

The Effects of Pine Tree Sawdust on the Volume Compressibility of Expansive Soils

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Abstract: Expansive soils are very important natural geological materials used in the geotechnical applications in the worldwide. After compacting, they are used as hydraulic barriers in earth structures, such as core of earth fill dams, landfill liners, and etc. However, these soils have some defects from technical points of view. To remove the defects, one of the soil improvement methods is mixing of these soils with granular materials. In this study, pine tree sawdust was used as granular additive material to stabilize the expansive soils. The effects of pine saw dust on the volume compressibility of expansive soils were investigated by using experimental studies under laboratory conditions. The test results showed that the pine saw dust positively affected the geotechnical properties in term of volume compressibility manner. As a consequently, the geotechnical properties of the expansive soil when blended with pine tree sawdust indicates that the pine tree sawdust is a good modification material for this problematic soil.

Keywords: Expansive soil, waste material, pine tree sawdust, soil stabilization, volume compressibility

1. INTRODUCTION

The soil is one of the oldest and perhaps most complex geological materials that humanity has been working on. Various problems have begun to be encountered by using the expansive soil as foundation or material. The expansive soil changes in volume in relation to changes in water content. This occurs as swelling upon wetting, and shrinkage upon drying. These soils have poor volume stability in the presence of water (Jones and Jefferson, 2012; Li et al., 2014; Khanduri, 2020). These soils have a problem worldwide undergoing considerable volume changes such as swelling on absorbing water and shrinking on evaporation.

Moreover, moisture fluctuations of them cause distinct changes in soil strength (Fredlund and Rahardjo, 1993; Sheng et al., 2008; Phanikumar, 2009; Lin, and Cerato, 2012; Poonia et al., 2019). Such soils should generally be avoided for the purpose of construction. Because, the structural damages of constructs built on expansive soils is well documented in literature (Petry and Little, 2002; Fall and Sarr, 2007; Kalkan and Bayraktutan, 2008; Ozer et al., 2011; Jones and Jefferson, 2012; Tiwari et al., 2012; Kalkan et al., 2019; James, 2020; Kalkan et al., 2020; Yarbaşı and Kalkan, 2020a). Also, the damage to lightly loaded structures founded on expansive soils has been widely reported (Cameron et al., 1987; Walsh and Cameron, 1997; Fityus et al., 2004; Delaney et al., 2005; Miao et al., 2012; Li et al., 2014; Kalkan et al., 2015).

The soil is one of the most important and primary media for any construction work. The strength and durability of any structure depends on the strength properties of soil (Nath et al., 2017). Soil stabilization is defined as a technique to improve the engineering characteristics in order to improve the parameters such as shear strength, compressibility, density, hydraulic conductivity. The techniques of soil stabilization can be classified into a number of categories such as vibration, surcharge load, structural reinforcement improvement by structural fill, admixtures, and grouting and other methods. There are many techniques that can be used for different purposes by enhancing some aspects of soil

behavior and improve the strength and properties of soil (Edil, 2003; Kazemain and Barghchi, 2012).

In some geotechnical engineering projects, such as core of earth fill dams, landfill liners, and etc, to achieve lower values of hydraulic conductivity it requires to compact clayey soils at wet of optimum water content. Shear strength of clayey soils in general is relatively low and when they subject to seasonal drying, loss of water occurs due to desiccation that alters their properties, including reduction in soil plasticity, possible cracking, and increasing of hydraulic conductivity (Soltani-Jigheh and Jafari, 2012).

Expansive soils pose the problem of swelling on absorption of water during monsoon and shrinkage on evaporation of water in summer (Chen, 1988, McKeen 1988; Nelson and Miller, 1992; Kenneth, 1993). As a result of the swell-shrink behavior of expansive soils, lightly loaded structures such as foundations, pavements, canal beds, and linings and residential buildings founded in them are severely damaged (Chen, 1988).

The several researchers have investigated the effect of granular material on the mechanical properties of mixed clayey soils (Holtz and Willard, 1956; Nakase et al., 1978; Shakoor and Cook, 1990; Shelley and Daniel, 1993; Howell et al., 1997). Vallejo and Mawby (2000) carried out direct shear tests on mixtures of Ottawa sand-kaolin clay and found that shear strength of the mixtures depends upon their sand contents (Soltani-Jigheh and Jafari, 2012).

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 (Kalkan, 2020; Kalkan and Yarbaşı, 2020; Kalkan et al., 2020; Yarbaşı and Kalkan, 2020a; Yarbaşı and Kalkan, 2020b; Yarbaşı and Kalkan, 2020c).

Soil stabilization is one of the most widely followed techniques to control the swelling behavior of expansive soils in lightly loaded structures (Selvakumar and Soundara, 2019). The stabilization techniques to control the swelling characteristics in expansive soils can be grouped into mechanical, chemical and polymer as well as unconventional stabilizer methods (Petry and Little, 2002; Ikizler et al., 2009; Estabragh et al., 2014; Kalkan et al., 2019; Kalkan, 2020; Yarbaşı and Kalkan, 2020a). 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). In recent times, the use of polymer-based product such as geosynthetics in expansive soil stabilization (Al-Omari and Hamodi, 1991; Sharma and Phanikumar, 2005; Viswanadham et al., 2009; Buzzi et al., 2010) is widely practiced due to their desirable properties and durability (Jewell, 1991; Koerner, 1999; Selvakumar and Soundara, 2019).

In this study, the pine tree sawdust was used as alternative low-cost stabilizer material. The main objectives of this research are to investigate the utilizable of pine tree sawdust as additive material for stabilization of expansive soils in geotechnical applications in term of volume compressibility manner. The stabilized expansive soils were subjected the consolidation tests and the results obtained were compared with that of natural expansive soils

2. MATERIALA and METHODS

2.1. Materials

The expansive soil material was supplied from the clayey soil deposits of Oltu-Narman sedimentary basin, Erzurum, NE Turkey. The expansive soil samples were taken 0,75 m deep. According to the United Soil Classification System, expansive 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 expansive soil was given in Figure 1.

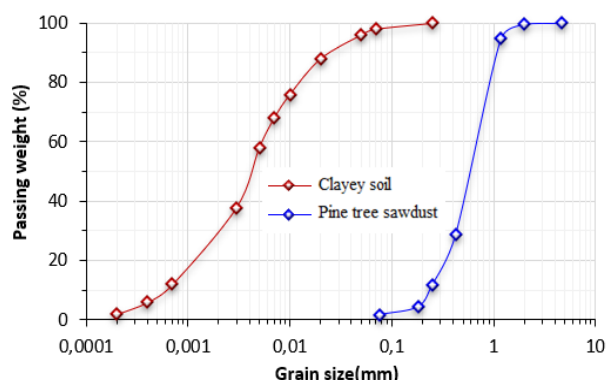


Figure 1. Grain size distribution of expansive soil and pine tree sawdust

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.

2.2. Methods

2.2.1. Preparation of samples

Before preparation of samples, the expansive soil and pine tree sawdust materials were mixed at the different contents of them. 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. The expansive soil and pine tree rates of mixtures

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

2.2.2. Standard odometer test

The compressibility behaviors of expansive soil and expansive soil-pine tree sawdust mixtures were assessed from standard odometer tests. The standard oedometer test is a classical laboratory test that allows characterizing the soil stress-strain behavior during one-dimensional compression or swelling. The samples compacted at their optimum moisture content in a standard proctor mold and then extruded using a cutting ring were subjected to one dimensional consolidation tests in accordance with ASTM D 2435.

3. Results and Discussion

3.1. Effects of pine tree sawdust on the coefficient of volume compressibility

The effects of pine tree sawdust on the coefficient of volume compressibility (mv) of pine tree sawdust-modified expansive soil were illustrated in Figure 2. The mv of pine tree sawdust-modified expansive soil samples significantly increased with addition of more pine tree sawdust content up to 0,5%, 1% and 1,5%. Contrary to this situation, the consolidation coefficient (cv) increases (Figure 3). These mv and cv value were varied at the same consolidation pressure and its might be due to content of clay mineral in the pine tree sawdust-modified expansive soil (Shirazi et al., 2010). The decrease in the void ratio and compressibility of pine tree sawdust-modified expansive soil samples was attributed to the addition of low plastic material and the interaction between clayey minerals and pine tree sawdust particles (Kalkan and Akbulut, 2004). A large number of researchers studied the effect of mineral composition on the compressibility and swelling behavior of expansive soil (Mesri and Olson, 1971; Mitchell, 1993; Di Maio et al., 2004).

3.2. Image Study

Figures 4a and 4b show SEM micrographs of natural expansive soil and 0,5% pine tree sawdust-modified

expansive soil samples, respectively. It is seen from the images that the addition of pine tree sawdust to the expansive soil caused the structural change pine tree sawdust-modified expansive soil samples. Silt and clay grains of expansive soil showed angular or subangular shapes (Figure 4a).

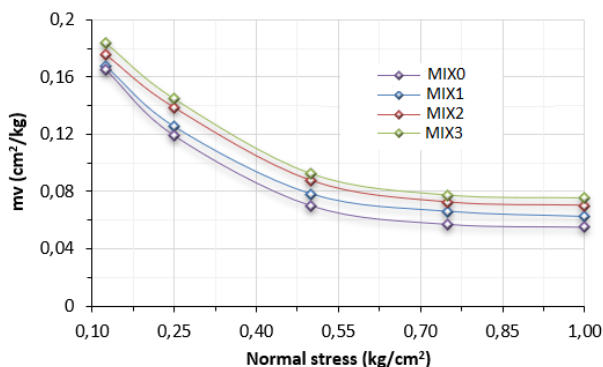


Figure 2. The change in the volumetric compression coefficients of samples

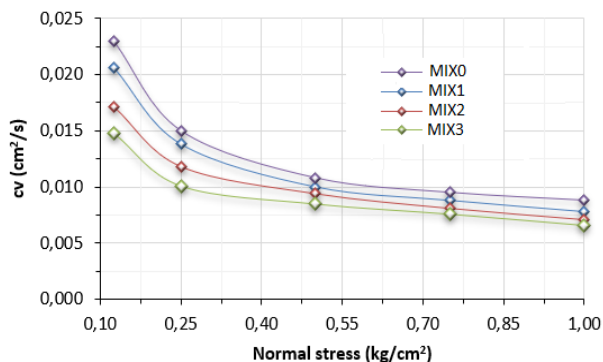


Figure 3. The change in consolidation coefficients of samples

In the 0,5% pine tree sawdust stabilized samples (MIX1), all grains were covered by relatively thick pine tree sawdust material, which formed cementing medium. This textural event caused a significant improvement in the geotechnical properties. A detailed examination of each micrograph reveals that most of the flocculation products are deposited on the surfaces of the soil grains or at the contact points (Fig. 4b). The bonding of particles into larger aggregates such that the soil behaved as a fine-grained, strongly bonded particulate material (Okay and Dias, 2010).

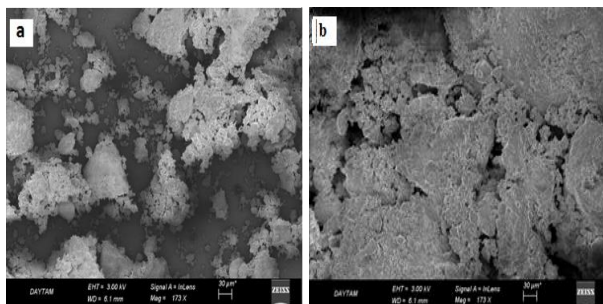


Figure 4. The SEM images of MIX0 and MIX1

4. CONCLUSIONS

In this study, the effects of pine tree sawdust on the compressibility behavior of expansive soils. According to the test results, additive of pine tree sawdust improved the compressibility behavior of expansive soil samples. As a result, the pine tree sawdust can be used as an additive material for the stabilization of the expansive soils in the geotechnical applications in term of the compressibility behavior of expansive soils.

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