EFFECT OF SAWDUST- LIME AND SAWDUST ASH-LIME ON THE GEOTECHNICAL PROPERTIES OF AN EXPANSIVE CLAYEY SOIL

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Abstract- When the applied loads on the soil is higher than its capacity, the engineers resort to certain methods to stabilize the soil by improving its load carrying capacity against the externally applied loads. The utilization of natural materials to improve engineering parameters of soil have become very popular in recent years; they are environmentally friendly materials and are available cheap. In this research, expansive clay is treated with a mixture of sawdust (SD) with Lime (L) and sawdust ash (SDA) with lime (L). Atterberg limits, unconfined compression, and permeability tests were conducted to study the effects of the additives in the soil. It was concluded from the tests that the sawdust – lime and sawdust ash – lime mixtures decreased the consistency limits of the clay. Also, an improvement was noticed in the unconfined compressive strength and coefficient of permeability of the stabilized soil. Also, optimum dosages of sawdust – lime and sawdust ash – lime of 3% and 4% respectively were found to give the best results.

Keywords- consistency limits, expansive clay, lime, sawdust, sawdust ash, permeability, unconfined compressive strength

1 INTRODUCTION

The expansive nature of clay usually makes it unsuitable to be used as a bed for roads, foundations for buildings etc. They are treated and stabilized so that their geotechnical properties could be enhanced before application of load. Using mineral addition in the soil is a very common method to improve the engineering properties of soil. Sometimes the added materials are considered expensive or harmful to the environment. There are many approaches to improve the geotechnical properties of soil such as grouting, adding lime and addition of natural and synthetic fibers. However, the recent trend follows the use of cheap and environmentally friendly materials to improve the geotechnical performance of the clay. The effects of the additives on geotechnical properties of soil are investigated by conducting different tests such as liquid limit, plastic limit, unconfined compression test, permeability, consolidation test etc.

One of the methods of the recent trend to improve the engineering properties of soil is mixing sawdust (SD) and sawdust ash (SDA) with lime (L) in clayey soil. Sawdust is a material that is produced from tree cutting and can also be produced in different ways such as woodworking and others. It can be extracted in different shapes and sizes depending on the mechanism of cutting. Johnson and Gopinath [1] used marble dust and coir fibers to enhance the engineering properties of expansive clay and revealed that the addition of the blend helped in reducing the swelling pressure of clay. Abdi, et al. [2] also studied the reduced swelling of the soil by using polypropylene fibers. Jasim and Cetin [3] Akinwumi, et al. [4] investigated the effects of sawdust in clayey soil. It was concluded that the use of sawdust decreased liquid limit and plastic limit of the clay. Many researches have been conducted on the addition of the natural fibers into the soil and their study reported positive impacts on the shear strength of clay [3, 5, 6]. Also, these studies outlined an optimum dosage of sawdust of about 3% of the dry weight of the soil on the immediate shear strength [3, 4]. It was also found that the optimum sawdust content decreased from 3 % to 2 % in the long term tests on the same clay used by [3]. In another study, the compressibility behaviour of natural additives in soil was investigated on Cochin marine clays (CH) with inclusion of randomly distributed coir fibers (extracted from coconut). This study concluded that the compressibility of reinforced clay is lower than that of unreinforced clay. It was also concluded that compression index values decreased with increase in coir fiber content. On the other hand coefficient of consolidation increased with increasing coir fiber content [7]. Another cheap, ecofriendly and acceptable stabilizing agent for improving the geotechnical properties of soil for the use of foundation is Sawdust ash (SDA) [8]. It was reported in a study that the liquid limits and the plasticity index decreased, and the shear strength parameters considerably increased after using SDA [9]. Ikeagwuani [10] investigated the characteristics of black cotton soil upon addition of mixture of SDA and lime. A mixture of 6% SDA and 4% lime by weight of the black cotton soil was added in the soil. The results showed decrease in the liquid limit and increase in the plastic limit. In conjunction to these results another study also revealed same behaviour [11]. Lime stabilization is considered globally as of the most effective methods to improve the geotechnical properties of cohesive soil [12]. The basic idea behind the lime addition is that limited addition of lime for soils generally improve their properties for construction purposes. Bell [13] modified fat clay by quick lime and concluded that the optimum moisture content of remodeled clay increases nonlinearly with increasing added content of quick lime. Also, it was noticed that the maximum dry density reduces with increasing quick lime content. In addition to this, the liquid limit and plasticity index of the remodeled clay was found to reduce with increase in the content of quick lime and time, but its plastic limit was found to increase with increasing mix-ratio of quick lime and time. Harichane, et al. [14] and Jasim [15] studied the effects of addition of lime, natural pozzolana and a blend of the two on the soil. Lime and natural pozzolana were added to these soils at ranges of 0-8% and 0-20% respectively. In the same study, blend of lime and natural pozzolana were also added in the similar ranges. The results presented significant improvement in cohesion and internal friction angle with curing period and particularly at later ages for each single soil. Similar behavior was reported by the addition of silica fume [16] and lime [17].

Keeping all the literature above into consideration, the aim of this research paper is to study the effects of sawdust- lime and sawdust ash-lime mixtures on clayey soil. Effects of SD-L and SDA-L have been studied on the consistency limits, unconfined shear strength, coefficient of permeability of expansive clay. Also, the optimum dosages of SD-L and SDA-L for improving the geotechnical properties of expansive clayey soil have been presented in this paper.

2 EXPERIMENTAL PROCEDURES

Materials used:

2.1.1 The soil

The soil used was brought from the city of Istanbul. It was located 5 meters below the surface. The colour of the soil used is brown. The basic laboratory procedures were conducted on the soil for classification. Table 1 presents the properties of soil whereas Figure 1 presents the grain size distribution of soil.

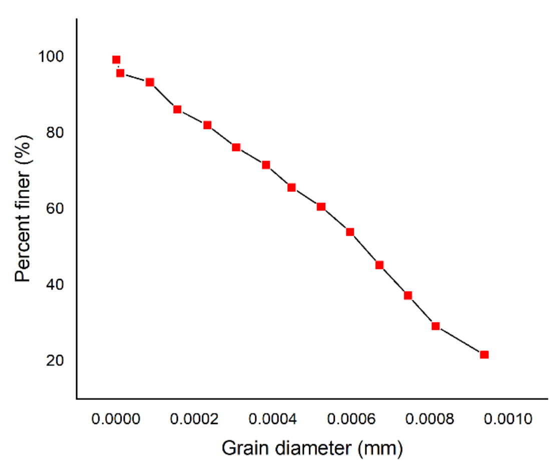

Figure 1: Grain size distribution of the silty clay soil

Table 1: Properties of the soil

LL (%)	PL (%)	PI (%)	Gs	Silt (%)	Clay (%)	USCS
63	30	33	2.64	69	31	CH

2.1.2 Sawdust (SD)

The sawdust used for soil improvement was brought from a wood factory. The specific gravity test was conducted on it and was estimated to be 1.37. The water content in the sawdust was 15.33% at the instant of mixing. The grain size distribution and the used sawdust is illustrated in Figure 2 and Figure 3.

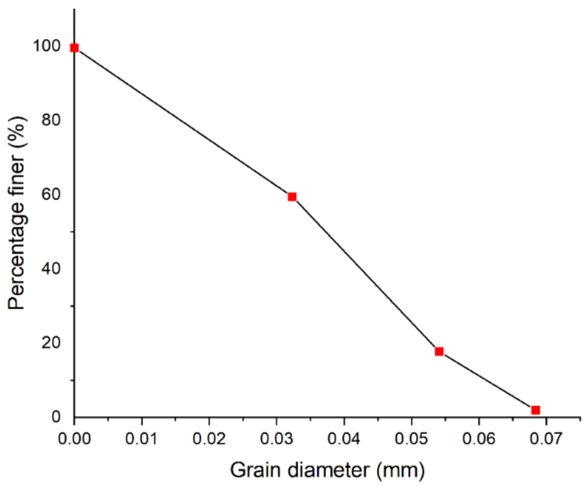

Figure 2: Grain size distribution of the sawdust

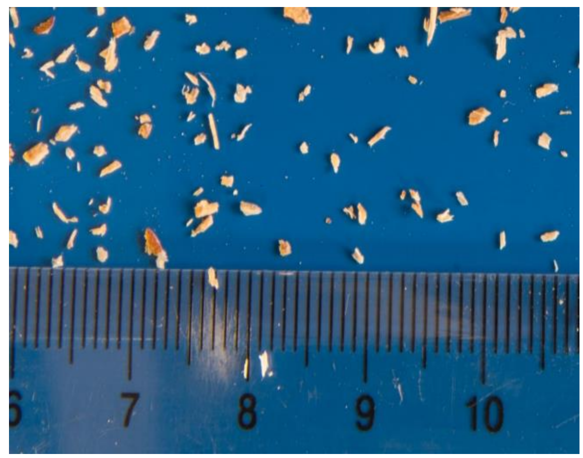

Figure 3: Used sawdust

2.1.3 Sawdust Ash (SDA)

The sawdust ash used for soil stabilization was prepared by burning the sawdust obtained from the wood factory in an oven at 500 ^oC for two hours to make sure that all of the sawdust was converted into sawdust ash.

2.1.4 Lime (L)

There are several types of lime quicklime, slaked lime and hydrated lime. The lime used in this study was hydrated lime with PH of 12.52. A 5kg bag of lime was purchased locally for this study.

Experimental Program

In order to find the maximum dry density (MDD) and optimum moisture content of soil, compaction tests were performed on the specimens according to ASTM D698-07. The Atterberg limits (Liquid limit and Plastic limit) were found according to ASTM D4318 and ASTM 4318, 15. The specific gravity of soil was also determined according to ASTM D 854-0. The unconfined compression strengths of stabilized and unstabilized soils were found according to ASTM D2166/ ASTM D2166M-13. The permeability test is based on ASTM D 5084.

3 RESEARCH METHODOLOGY

Compaction test on soil

The method given in the ASTM D698-07 using the standard compaction test was applied to determine the maximum dry density and the optimum moisture content of the soil sample. An optimum water content of 28% while maximum dry unit weight of 13.7 (kN/m^3) was reported on the completion of test.

Sample Preparation

The samples were prepared by drying the soil sample in an oven for 24 hours at 105ºC. The additives (Sawdust- Lime and Sawdust Ash-Lime Mixtures) were added to the dry soil. The effects of the additives were investigated on five different percentages ranging between (1-5) percent by the dry weight of the soil. Each ratio consisted of half portion of the first mineral addition and the remaining half the other. For example, for 1% of the (SD-L) additive used, 0.5% SD and 0.5% L by dry weight of the soil were added to the soil. The mixing was done manually under ideal circumstances to obtain a homogeneous mixture followed by the addition of water. After compaction of samples, they were extruded by inserting oiled Shelby tubes. The extruded samples were covered with thin polyethylene nylon and kept in the desiccator to maintain the required water content for an hour and then they were tested. However, the Atterberg limit samples were tested directly.

4 RESULTS

Atterberg Limits Tests

Liquid limit and plastic limits tests were conducted in order to identify the immediate effect of SDL and SDL-A on the consistency limits of the clay. From Figure 4 and Figure 5 it is clear that the liquid limit and the plastic limit decreases as the mixture content increases, the same behaviour was confirmed by [3, 13, 15, 18]. According to Bell [13], generally adding lime to the clay causes immediate effect on the plasticity because of increasing the calcium content in the soil. The particles experience flocculation and are lumped. The sawdust is considered as cohesionless material and causes decrease in the consistency limits of the soil. It reduces the fine content of the soil [3, 15]. The sawdust ash also works as a cohesionless materials and it tends to reduce the plasticity of the clay. It was reported that on adding SD-L and SDA-L up to 5 % reduced the liquid limit by (12.6 %, 12.3 %) respectively. The plastic limit results also decreased by (5.69 %, 8.33%) respectively for both of the mixtures.

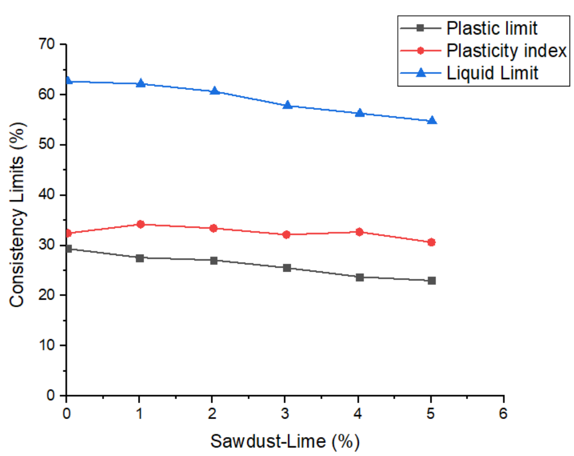

Figure 4: Effect of SD-L content on consistency limits

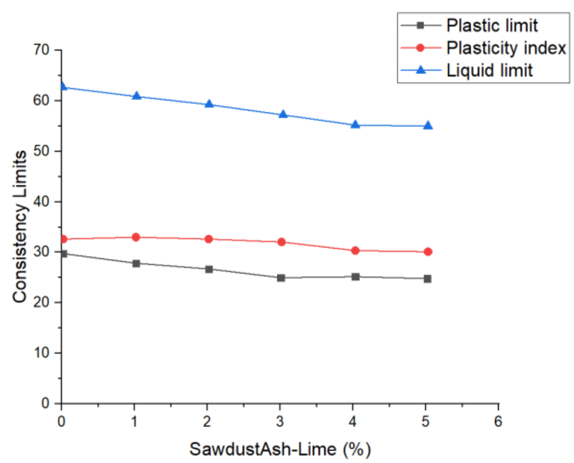

Figure 5: Effect of SDA-L content on consistency limits

Unconfined Compressive Strength

The unconfined shear test was performed on the raw soil as well as the treated soil. It was reported that the addition of sawdust ash lime and the sawdust lime enhanced the shear strength of the clayey soil [3, 13, 15, 18]. Adding SDL up to 5 % increased the shear strength by (21.4 %) as compared to the raw soil (0% SDL). However, 3% of SD-L was found to be the optimum content for the soil in terms of improving its shear strength, see Figure 8. On the other hand, on adding 5% of SDA-L content to the soil, an improvement of 59% was reported as compared to that of the raw soil (0% SDA-L). However, 4% content of SDA-L was found to be the optimum content for soil in terms of improving its shear strength, see Figure 9.

The gain in strength is because of the chemical reactions taking place between the admixtures and soil minerals. On adding mixture of lime and sawdust/sawdust ash in soil two types of reaction takes place. Lime possess cementing properties and the hydration reaction takes place immediately as the mixture is added into the soil. The sawdust ash on the other hand, are responsible for the pozzolanic reaction and contributes in strength of soil at the later ages. Overall, the results reflect a positive impact on the improvement of unconfined compression strength of clayey soil. The effects of sawdust-lime and sawdust ash lime on the unconfined compressive strength for stabilized soil samples are shown in Figure 6 and Figure 7.

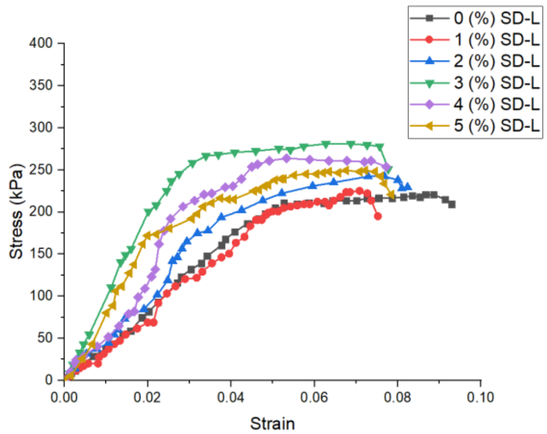

Figure 6: stress strain relationship for soil SD-L

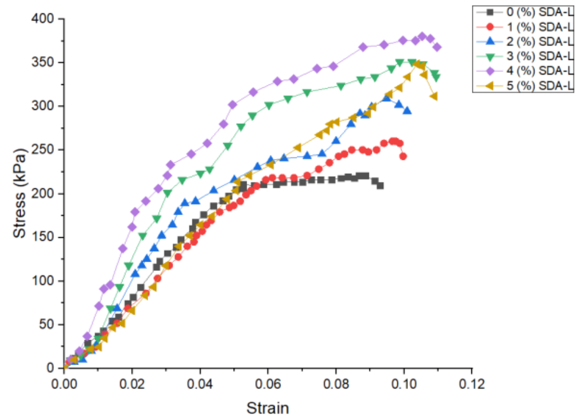

Figure 7: stress strain relationship for soil SDA-L

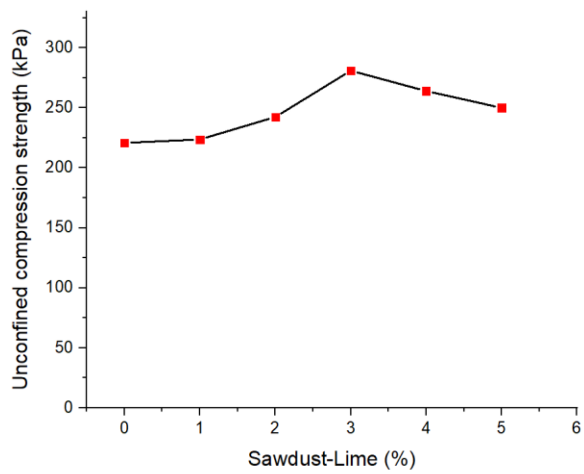

Figure 8: Unconfined compression strength of at various percentages of SD-L

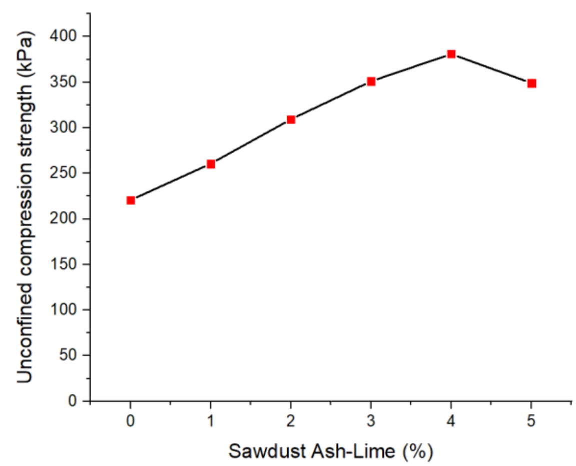

Figure 9: Unconfined compression strength of at various percentages of SD-L

Permeability test

A comparison of the hydraulic conductivity was conducted between the unstablized specimens and the specimens stabilized with mixture of SD-L and SDA-L. The coefficient of permeability of the specimens stabilized with mixture of SD-L and SDA-L was relatively more than that of the unstabilized specimens. The coefficient of permeability increased with increase in the contents of SD-L and SDA-L as shown in Figure 10. The increase in the permeability with the contents of these mixtures is due to the added materials (SD and SDA) acting as barrier between the fusion of clay particles thus increasing its permeability. Also, formation of gel due to hydration and pozzolanic reaction is another reason contributing to the increase in permeability. The moisture from the clay is utilized in the formation of gel which gives rise to capillary voids (the voids previously filled by water are replaced with air) and as a result the coefficient of permeability increases.

A remarkable difference in the rate of increase of permeability at higher and lower doses than the optimum dose can be seen in Figure 10. The reason to this difference can be attributed to the excess sawdust particles present above the optimum dose. The clay-clay particle cohesion is reduced due to more sawdust accumulating in-between the soil particles thus forcing the soil matrix to change and as a result greater rate in the increase of permeability is recorded at the contents of both the mixtures above the optimum dose. On the other hand, at lower doses the sawdust particle being low in quantity do not significantly reduces the cohesion between clayey particles thus not forcing the soil matrix to change and as a result low rate of increase in permeability is recorded at the lower doses.

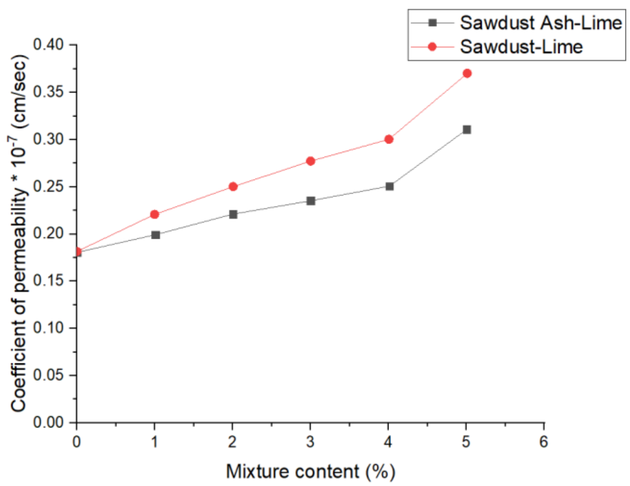

Figure 10: Effect of sawdust lime and sawdust ash lime on permeability.

5 CONCLUSIONS

Following conclusions can be derived from the conducted study:

- The consistency limits of the clay decreased with increasing percentages of sawdust – lime and sawdust ash – lime. The reason is that sawdust acts as a non-cohesive material between clay particles and thus reduces the fusion of clay particles resulting in decreased consistency limits.
- Unconfined compressive strength of clay improved remarkably with increasing content of sawdust – lime and sawdust ash – lime mixtures. This is because of hydration and pozzolanic reactions taking place as a result of addition of sawdust, sawdust ash and lime.
- The permeability coefficient increased as the ratio of the added mixture increased. The reason for the increase is due to the particles of sawdust and sawdust ash preventing the cohesion between the soil and the formation of the supplementary cementitious products leaving voids behind and thus increasing the permeability coefficient.
- Based on the unconfined compressive strength results of the stabilized soil, the optimum dosages of sawdust – lime and sawdust ash – lime was reported to be 3% and 4% respectively.

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