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Stabilization of Black Cotton Soil Using Plastic Bottle Waste And Lime Sludge (A Case Study of Jiddari and Sulemanti Environs, of Jere And Maiduguri, Borno State, Nigeria)

Hassan Biu SANI
Department of Civil Engineering Technology, Ramat Polytechnic Maiduguri, Nigeria

Abstract: *For many years, researcher has come up with different forms of ideas for improving the engineering properties of soil in other to meet up with the requirement of having a stable foundation base for any proposed engineering structure. There are different forms and types of conventional soil stabilizer that has been recommended by geotechnical engineers as soil stabilizing agents. But sometimes, using these recommended conventional soil stabilizing materials attracts huge cost to the project at hand, because most of these conventional stabilizing materials are primarily manufactured for other purposes. In view of that, this research will focus on using locally available waste materials as stabilizing agents; that is, plastic bottle waste and lime sludge. This will not only save cost for engineering project, but also provide a clean and healthy environment. This study will also focus on improving the engineering properties of clay soil by conducting a case study at Jiddari-Polo and its environs. This is due to the facts that clay soil are responsible for most of the problems faced by geotechnical engineers as regards to the stability and settlement problems of engineering structures. The study will also analyze and determine the percentage 'by weight' of the stabilizing agents that will be most effective in improving the clay soil engineering properties. These analysis and evaluations will be obtained by series of different soil material laboratory test.*
Keywords: Plastic Bottle Waste, Lime Sludge, Clay soil, Soil Stabilization and Engineering Properties of Soil.

Key words: Stud shear connectors; composite slab; profiled metal deck; longitudinal shear

1.0 INTRODUCTION

The stability of Civil Engineering structures like buildings, bridges, highways, tunnels, dams, etc, depends largely on the engineering properties of the soil encountered on the construction site. The suitability of soil to be used as a foundation or construction materials depends on its engineering properties. These properties are required to be assessed. Therefore, the assessment of soil geotechnical properties at any project site is necessary in order to generate the relevant input data for the design and construction of foundation of any proposed structure. All types of soil that are encountered at construction site, one of the most problematic soil types that create serious problem to geotechnical engineers as regards to the stability and settlement problems of engineering structures are black cotton soil. Black Cotton soils are inorganic clay of medium to high compressibility and form a major soil group in Maiduguri. Black Cotton soil has a high percentage of clay, which is predominantly montmorillonite in structure and black or blackish grey in color. Because of its high swelling and shrinkage characteristics, the Black Cotton soil has been a challenge to geotechnical and highway engineers. The soil is very hard when dry, but loses its strength completely when in wet condition (Balasubramaniam, *et. al,* 1989). The wetting and drying process causes vertical movement in the soil mass which leads to failure of a pavement and buildings, in the form of settlement, heavy depression, cracking and unevenness. It also forms clods which cannot be easily pulverized as treatment for its use in road construction (Holtz & Gibbs, 1956). This poses serious problems as regards to subsequent performance of the road. Moreover, the softened sub grade has a tendency to heave into the upper layers of the pavement, especially when the sub- base consists of stone soling with lot of voids. Gradual intrusion of wet Black Cotton soil invariably leads to failure of the road (Bell, 1988). Some of the factors which influence the behavior of these expansive soils are initial moisture content, initial dry density, amount and type of clay, Atterberg limits of the soil, and swell potential.

Black cotton soil are extremely common on construction sites in Maiduguri. It is therefore more beneficial and cost effective to stabilize the black cotton soil on the construction site than to opt for high quality soil which are scarcely available. The stabilization method will be more cost effective and environmental friendly when locally available waste products/materials are use as stabilizing agents. In view of that, lime sludge and plastic bottle waste will be used as stabilizing agents for the intended research study.

2.0 LITERATURE REVIEW

Black cotton soil has a tendency to shrink and swell excessively. When dry, it shrinks and is hard like stone and has very high bearing capacity. But when the soil is moist, it expands, becomes very soft and loses its bearing capacity. It increases in volume to the extent of 20% to 30% of its original. This alternate process of swelling and shrinking results in the differential settlement of foundation which in turn causes cracks in building and failure in flexible pavement.

Tarun Kumar and Suryaketan (2018) study the behavior of clay soil by mixing with plastic strips. The study was carried out on the development of a roadway which was required to be strong enough to support different loads. To meet these challenges plastic wastes were used in the forms of strips of various sizes to stabilize the soil. To study the reinforcing effect of mixed plastic strips in soil, a series of standard proctor test and unsoaked CBR tests were conducted. It was observed that the maximum dry density of plastic mix soil decreases with increase in percentage of plastic strips whereas the CBR increases with increase in percentage of plastic strips within a certain limit. The maximum CBR value was obtained when the percentage of the plastic strips, having a length of 2cm, was 0.8% of the dry weight of soil.

Kiran Patil, Shruti Neeralagi (2017) carried out 'Soil Stabilization Using Plastic Waste'. Plastic such as shopping bags was used for reinforcing the soil and for improving the various properties of the soil. From the study, conclusion made was there is increase in CBR value of the soil and maximum CBR was achieved when 0.75% amount of plastic bottle strips were added to the soil; after further addition of the strips, there was decrease in the CBR value. In the case of plastic bag strips, it has been observed that 2% of the total weigh of the soil is the optimum proportion of the strip. We can also state from this study that strips cut out of plastic bottles are better option than strips of plastic bags, in increasing the CBR value of the soil.

Sayli, Madavi, Divya Patel (2017) reviewed the experimental program that was conducted for stabilization of black cotton soil in Amravati, Andhra Pradesh state. They performed series of CBR test to find out optimum amount of plastic content that is required for obtaining maximum CBR value. It can be concluded that CBR percentage goes on increasing up to 4% plastic content in the soil and there on it decreases with increament of the plastic content. Hence, we can say that 4% of plastic content is the optimum content of plastic waste in black cotton soil. Thus, using plastic as a soil stabilizer is an economical and gainful usage because there is lack of good quality soil for various constructions. These techniques can also serve the purpose of reducing environmental.

Chandak. (2015) conduct a process of soil stabilization with lime sludge to help to improve the properties of the soil needed in a construction work. The optimum moisture content of the soil was found to increase with an increase in lime sludge value. This is probably as a result of the additional water needed for the necessary reactions for the stabilization process. The lime sludge also increased the MDD the angle of internal friction. Akshaya Kumar Sabat (2005) conducts a study on expansive soil. The soil properties were improved by adding lime sludge. The tests performed were Standard proctor, Unconfined Compressive Stress and California Bearing Ratio. The deferent proportions of lime sludge used were 2%, 8%, 10%, 15%. The maximum strength was obtained at 8% lime sludge. This study indicates that Lime sludge can therefore be used to improve the quality of soil subgrade soil.

Though, there was no research on the combination of 'lime sludge and cut strips from plastic bottles' as soil stabilizing agents, it is assume that using these agents when combined will provide better outcome than when used separately. While lime sludge reacts with clayey soil and makes more friable, the plastic strips will provide additional lateral restrain.

3.2 METHODOLOGY

Geotechnical tests are test carried out in order to obtain the needed information about the index properties and engineering properties of the soil to be used as foundation or construction material. This type of investigation can be done either by surface and subsurface soil exploration or by geophysical methods. The soil sample needed for the geotechnical tests can be collected by various types of soil samplers. The soil sample collected can be classified as disturbed sample or undisturbed soil sample; depending on the method or sampler used in collecting the soil sample. For the purpose of this research the soil sample will be collected by means of wheelbarrow, shovel and hand digger. The soil sample will be transported to the various soil mechanics lab by a pickup truck. The tests to be carried out are-

1. Specific Gravity test.
2. Liquid Limit test.
3. Plastic Limit test.
4. Plasticity Index.
5. Free Swell Index.
6. Standard Proctor.
7. Unconfined Compressive Strength test.
8. California Bearing Ratio test

The specific gravity test will be conducted on the black cotton soil in its natural state only. The remaining lab tests will be conducted on:
- The black cotton soil in its natural state.
-The 'black cotton soil and lime sludge mix' with the proportion of the lime sludge at 3%, 6%, 9% and 12% of the total weight of the mix.
-The 'black cotton soil and plastic strips mix' with the proportion of the plastic bottle strips at 0.25%, 0.5%, 0.75% and 1.0% of the total weight of the mix.
-The 'black cotton soil, the lime sludge and the plastic bottle strips mix'. The proportion of the lime sludge and the plastic strips combination will depend on the test results obtained when the waste were use separately.

4.0 RESULTS AND DISCUSSION

The results of the various Laboratory Experiments conducted on the Clay, Lime sludge and Plastic bottle waste (at different percentage and mix ratio) were as follows:-

4.1 Specific Gravity Test

Weight of empty pyconometer, W_1 = 584g
Weight of pyconometer + oven dry soil, W2 = 784g
Weight of pyconometer + oven dry soil + water, W_3 = 1594g
Weight of pyconometer + water, W_4 = 1474g

$$S.G = \frac{(W_2 - W_1)}{((W_4 - W_1) - (W_3 - W_2))} = \frac{(784 - 584)}{((1474 - 584) - (1594 - 784))}$$

Specific Gravity of the clay soil sample = **2.63**

4.2 Consistency Limits

Liquid Limit	
No. of Blows	**Moisture Content**
18	54
22	50
26	48
41	36

Table 4.1 Liquid Limit Readings

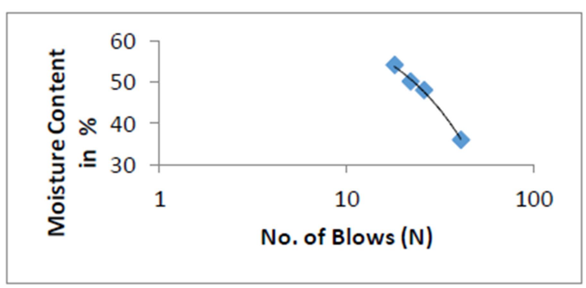

Fig 4.1 Clay Soil Liquid Limit Graph

4.2.1 Liquid Limit Test for Unreinforced Clay
Liquid Limit
No. of Blows Moisture Content
18 54

22	50
26	48
41	36

Table 4.1 Liquid Limit Readings Fig 4.1 Clay Soil Liquid Limit Graph The Liquid Limit of the clay soil was found to be 48%

4.2.2 Plastic Limit Test

The plastic limit test conducted on three different moulded ball samples of the clay that were rolled to 3mm thick thread were found to be at 22%, 24% and 22%. The plastic limit was therefore considered to be 22%.

4.2.3 Plasticity Index

The Plasticity Index of the clay was calculated from the results obtained from the liquid limit and plastic limit test.

PI = LL-PL= 48-22= 26%

4.2.4 Liquid Limit for Clay-Plastic bottle waste mix

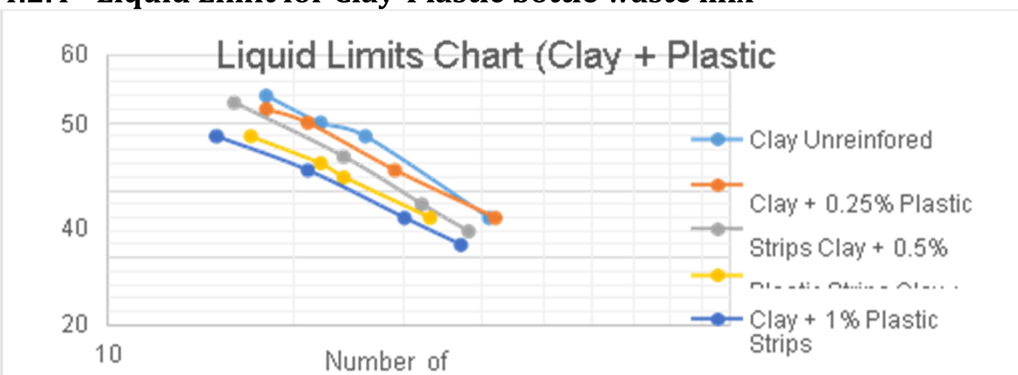

Figure 4.2 Clay-Plastic bottle waste mix Liquid Limit Graph

4.2.5 Liquid Limit for Clay-Lime Sludge mix

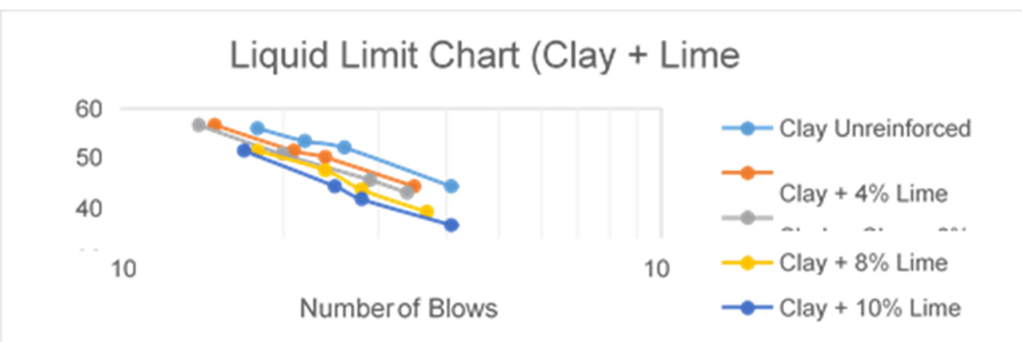

Figure 4.3 Clay-Lime Sludge mix Liquid Limit Graph

4.2.6 Liquid Limit for Clay-Lime Sludge-Plastic bottle waste mix

Liquid Limit Chart (Clay + Lime Sludge + Plastic Strips)

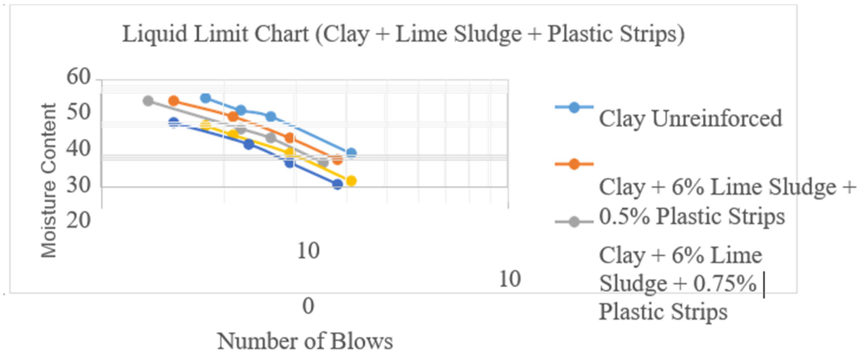

Figure 4.4 Clay-Lime Sludge-Plastic bottle waste mix Liquid Limit Graph

4.3 Free Swell Index Test

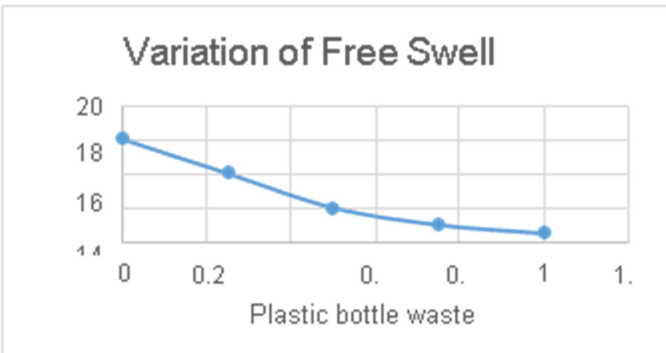

Figure 4.5 Variation of FSI of Clay with Plastic bottle waste mix Percentage

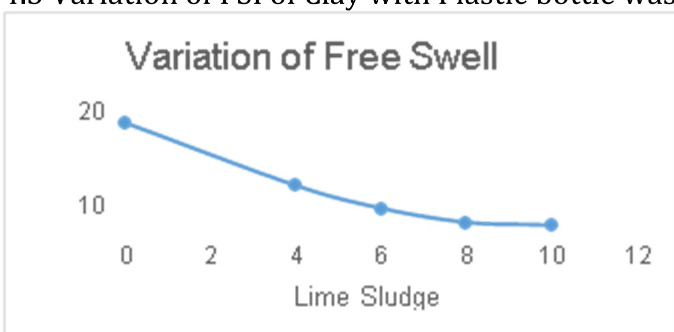

Figure 4.6 Variation of FSI of Clay with Lime Sludge mix Percentage

4.4 Standard Proctor Test

The optimum moisture content and maximum dry density of the clay soil was found out to be 19.6% and 16.35KN/m3 respectively as shown below.

4.4.1 Standard Proctor test on natural clay soil sample

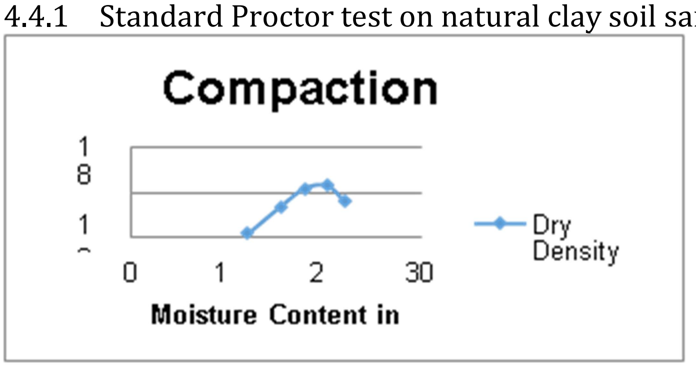

Fig 4.7 Moisture Content vs. Dry Density Graph

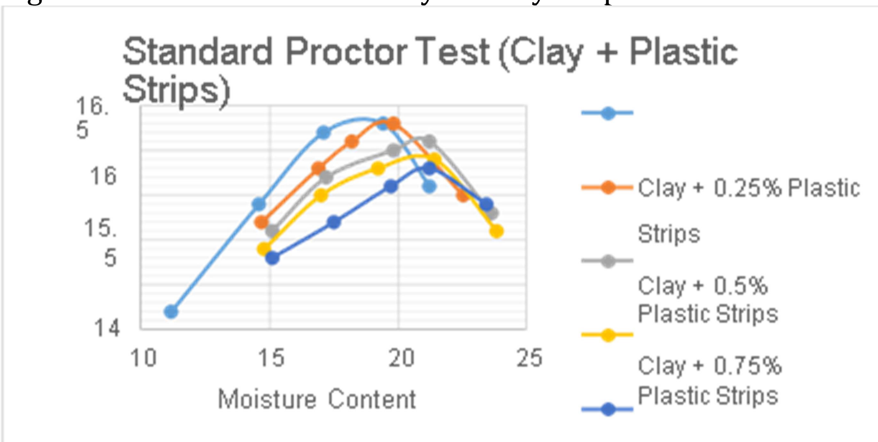

Figure 4.8 Compaction Curves of Clay-Plastic bottle waste mix

4.4.3 Compaction Test for Clay-Lime Sludge mix

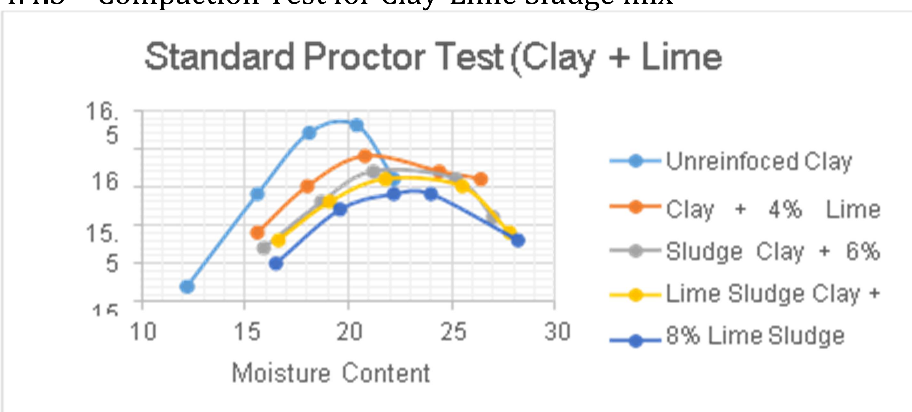

Figure 4.9 Compaction Curves of Clay-Lime Sludge mix

4.4.4 Compaction Test for Clay-Lime Sludge-Plastic bottle waste mix

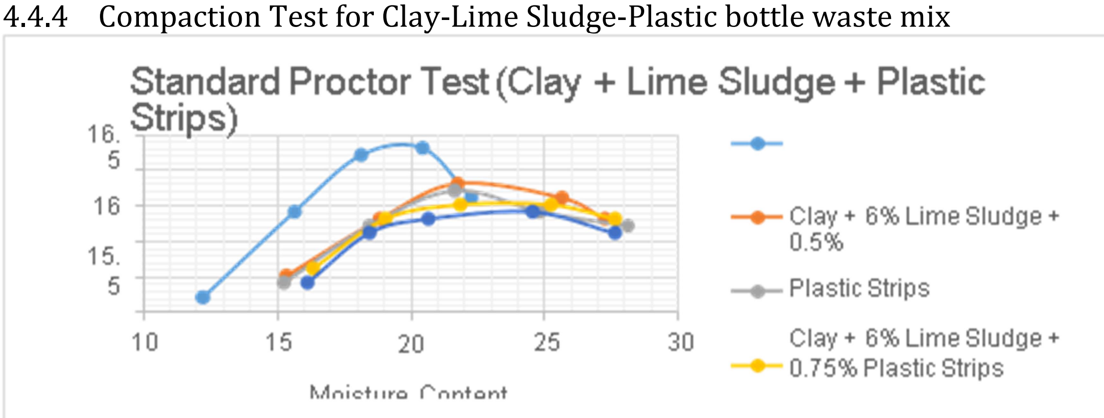

Figure 4.10 Compaction Curves of Clay-Lime Sludge-Plastic bottle waste mix

4.5 UNCONFINED COMPRESSION TEST

4.5.1 Unconfined Compressive Strength Test of the Clay

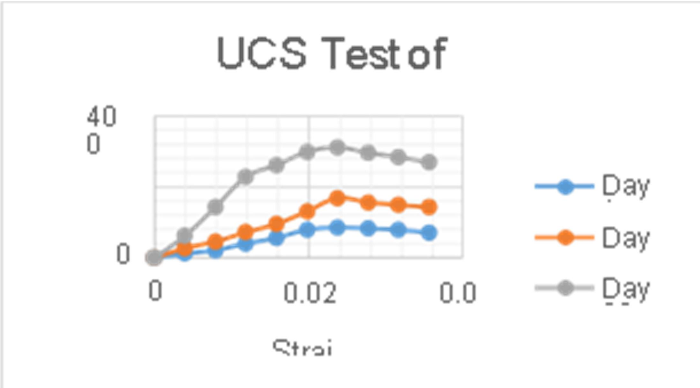

Figure 4.11 Unconfined Compressive Strength test Clay

4.5.2 UCS Test at Day 1 Curing Period for Clay-Plastic bottle waste mix

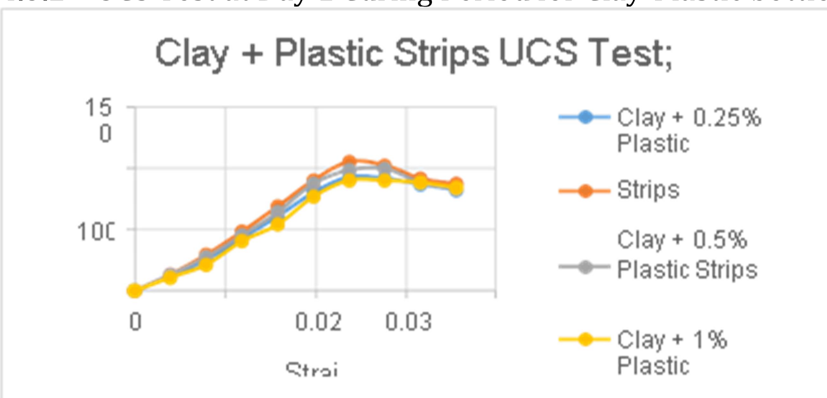

Figure 4.12 Clay-Plastic bottle waste mix UCS Test: Day 1 of Curing Period

4.5.3 UCS Test at Day 1 Curing Period for Clay-Lime Sludge mix

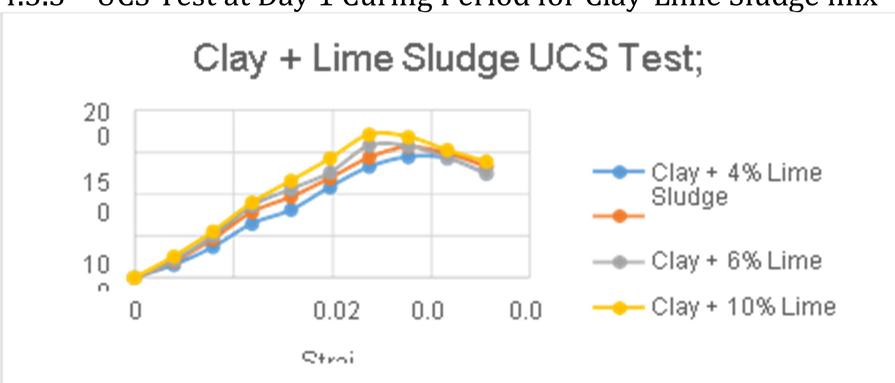

Figure 4.13 Clay-Lime Sludge mix UCS Test: Day 1 of Curing Period

4.5.4 UCS Test at Day 1 Curing Period for Clay-Lime Sludge-Plastic bottle waste mix

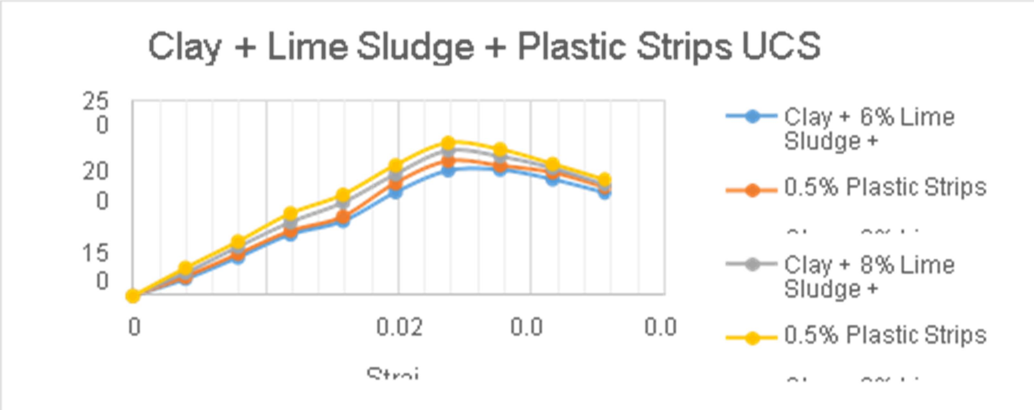

Figure 4.14 Clay-Lime Sludge-Plastic bottle waste mix UCS Test: Day 1 of Curing Period

4.5.5 UCS Test at Day 7 Curing Period for Clay-Plastic bottle waste mix

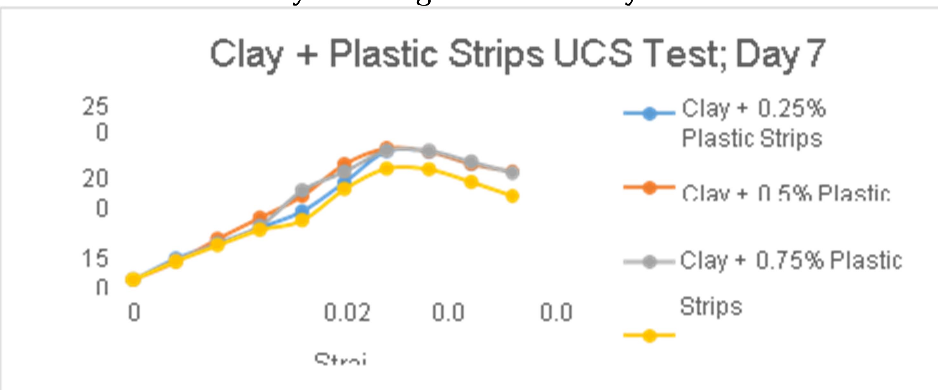

Figure 4.15 Clay-Plastic bottle waste mix UCS Test: Day 7 of Curing Period

4.5.6 UCS Test at Day 7 Curing Period for Clay-Lime Sludge mix

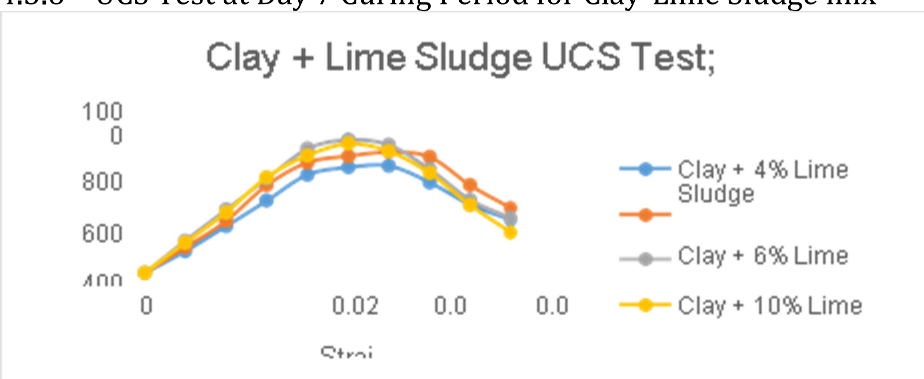

Figure 4.16 Clay-Lime Sludge mix UCS Test: Day 7 of Curing Period

4.5.7 UCS Test at Day 7 Curing Period for Clay-Lime Sludge-Plastic bottle waste mix

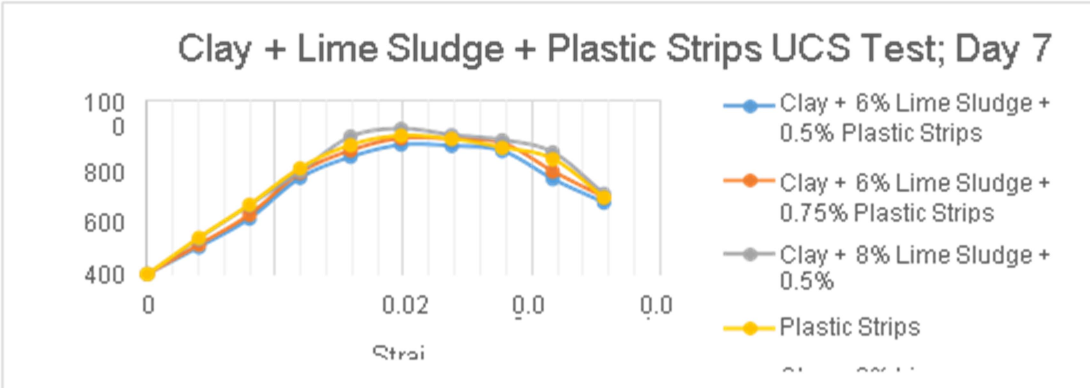

Figure 4.17 Clay-Lime Sludge-Plastic bottle waste mix UCS Test: Day 7 of Curing Period

UCS Test at Day 28 Curing Period for Clay-Plastic bottle waste mix

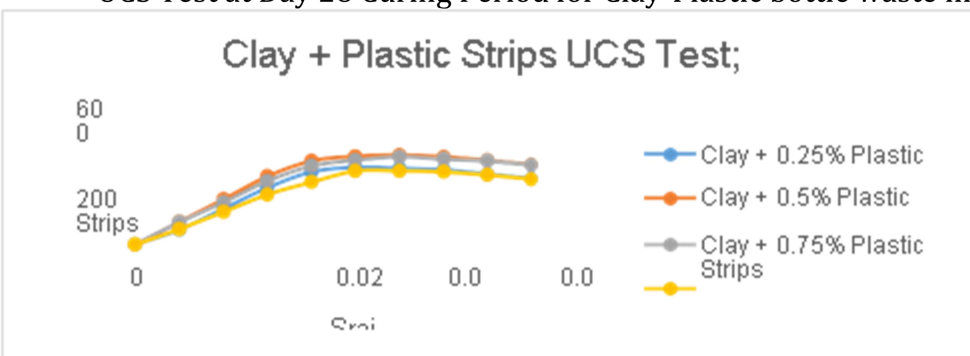

Figure 4.18 Clay-Plastic bottle waste mix UCS Test: Day 28 of Curing Period

4.5.8 UCS Test at Day 28 Curing Period for Clay-Lime Sludge mix

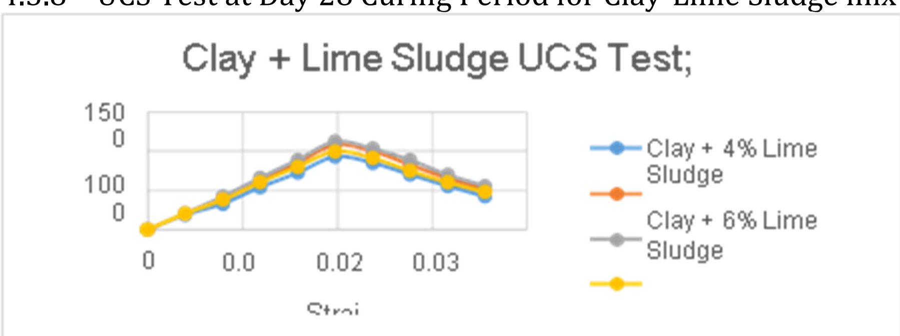

Figure 4.19 Clay-Lime Sludge mix UCS Test: Day 28 of Curing Period

4.5.9 UCS Test at Day 28 Curing Period for Clay-Lime Sludge-Plastic bottle waste mix

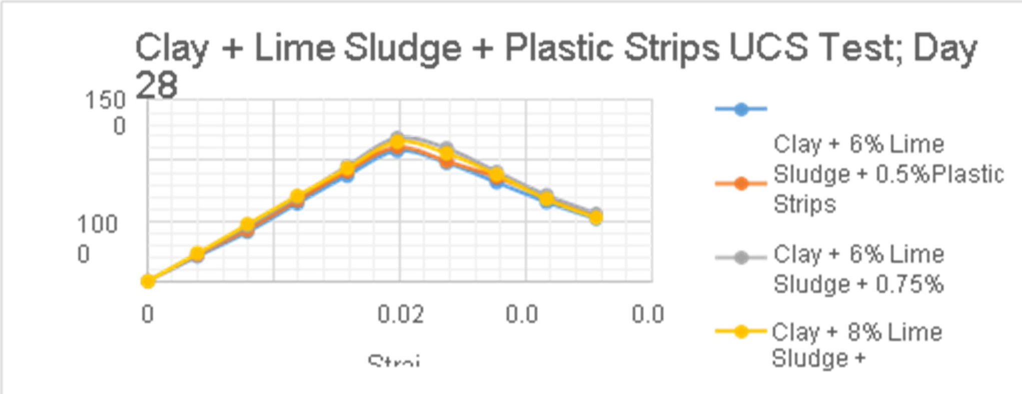

Figure 4.20 Clay-Lime Sludge-Plastic bottle waste mix UCS Test: Day 28 of Curing Period

4.6 CALIFORNIA BEARING RATIO TEST

4.6.1 CBR Test for Unreinforced Clay

Soaked California Bearing Ratio test was performed on the clay soil and the observations were recorded and plotted as shown below. The CBR Values at 2.5mm and 5mm penetration was found to be 2.2% and 2.1% respectively. The CBR value of the clay soil was therefore taken as 2.2%.

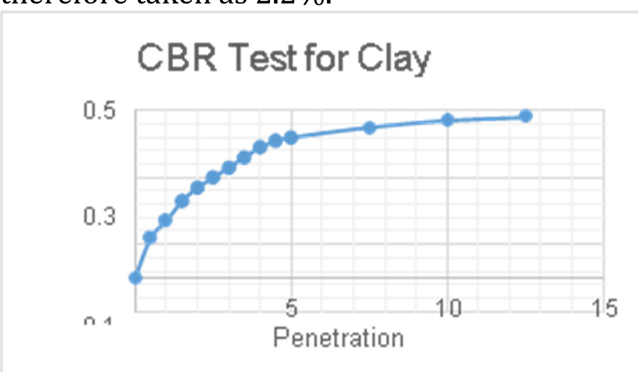

Figure 4.21 Load versus Penetration Graph for unreinforced Clay CBR Test

CBR Test for Stabilized Clay

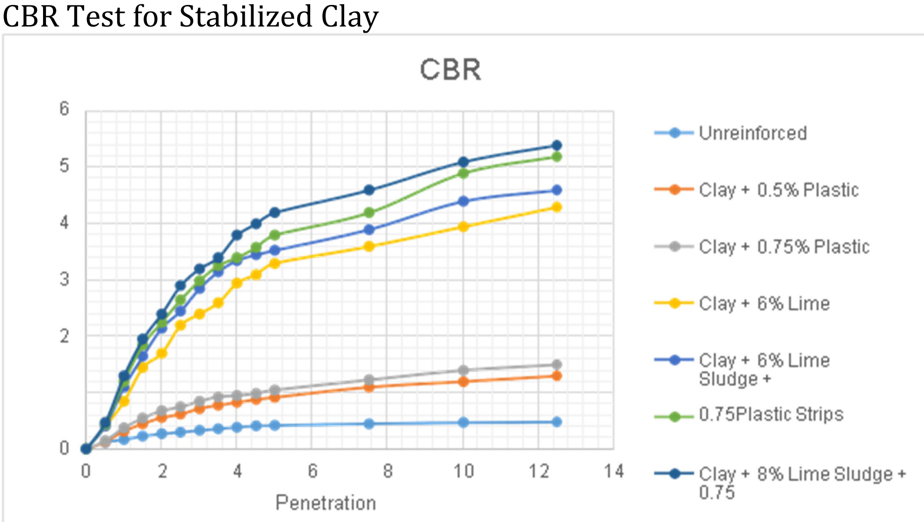

Figure 4.22 Load versus Penetration Graph for Stabilized Clay CBR Test

5.0 C0NCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From all the test results, it can be concluded that the addition of lime sludge reduces the free swell index of the clay to zero. The clay becomes non-plastic when the optimum amount of lime sludge was added. Addition of the lime sludge also reduces the plastic limits of the clay by making it more friable. For compaction tests, addition of the two additives (lime sludge and plastic bottle waste) increases the clay OMC and reduces it MDD. In the unconfined compressive strength tests, there was a significant increment in the clay shear strength when the optimum value of the additives (either combined or separate) was added. For the CBR tests, the increase in the CBR values when these additives were added were very remarkable. The usage of these additives will therefore save cost in any civil engineering construction where clay soils are encountered and also help in keeping the environment clean.

5.2 RECOMMENDATION

Based on the results obtained and observations from the tests conducted, I will like to recommend further research work on other non-biodegradable waste materials/products to be considered as soil stabilizing agents. Research work on the utilization of dumped waste in other aspects of Civil Engineering Construction should also be encourage.

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