EFFECT OF MOLDING WATER CONTENT ON SWELLING AND STRENGTH CHARACTERISTICS OF LIME STABILIZED EXPANSIVE SOIL

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Abstract

Expansive soils are problematic soils that undergo huge volume change when exposed to moisture fluctuation. Thus, in alternate rainy and summer seasons, expansive soil strata undergo swelling and shrinkage. Lightly loaded civil engineering structures founded in these soils are, therefore, subjected to severe distress. Lime stabilization is one of the most effective techniques used to treat this type of soil. Due to cationic exchanges, lime can significantly reduce swell potential. However, stabilization of such type of soil with lime depends on the amount of water added during stabilization (also known as molding water content). Hence, the molding water affects the swelling tendency of the soil and stabilizing activity of the lime. This research investigated the effect of molding water contents on swelling pressure and strength of an expansive soil stabilized with optimum amount of lime. For that purpose, a series of laboratory tests were performed in two phases. From the first phase of the experimental program the optimum amount of lime for stabilization of the soil underinvestigation was found to be 6%. In the second phase of the program, swell-consolidation and unconfined compressive strength tests were conducted on specimens treated with optimum amount of lime prepared at maximum dry density (MDD) but having different molding water contents, optimum moisture content (OMC) and dry and wet sides of OMC. The results of this research have shown that molding water content does not affect the swelling pressure. However, unconfined compressive strength improves significantly on soil-lime specimens prepared on the wet side of optimum moisture content.

Keywords: Expansive clay soil, Lime, Soil Stabilization, Molding water content, Swelling pressure, Unconfined Compressive strength.

1 Introduction

Soil stabilization is a method of effectively and economically solving problems associated with defective soil properties. There has been much advancement on researches focused on identifying materials that can be used to improve soil properties either by mechanical or chemical stabilization. Industrial wastes, agricultural bi-products and commercially available chemicals are typical materials being commonly researched for successful soil stabilization.

Lime stabilization is one of the methods of improving the properties of soils especially for cohesive soils. In general, fine-grained clay soils (with a minimum of 25 percent passing the #200 sieve (0.075mm) and a plasticity index greater than 10) are considered to be good candidates for stabilization by lime. The mineralogical properties of the soils will determine their degree of reactivity with lime and the ultimate strength that the stabilized soil will develop (Little, 1995; Little and Epps, 2006). These reactions produce decreased plasticity, increased workability, reduced swell and increased strength of the soil Koteswara et al (2011).

When lime is added to a clay soil, chemical reactions take place between the soil minerals and the lime. Cation exchange, Flocculation and agglomeration, Pozzolanic reaction and Carbonation are among those reactions

In lime stabilization, molding water content plays a contradicting role. The usual trend in projects involving lime stabilization is to use the optimum moisture content (also known as moisture content at maximum dry density) as the molding water content. This will result in large amount of clay minerals to fill a certain volume, which may amplify the concentration of the swelling minerals (montmorillonite) at the given volume. If the wet side of the optimum moisture content is used as molding water content, the clay minerals may absorb the water and go through large volume change providing high swelling pressure. Alternatively, the dry side of the optimum moisture content hinders the chemical reactions that are essential for the lime stabilization. This research tends to study the effect of molding water content on the swelling and strength characteristics of expansive soil stabilized with optimum amount of lime.

2 Materials and Methods

2.1 Materials

EXPANSIVE SOIL

The soil samples used for this research were obtained from eastern Addis Ababa, around Gelan condominium on the Addis Ababa outer ring road project. The geographical location of Gelan is located at 8°52’ North latitude and 38°49’ longitudes with an average elevation of 2240m. The expansive soil samples were taken at a depth of 2 m from the ground surface.

LIME

The hydrated lime used as the stabilizing agent for the research was provided from Derba Chemicals P.L.C. It was stored in a cool and dry place away from weather effect.

2.2 Methods

The preparation of soil samples for the study was done in accordance with ASTM specifications. The untreated soil was air dried, cleaned, pulverized to break clumps, and then sieved as per the requirements of the test. The soil was then tested for its properties in accordance with ASTM test methods shown in Table 1, and classified as per Unified Soil Classification system (USCS).

To prepare lime treated samples, lime was added to the air dried, pulverized and sieved soil sample at the rate of 2%, 4% and 6% by dry weight of soil and effectively mixed. Measured amount of water was added and mixed thoroughly until the mix appears uniform. Then the mix was put in to a water tight plastic bag to be cured.

Table 1 Methods Adopted for this Study

Type of test	Methods adopted
Grain size distribution	ASTM D 422-63
Atterberg limits	ASTM D 4318-10
Specific gravity	ASTM D 854-02
Free swell	IS: 2720(Part 40)
Compaction	ASTM D 698-07
Swell-consolidation	ASTM D4546-85
Unconfined compressive strength	ASTM D2166-66

In the first phase the experimental program the optimum amount of lime for stabilization of the expansive soil was found out. For that purpose, the prepared lime treated specimens were tested for characteristics like compaction, swell -consolidation, unconfined compressive strength (UCS) as per ASTM specifications as shown in Table 1. Swell-consolidation and UCS tests were conducted by preparing the specimens at MDD and OMC. Based on the results of the swell consolidation tests, the optimum amount of lime for stabilization of the expansive soil under investigation was found to be 6%.

In the second phase of the experimental program, swell- consolidation and UCS tests were carried out on specimens treated with optimum amount (6%) of lime prepared at MDD but at seven different molding water contents these are, optimum moisture content (OMC) and three on the dry side and the remaining three on the wet side of the OMC. Specimens for all tests were cured for seven days, allowing lime to react and cation exchanges to occur.

3 Test Results and Discussions

3.1 Properties of Natural Soil

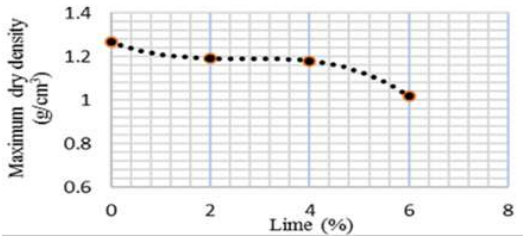
The geotechnical properties of the natural soil obtained from laboratory test procedures are presented in Table 2.

Table 2 Geotechnical Properties of the Natural Soil (Demissu, 2015)

Property	Value
Percentage passing No. 200 sieve (%)	96
Liquid limit (%)	103
Plastic limit (%)	36
Plasticity index (%)	67
Specific gravity	2.72
Free swell (%)	160
USCS soil classification	CH
Maximum dry density (g/cc)	1.27
Optimum moisture content (%)	34
Swelling pressure at maximum dry density and optimum moisture content (kPa)	437
Unconfined compressive strength at maximum dry density and optimum moisture content (kPa)	235

3.2 Compaction Test Results

The effects of lime on the maximum dry density and optimum moisture content are shown in Figure 1. As the amount of lime added to the soil increases, OMC increases and MDD decreases. The reason for the reduction in dry density is mainly due to an immediate formation of flocculates and agglomerated particles that occupy larger spaces. Hence compatibility is greatly reduced. The lime requires more water for the chemical reactions that are basic for stabilization.



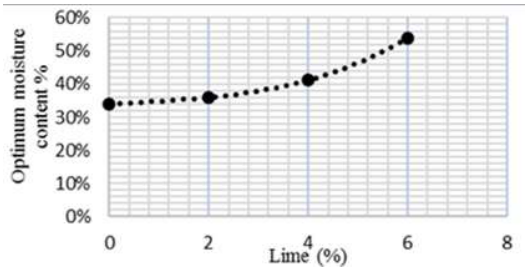


Figure 1 Variation of Optimum Moisture Content with Lime Content

Therefore, as more lime is added to the soil more water will be absorbed by the lime thereby increasing the optimum moisture content.

3.3 Swelling Pressure Test Results

As shown in Figure 2, the addition of lime significantly reduced the swelling pressure of the soil. At 6 % amount of lime addition the swelling pressure of the soil reduced to a value of zero. Based on this result, it can be deduced that 6% lime is the optimum amount required to stabilize the swelling property of the expansive soil under investigation.

As can be seen, the swelling pressure remains zero on each side of the optimum moisture content. The main factor responsible for the zero swelling pressure recorded at all molding water contents may be due to the flocculation and agglomeration of the soil structure. As explained by Herzog & Mitchell (1963) and Harichane et al. (2011), the flocculation and agglomeration are caused by the increased electrolyte content of the pore water and cation

exchange of clay to the calcium form following the addition of lime to the soil. As a consequence of this series of reactions, the original clay is changed to a flocculated calciumsaturated clay that has a tendency to reduce swell because of its affinity for water.

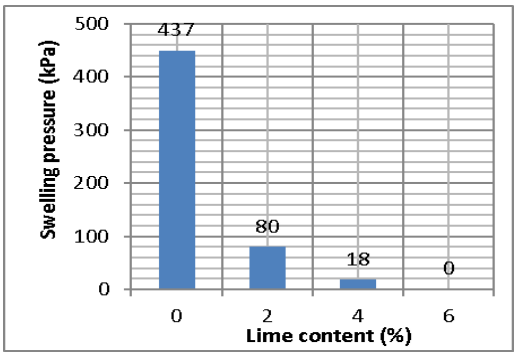


Figure 2 Effect of Lime on Swelling Pressure of Soil

3.4 Unconfined Compressive Strength Test Results

The effect of lime addition on the unconfined compressive strength of the soil was investigated. The UCS results for each concentration of lime are shown in Table 3. It shows that the expansive soil has revealed the highest unconfined compressive strength at the addition of 2% lime. Then it starts to decline at higher percentages of lime contents. The reason for the decline could be, the molding water used in sample preparation was optimum moisture content. Since the optimum moisture content is related to the dry density of the soil rather than compressive strength of lime treated soil. The optimum moisture content used as molding water could have been insufficient to react with the lime.

Table 3. Effect of Lime on Unconfined Compressive Strength of the Soil

Lime (%)	UCS (kPa)
0	235
2	524
4	399
6	340

The effect of molding water content on swelling pressure and strength of lime stabilized expansive soil was investigated in the laboratory and the results are listed in Table 3. As can be seen, the swelling pressure remains zero on each side of the optimum moisture content. The main factor responsible for the zero swelling pressure recorded at all molding water contents may be due to the flocculation & agglomeration of the soil structure.

As explained by Herzog and Mitchell (1963), the flocculation and agglomeration are caused by the increased electrolyte content of the pore water and cation exchange of clay to the calcium form following the addition of lime to the soil. As a consequence of this series of reactions, the original clay is changed to a flocculated calcium- saturated clay that has a tendency to reduce swell because of its affinity for water. Figure 3 shows the variation of UCS of expansive soil stabilized with optimum amount (6%) of lime with molding water content.

Table 4 Effect of Molding Water Content on Swelling Pressure of Lime Stabilized Expansive Soil

Molding Water Content, (%)	Swelling Pressure, (kPa)
41	0
45	0
50	0
53	0
60	0
62	0
67	0

As can be seen from the figure, lime stabilized specimens with moisture content on the wet side of the OMC achieved higher compressive strength than specimens on the dry side of the OMC. The specimen prepared at the OMC has higher compressive strength than those samples prepared on the dry side of the OMC and lower compressive strength than samples prepared on the wet side of the OMC.

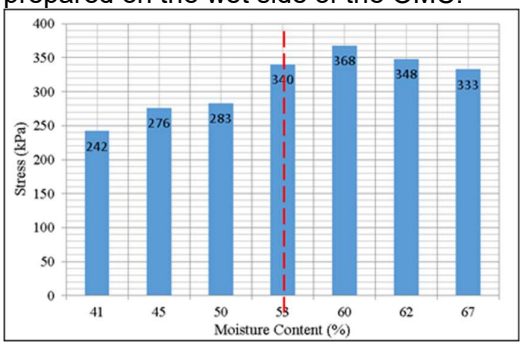


Figure 3 Effect of Molding Water Content on UCS of Lime Stabilized Expansive Soil (7 day Curing)

The additional water added, after the OMC has been attained contributed to the lime stabilization process by providing higher compressive strength. These experimental results indicate that soil stabilized with lime needs more water to maintain the chemical reaction to produce pozzolanic material.

4 Conclusion

The research investigated the effect of molding water content on the swelling and strength characteristics of expansive soil stabilized with optimum amount of lime. Based on the results of this study, the following conclusions can be drawn.

1. Once optimum amount of lime is added to expansive soil, variation in molding water content has no effect on the swelling pressure.
2. On the other hand, molding water content has significant effect on unconfined compressive strength of lime stabilized expansive soil. The unconfined compressive strength of samples on the wet side of optimum moisture content is found to be higher than the sample at optimum moisture content. However, the highest strength is obtained at moisture content slightly larger than the OMC.

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