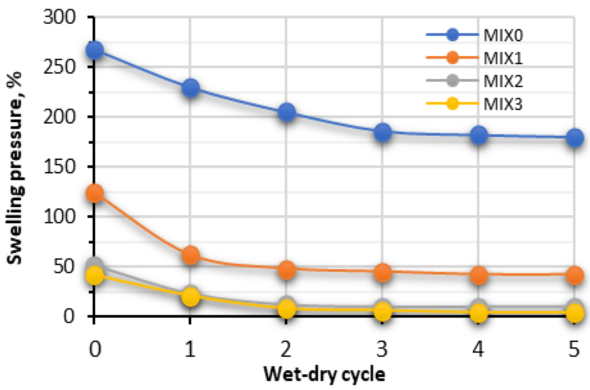

Figure 4. Change in swelling pressure with wet-dry cycle

It was observed that the pine tree sawdust additive material played an important role on the changing of swelling pressure and swelling potential values with the wet-dry cycles. It is an important finding that with the addition of pine tree sawdust, both the swelling pressure and swelling potential decrease with increasing wet-dry cycles. However, the swelling pressure and swelling potential increase when a clayey soil is modified by lime and was subjected to wet-dry cycles (Guney et al., 2007; Rao et al., 2000; Rao et al., 2001; Yong and Ouhadi, 2007).

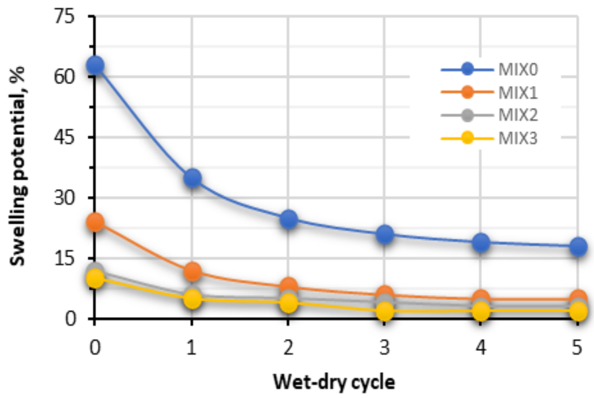

Figure 5. Change in swelling potential with wet-dry cycle

For the natural and modified clayey soil samples, both the swelling pressure and swelling potential decreased with increasing wet-dry cycles and they reached equilibrium at the end of fifth wet-dry cycle. The decrease in the swelling pressure and swelling potential is attributed to a gradual destruction of the matrix of the clay structure brought about by the cyclic swelling process (Kalkan, 2011).

4. CONCLUSIONS

In this study, the effect of wet-dry cycles on the swelling pressure and swelling potential behavior of expansive clayey soils stabilized with the pine tree sawdust waste material was investigated. The swelling pressure and swelling potential values steadily decreased with increasing pine tree sawdust content. Both the swelling pressure and swelling potential of natural expansive soil samples decreased with increases in the wet-drying cycles. It is an important finding that with the addition of pine tree sawdust waste material, both the swelling pressure and swelling potential decreased with increases in the wet-dry cycles compared with that of the natural expansive soil samples.

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