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Stabilization of Clay Soil with Cement and Sawdust Ash

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ABSTRACT

One of the most pressing needs for research in geotechnical engineering is the issue of the use of marginal soils for fills and as backfill material for walls and bridge abutments. It is therefore essential to come up with more economical methods of soils stabilization. Due to the poor disposal of sawdust in Nigeria, this study investigated the possible effect of the addition of sawdust ash and/or cement to the clayey soil on its basic geotechnical properties and strength characteristics. Geotechnical property tests were performed on the samples, both at the stabilized and unstabilized states by adding 1.5,3, 4.0, and 7.0% cement and also 1.5, 3.0, 4.0, and 7.0% cement-sawdust ash by weight of stabilizer to the soil. Results obtained show that cement and cement-sawdust ash mixture treatments resulted in significant reductions in the soil plasticity index and liquid limit. The plasticity index of the cement stabilized soil reduced from 18%to 3% at the addition of 7% cement. The compaction test carried out on the stabilized soil samples indicated that the use of cement and cement-sawdust ash for soil stabilization increases the optimum moisture content and decreases the maximum dry density with increase from 19.8% to 28.2% and 19.8% to 26.4% for cement and cement sawdust ash stabilized soil respectively. The cement alone when used to stabilize the clayey soil resulted in a significant increase in the unconfined compressive strength of the soil, whereas combining sawdust ash with cement resulted in a small but reasonable increase in the unconfined compressive strength of the cement and cement-sawdust ash stabilized soil increased from 185.1 Kpa to 1356.5kpa and 185.1 Kpa to 1003.8 Kpa respectively at optimum binder content. This research shows the viability of sawdust ash combined with cement as a suitable stabilization agent for soil.

Keywords: stabilization, clay soil, cement, sawdust Ash

INTRODUCTION

Soil stabilization is the treatment of soils to enable their strength and durability be improved such that become totally suitable for construction beyond their original classification (Norazlam *et al.*, 2012). Clay soils swell significantly when it comes in contact with water and shrinks when water is lost. Because of this swell-shrink behavior, civil engineering structures situated on them experience damages and it is therefore a necessity to stabilized the soil before civil engineering structures are situated on them (Deepiya *et al.,* 2014). Various researchers have carried out and studied the stabilization of clayey soil using different materials like lime, coal bottom ash (fly ash), natural gypsum, high density polyethylene etc. most of these materials contained a reasonable amount of Ca, Mg, Si, or Al oxides in them (seco *et al*., 2010).

Achmad *et al*., (2013) conducted laboratory tests on the soil they stabilized with high density polyethylene (HDPE) and crushed glass and they observed that with increase in the content of HDFE and glass in the soil, the soil experienced an increase in the optimum water content and CBR value and also a decrease in its maximum dry density thereby implying that the addition of these water materials improved the physical property of the clayey soil.

Seco *et al.,* (2010) carried out experiments on the stabilization of expansive soil using lime and other industrial waste or by-products material and recommend that these products can be used as an effective stabilizing agent for the improvement and stabilization of soils.

Ramadas *et al*., (2010) studied the swelling and strength characteristics of expansive soil treated with stone dust and fly ash, and they observed that the plasticity characteristics of soil are low in case of soil treated with the stone dust compared to that treated with fly ash, and there was a decrease in optimum water content and increase in maximum dry unit weight value with the increase in percentage of stone dust/fly ash. Also, Cimen *et al.,* (2011) studied the effect of waste marble aggregates and the decrease in the amount of the additivies resulted in more swelling (Osman *et al*., 2014).

BACKGROUND UNDERSTANDING

Soils

In Nigeria, weak soils are present in every geo-political zone. Due to the swelling and the shrinkage of this soil, road facilities, dams etc. situated on it can experience damages thereby imposing unforeseen costs on the maintenance of the damaged structures. These costs can be avoided if the soil is stabilized. On the other hand, Nigeria faces challenges in the disposal of sawdust due to the poor waste control and management system in the country thereby leading to pollution and also making that particular area aesthetically displeasing. If sawdust is used in the stabilization of weak and expansive soils in the country, the damages caused to structures on it can be curbed thereby eliminating the cost of maintenance on the structures and also help in the reduction of sawdust in the country to a reasonable amount. Also, the addition of sawdust to cement will reduce the amount of cement used thereby making it economical for use in stabilizing weak and also expansive soils. In view of the importance of tackling the disposal and management of sawdust, the innovation of using sawdust ash combined with cement was researched.

Clay Soils

Clay soils are naturally occurring soil materials that are composed of fine-graded clay minerals (Stephen and Martin, 1995). Clay soils are naturally plastic at appropriate water contents and harden, become non-plastic upon drying. Clay soils also called expansive soils experience great changes in volume when there are variations in water content. Clay soils are widely distributed around the world but are abundantly found in the arid region (seco *et al.,* 2010). Clay can be used as a building and construction materials for different purposes. It can be used for the production of tile for wall, earthenware and also pipe for sewage and drainages. Because of its absorbent nature, it can be used in foundry works for facing the mould and for preparing moulding sands for casting metals (Columbia Electronic Encyclopaedia, 2012).

Formation

Clay soils can be classified into residual clay and transported clay. Residual clays are clays that are found at the place of origin while transported clays are transported clays are transported from their original position by action of erosion and are deposited in a far and new position. Clays are formed from the gradual chemical weathering of rocks by the decomposition of rocks containing silica and alumina, usually granite; by the solution of rocks containing clayey impurities which are naturally insoluble and are deposited as clay; and also by the disintegration of shale. The most common clay formation process is the chemical weathering of feldspar (Columbia Electronic Encyclopaedia, 2012)

FACTORS AFFECTING CLAY FORMATION

Relative Position of the Soil from the Surface

Barshad (1989) observed that in all the soil profiles studied, there was a decrease in the formation of clay with an increase in distance from the surface. It was also observed that in majority of the soil profile, the maximum clay formation occurred in the horizon below the soil surface.

Climate (Effect of Temperature and Rainfall)

Soils tend to show a strong geographical correlation with climate, especially at the global scale. Energy and precipitation strongly influences physical and chemical reactions on parent material. Climate also determines vegetation cover which in turn influences soil development. Precipitation also affects horizon development factors like the translocation of dissolved ions through the soil. As time passes, climate tends to be a prime influence on soil properties while the influence of parent material is less (Ritter, 2006). Barshad (1989) also reported that an increase in annual temperature favours clay formation and is most sharply expressed in the lower horizons of the profile rather than in the surface origin. Also an increase in rainfall brings about an increase in clay formation.

Effect of Topography

Topography has a significant impact on sol formation as it determines runoff of water, and its orientation affects microclimate which in turn affects vegetation. For soil to form, the parent material needs to lie relatively undisturbed so soil horizon processes can proceed. Water moving across the surface strips parent material away impeding soil development. Water erosion is more effective on steeper, unvegetated slopes (Ritter, 2006). Barshad (1989 after comparing his studies of area with better drainages to areas with poorer drainages; he concluded that clay formation is enhanced by decrease in drainage.

Effect of Vegetation

In areas with grass type of vegetation, clay formation is high compared to areas with tree type vegetation.

Effect of Parent Material

Soils will carry the characteristics of its parent material such as colour, texture, structure, mineral composition and so on. For example, if soils are formed from an area with large rocks (parent rocks) of red sandstone, the soils

will also be red in colour and have the same feel as its parent material.
Using different parent materials as a case study, Barshad (1989) concluded that the mineral and chemical composition, texture, degree of consolidation, porosity, density and base content of the parent material influences the formation of clay.

MATERIALS AND METHODS

Soil Sampling

The clayey soil samples were sourced from the front of the mandate Lodge at Landmark University Omu-Aran, Kwara State. The method used for sample collection was the trial pit method. The pit was dug up to a depth of 1m by hand excavation with the aid of a spade and the clayey samples were collected using a soil hugger. The samples collected were placed in leather bag.

Cement

An ordinary Portland cement of grade 42.5 was sourced from a cement depot in Omu- Aran town

Sawdust

The sawdusts were collected from the carpentry workshop close to the New College Building in Landmark University. The sawdust was burnt using a fabricated sawdust burner after which the sawdust ash was collected and sieved in the laboratory using the 300um sieve. The sieved sawdust ash was placed in the oven for 2 hours at a temperature of 300C prior to mixing so as to remove the Carbon in the ash.

Soil Binder Preparation

The soil was mixed the various stabilizing volume by dry weight in the Los
Angeles abrasion machine the metal balls at a rotation of 200 after which the different laboratory test were carried out on the stabilized sample. For the unconfined compression test, the stabilized soil were compacted at optimum moisture content gotten from the proctor compaction test results and was covered with a plastic bag so as to avoid moisture loss. The sample was mixed every 30 minutes interval for 2 hours after which it was compacted in the split mould of diameter 38mm and height of 85mm.The remoulded samples were then wrapped in plastic bag and allowed to cure at laboratory condition for 7,14 and 28 day. The unconfined compressive strength test was then carried out the different soil samples at each curing day interval.

The soil- binder mix used in this project was in the same range with that used by Raoul *et al.*, (2010). The experimental design is as follows

Cement Stabilization

1. 100%clayey soil +o% cement
2. 98.5%clayey soil+1.5% cement
3. 97% clayey soil +3% cement
4. 96%clayey soil +4% cement
5. 93%clayey soil+7% cement

Cement-Sawdust Ash Stabilization

1. 100%clayey soil +0%cement 0%sawdust Ash
2. 98.5% clayey soil +0.7%cement +0.75 cement +0.75% Sawdust Ash
3. 97%clayey`soil+ 1.5% cement+1.5%sawdust Ash
4. 96% clayey soil+2% cement +2%sawdust Ash
5. 93%clayey soil+3.5% cement +3.5sawdust Ash

Experimental Programme

Laboratory tests were performed on both the control soil sample and the stabilized soil sample to evaluate some of their physical characteristics and engineering properties. Using different codes for laboratory experiments, the following laboratory tests were carried out on both the control sample and the stabilized sample:

i. Particle size Analysis by sieving
ii. Atterberg Limits
iii. Specific Gravity Test
iv. Proctor compaction Test
v. Unconfined Compression Test
vi. Direct Shear test

Liquid Limit Test

Liquid limit test was performed on the soil samples to determine their liquid limits using the cone penetration method as per BS1377-2:1990.

Apparatus and Equipment

A flat glass plate, 425 μm sieve, spatula, cassagrande liquid device, metal cups, evaporating dish, moisture content apparatus, Beaker containing distilled water, a metal straight edge.

Test Procedures

1. Roughly ¾ of the soil was taken and placed it into the porcelain dish. The soil was then thoroughly mixed with a small amount of distilled water until it appeared as a smooth uniform paste. The dish was covered with cellophane to prevent moisture from escaping.
2. Four of the empty moisture cans with their lids were weighed, and their respective weights and can numbers were recorded on the data sheet.
3. The liquid limit apparatus was adjusted by checking the height of the drop of the cup. The point on the cup that comes in contact with the base rose to a height of 10mm.

the block on the end of the grooving tool is 10mm high and was used as a guage.

4. A portion of the previously mixed soil was placed into the cup of the liquid limit apparatus at the point where the cup rests on the base. The soil was then squeezed down to eliminate air pockets and spread it into the cup to a depth of about 10mm at its deepest point.
5. The grooving tool was carefully used to cut a clean straight groove down the centre of the cup. The tool remained perpendicular to the surface of the cup as the soil groove was being made. Extreme care used so as to prevent sliding the soil relative to the surface of the cup.
6. The base of the apparatus below the cup and the underside of the cup were made clean of soil. The crank of the apparatus was turned at a rate of approximate two drops per second and the number of drops it takes to make the two halves of the soil pat come into contact at the bottom of the grieve along a distance of 13mm (1.2in.) was counted.
7. A sample was taken, using the spatula from edge to edge of the soil pat. The sample included the soil on both sides of where the groove came in contact. The soil was then placed into a moisture can containing the soil was taken and recorded. The can was then placed into the oven. The moisture can was left in the oven for at least 16hours. The soil remaining in the cup was transferred into the porcelain dish. The cup on the apparatus and the grooving tool were cleaned.
8. The entire soil specimen was remixed in the porcelain dish. As small amount of distilled water was added to the paste to increase the water content so that the number if drops required closing the groove decreases.
9. Step six, seven, and eight were repeat for at least two additional trials producing successively lower numbers of drops to close the groove.

Plastic Limit

The plastic limit test carried out on the soil sample was done following BS1377-2:1990.

Apparatus and Equipment

Two flat glass plates, two palette knives, moisture content apparatus, a length of rod.

Test Procedures

1. About 20 g from the soil paste sample was taken and placed on the glass mixing plate.
2. The soil was allowed to dry partially on the plate until it became plastic enough to be shaped in to a ball.

3. The ball of soil was moulded between my fingers and rolled between my palms until the heat of my hand had dried the soil sufficiently for slight cracks to appear on its surface.
4. The sample was then divided in to two sub-samples of about 10 g each and a separate determination was carried out on each portion. Each subsample was then divided in to two parts.
5. The soil was moulded with fingers to equalize the distribution of moisture. The soil was formed in to thread about 6mmdiameter between first finger and thumb of the hand.
6. The thread was rolled between fingers, from finger-tip to the second joint of the hand and the surface of the glass rolling plate. Enough pressure was used to reduce the diameter of thread to about 3mm in five to 10 complete, forward and back, movement of my hand.
7. The soil was picked up, moulded in between fingers to dry further and transversely when it had been rolled out again as specified above.
8. The procedure was repeated until the thread sheared both longitudinally and transversely when it had been rolled to about 3mm diameter, the first crumbling point was the plastic limit.
9. The portion of the crumbled soil thread were gathered together and transferred in to a suitable container for determination of moisture content and the lid was replaced immediately.
10. The rolling procedure was repeated on the other portion of soil, placing them all in the same container. The moisture content of soil samples was determined in the container.
11. The rolling process was also repeated on the 2nd sub-sample as described above so that two completely separate deter determinations were made.

Using the liquid limit and the plastic limits of the soil samples, their plasticity index were calculated respectively using

I_ρ=W-wρ ---------------- (3.1)

W=liquid limit

W_ρ=plastic limit

Particle Size Distribution (Sieve Analysis Method)

The sieve analysis of the soil samples helps to determine the particle size distribution of the soil samples and also helps in the classification of the samples. Sieve analysis was carried out the soil samples.

Apparatus and Equipment

Balance, set of sieves, Cleaning brush, sieve shaker.

Test Procedures

1. The weight of each sieve was recorded as well as the bottom pan to be used in the analysis.
2. The weight of the given dry soil sample was also taken and recorded.
3. All the sieves were clean, and assembled in ascending order of sieve numbers (#4 sieves at top and #200 sieves at bottom). The pan was then placed below the #200 sieve.
4. The soil sample was carefully poured into the top sieve and the cap was placed
5. The sieve stack was then placed in the mechanical shaker and shook for 10minutes.
6. The stack was removed from the shaker and carefully weighed and each sieve with its retained soil were carefully weighed and recorded. The bottom pan with its retained fine soil was also weighed.

Specific Gravity Test

The specific gravity of a soil is the ratio of the weight of the soil solids at a stated temperature to the weight of equal volume of distilled water at a stated temperature.
The specific gravity test was carried out on the soil sample to determine their specific gravity value as per BS13772:1990.

Apparatus and Equipment

Density bottle of 50ml with stopper having capillary hole, balance to weigh the materials (accuracy 10gm), wash bottle with distilled water, alcohol and ether, water bath, desiccators, oven.

Test Procedures

1. The density bottle was cleaned and dried.
   a. The bottle was washed with water and allowed it to drain.
   b. It was washed with alcohol and drained to remove water.
   c. It was also washed with ether, to removed alcohol and the ether drained,
2. The weight of the empty bottle with stopper was taken and recorded (W1)
3. About 10 to 20 gm of oven soil sample which was cooled in a desiccator was taken and transferred into the bottle. The weight of the bottle and soil with the stopper was taken and recorded (W2).
4. 10ml of distilled water was put in the bottle to allow the soil to soak completely and left for about 2 hours.

5. Again the bottle was filled completely with distilled water and the stopper was placed on it. The bottle was kept under constant temperature in the water bath.
6. The bottle was taken outside and wiped clean to dry. The weight of the bottle and its contents were then determined and recorded (W3).
7. The bottle was emptied and thoroughly cleaned. The weight was recorded (W4).
8. The same process was repeated two times, and the average of the reading was taken.

$$\textbf{Specific Gravity } G = \frac{W2-W1}{(W_4-W_1)-(W_3-W_2)} \quad \ldots (3, 2)$$

W1= weight of bottle (in g)
W2= weight of bottle + dry soil (in g)
W3= weight of bottle + soil + water (in g)
W4= weight of bottle + water (in g)

Compaction Test

Compaction test was carried out on both the control and stabilized soil samples so as to determine their optimum moisture content and maximum dry density using the proctor compaction test method. The test was carried out using the light weight method as per BS1377:Part4: 1990.

Apparatus and Equipment

Moulds, manual rammer, extruder, Balance, Drying oven, Mixing pan, Trowel, #4 sieve, Moisture cans, Graduated cylinder, Straight Edge.

Test Procedure

1. The weight of the mould with the base plate attached was taken and recorded to the nearest 1g.
2. The extension collar was then attached and the mould was placed on a solid base.
3. A quantity of moist was placed in the mould such that when compacted it occupied a little over 1/3 of the height of the mould body.
4. The rammer was placed with guide on the material in the mould. The rammer handle was lifted until it reached the top of the guide and then released allowing it to drop freely on the sample.
5. The position of the guide was change and the rammer was dropped again. The process was repeated, systematically covering the entire surface of the sample. A total of 27 blows were applied.
6. The rammer was removed and the next layer of soil was

filled in the mould. The above process was repeated twice by applying 27 blows to both the second and the third layer.

7. With all three layers compacted, the extension collar was removed, excess soil was stroked off and the surface of the compacted soil was leveled to the top of the mould using the straightedge.
8. The weight of the soil and the mould with base plate attached was taken and recorded to 1g.
9. The compacted sample was then removed from the mould and a representative sample of 300g of the soil was taken so as to determine its moisture content.
10. The whole process was carried out for 5 portions of the sample.

Direct Shear Test

This test was carried out on the control and stabilized soil samples according to BS1377: part 7: 1990. The direct shear test helps in determining the cohesion and angle of internal friction of the soil. These parameters can be used in calculating the bearing capacity of the soil.

Apparatus and Equipment

Shear box apparatus, two porous of corrosion-resistant material, two perforated grid plates, a loading cap, loading yoke, a motorized loading device, loading ring, two Dial gauges, specimen cutter, Tool for removing the specimen from the cutter, leveled template, calibrated vernier caliper, stop clock, weigh Balance, apparatus for determining moisture content, petroleum jelly.

TEST PROCEDURE

Initial Adjustments

1. The carriage was positioned on the machine bed, and the drive unit was adjusted to the correct starting point of the shear test. The horizontal displacement gauge was also secured in position.
2. The loading system was assembled so that the loading yoke was supported by the ball seating on top of the lead cap
3. The vertical deformation gauge was also secured in position so that it could measure that vertical movement of the center of the loading cap; ensuring that it allowed enough movement in either

direction. The initial zero reading was recorded

Consolidation

1. A normal force was applied to the specimen, to give the desired vertical stress,ση(in kpa), smoothly and as rapidly as possibly without jolting. The clock was started at the same instant when the consolidation readings were significant.
2. The carriage was then filled with water to a level just above the top of the specimen and maintained it at that level throughout the test.
3. The readings of the vertical deformation gauge and elapsed time were recorded at suitable intervals to allow a graph to be drawn of vertical deformation as ordinate, against square-root of elapsed time as abscissa. This was continued until the plotted reading indicated that primary consolidation was complete

Final Adjustments

On completion of the consolidation stage and before shearing the following checks and adjustment were made:

4. It was ensured that all adjacent components from the constant of displacement device through to the load measuring device and its point of restraint were properly in contact but under zero horizontal loads.
5. The clamping screws were removed which lock the two halves of the shear Box together.
6. The upper half of the box was raised, keeping it leveled, by turning the lifting screws. the lifting screws were retracted
7. The initial reading of the horizontal deformation gauge and the force measuring device were then recorded.

Shearing

The specimen was then sheared to failure

8. The test and the timer were started at the same time. The reading of the force measuring device, the horizontal displacement gauge, the vertical deformation gauge and elapsed time were recorded at regular intervals of horizontal displacement such that at least 20 readings are taken up to the maximum load ('peak' shear strength).
9. Additional readings were taken as the maximum horizontal force was approached, so that if the

peak occurs it could be clearly defined.

10. Shearing was continued and readings were taken beyond the maximum force until the full travel of the apparatus had been reached.
11. The direction of travel of the carriage was reversed and returned the two halves of the shear box to their original alignment.
12. The vertical force and loading yoke were then removed from the specimen
13. The specimen was transferred from the shear box to a small tray, taking care not to lose any soil. Free water from the sample was removed with a tissue.

Unconfined Compression Test

The unconfined compression test was carried out according to ASTM standards so as to determine the unconfined strength of the soil

Apparatus and Equipment

Unconfined compression testing machine (Triaxial Machine), Specimen preparation equipment, sample extruder, weighing Balance, venire caliper.

Test Procedure

1. The diameter and length of the specimen to be tested were measured.
2. The triaxial cell was placed above the sample and no confinement was applied.
3. The rate strain at 1.2700mm/min as per ASTM specifications was maintained.
4. The data acquisition system collected real time data and the test was stopped when there was a drop observed in the strain versus load plot.

RESULTS AND DISCUSSION

This study present the results of laboratory tests on control sample as well as cement and cement-sawdust ash treated soils and a discussion on their relevance to practice. The laboratory tests and unconfined compressive strength.

Atterberg Limits

The results of atterberg limits test using Cassagrande method with different content of cement and cement-sawdust ash for the soil is as shown in Table 4.1. The tests were performed 30 minutes after addition of cement to the soil.

Table 1: Atterberg limits of the soil for different cement and cement sawdust ash content

Stabilizer Content	Liquid limit (%)	Plastic Limit (%)	plasticity index (%)
Control Sample	58	40	18
1.5% cement	53	41	12
3.0% cement	50	42	8
4.0% cement	48.5	43	5.5
7.0% cement	42	39	3
1.5% cement-sawdust ash	55	39	16
3.0% cement-sawdust ash	54.1	40	14.1
4.0% cement-sawdust ash	52	42	10
7.0% cement-sawdust ash	48	44	4

Variation of liquid and plastic limits for different cement and cement-sawdust ash content for the soil is shown in figures 4.1. And4.2. it can be seen from figure 4.1 that liquid limit decreased with increase in cement content, while the plastic limit increased slightly with increase in cement content but decreased at 7% addition of cement. Figure 4.2 shows a reduction in liquid limit with respect to increase in cement-sawdust ash content and also an initial decrease in the soil's plastic limit with subsequent increase with stabilizer content. Generally, it was observed that the plasticity index decreased with increase in cement and cement-sawdust ash content. The result gotten from experiment falls within the range gotten by Thomson (2012). Thompson (2012) reported a reduction in the soils liquid limit and plasticity index with a relative increase in the soils plastic limit.

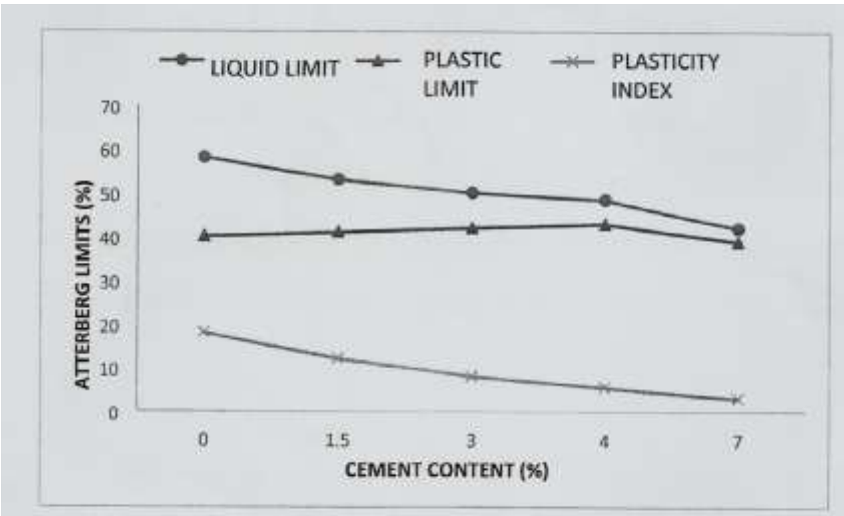

Figure 1: variation of Atterberg limits of the soil for different cement content

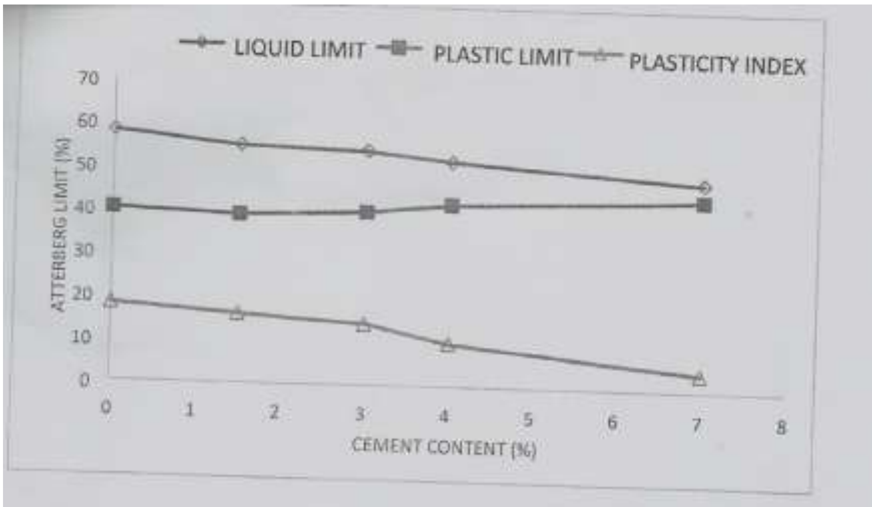

Figure 2: variation of Atterberg limits of the soil for different cement-sawdust ash content

Particle Size Distribution

The grain size distribution of the soil is shown in figure 4:3. It can be seen that soil used is fine-grained. According to the American association of state highway and transportation officials system the soil is a clayey soil and is classified under group A-7-5 (3).

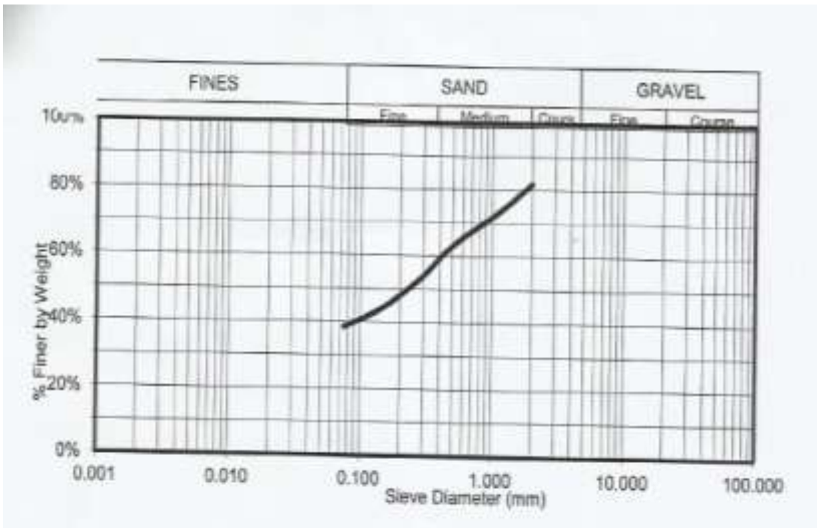

Figure 3: Grain size distribution of the soil

Specific Gravity

The specific gravity test of the soil was carried out using the standard pycnometer test and the average specific gravity gotten was 2.37. Table 4.2 shows the specific gravity of the soil with respect to binder dosage.

Table 2: Specific gravity of the soil with respect to cement and cement-sawdust ash content

Stabilizer Content	Specific Gravity
Control Sample	2.37
1.5% cements	1.89
3.0% cement	1.94
4.0% cement	1.88
7.0% cement	2.04
1.5% cement-sawdust ash	2.25
3.0% cement-sawdust ash	1.87
4.0% cement-sawdust ash	1.86
7.0% cement-sawdust ash	2.00

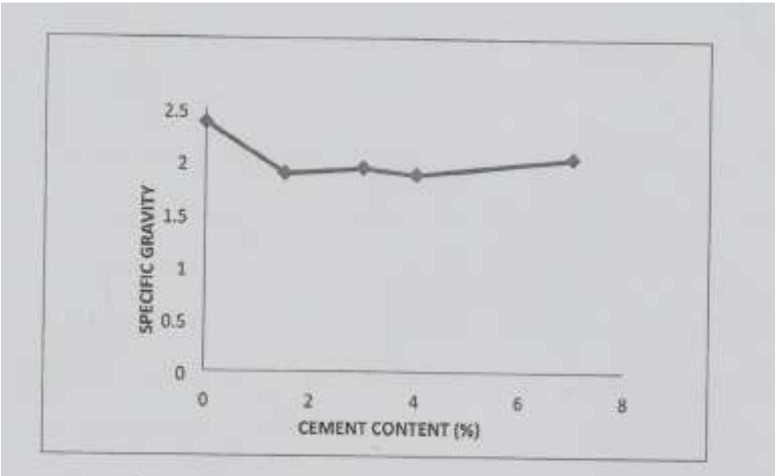

Figure 4.4 shows the variation of the soil `s specific gravity with cement content

It was seen that the specific gravity of the soil decreased initially on addition of cement but increased gradually with cement content. However, there was a slight decrease in the specific gravity at4% cement content after which an increase was observed. Also, Figure 4.5 shows the variation of the soil`s specific gravity with cement –sawdust ash content. It is seen that the specific gravity decreased gradually but later increased at 7%cement content. The soil`s specific gravity decreased due to the low specific gravity of participating cement and sawdust ash as compared with the soil.

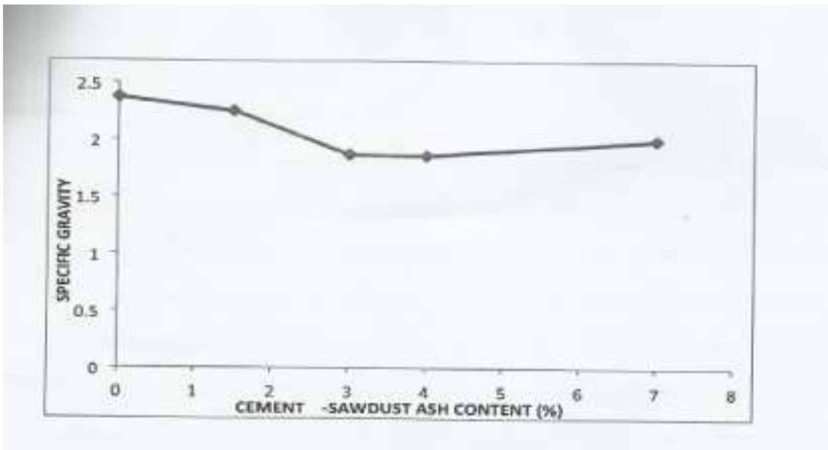

Figure 5: Variation of specific gravity of soil with cement. Sawdust Ash content

Compaction Test

Standard proctor compaction test was carried out on the control sample and the stabilized soil sample to determine their individual optimum moisture content and maximum dry density.

A standard proctor mold of 100mm diameter x 117mm height was filled in three layers; each layer having 25 blows at a height of 300mm. Table 4.3 shows the optimum moisture and maximum dry density for different binder dosage.

Table 3: Optimum moisture content and maximum dry density of the soil for different cement and cement-sawdust ash content

Stabilizer Content	Optimum Moisture Content(%)	Maximum Dry DENSITY (Kg/m^3)
Control sample	19.8	1540
1.5%cement	17.4	1608
3.0%cement	20	1444
4.0%cement	24	1424
7.0%cement	28.2	1358
1.5%cement-sawdust ash	16.9	1900
3.0%cement-sawdust ash	21.8	1553
4.0%cement-sawdust ash	22.2	1490s
7.0%cement- sawdust ash	26.4	1450

The effect of cement and cement-sawdust ash treatment on optimum water content and maximum dry density of the soil are shown figures 4.6, 4.7, 4.8, and 4.9, it was observed generally that the optimum moisture content of the soil increased cement-sawdust ash content. Also the maximum dust density of the decreased with increase in with cement and cement-dust ash content.

However, an initial increment in the soil's maximum dry density was observed at the initial addition of cement and also cement-sawdust ash to the soil. The reduction in maximum dry density is due to the low value of cement and sawdust ash's specific gravity than that of the replaced soil and also because they are both finer than the soil. The increase in water content can also be related to the pozzalanic reaction of cement and sawdust ash with the soil and also which may be explained by the floccution and cementation of soil particles (sayed *et al.,* 2014). The result is in agreement with previous works. Sayed *et al.,* (2014) carried out "stabilization or residual soil using $Si0_2$ nanoparticles and cement" and reported a reduction in the maximum dry density of the soil and a relative increment in the soil's optimum moisture content as the stabilizer content increased. Also, Shahram *et al.,* (2015) in their study on stabilization of clayey soil using ultrafine palm oil fuel (POFA) and cement, observed an increment and decrease in optimum moisture content and maximum dry density respectively with increase in cement in the soil

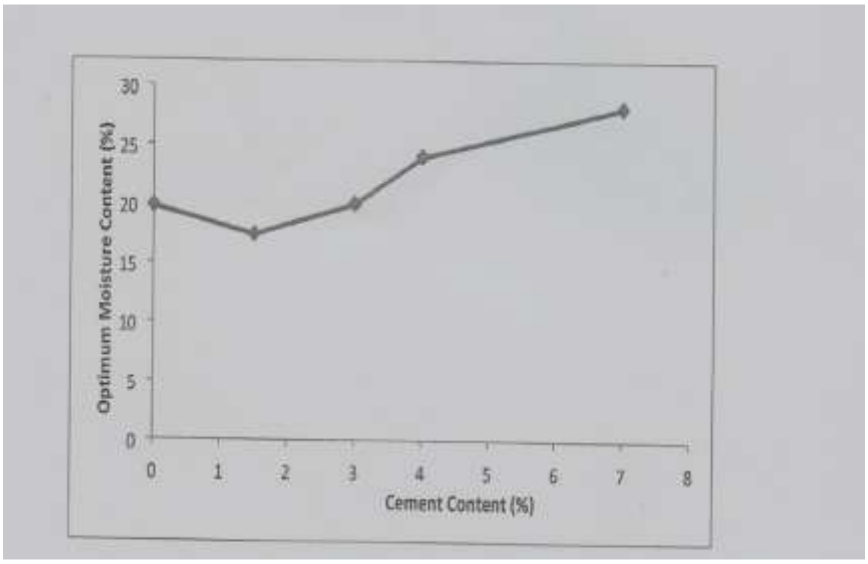

Figure 6: Effect of Cement content on the optimum moisture content of the soil

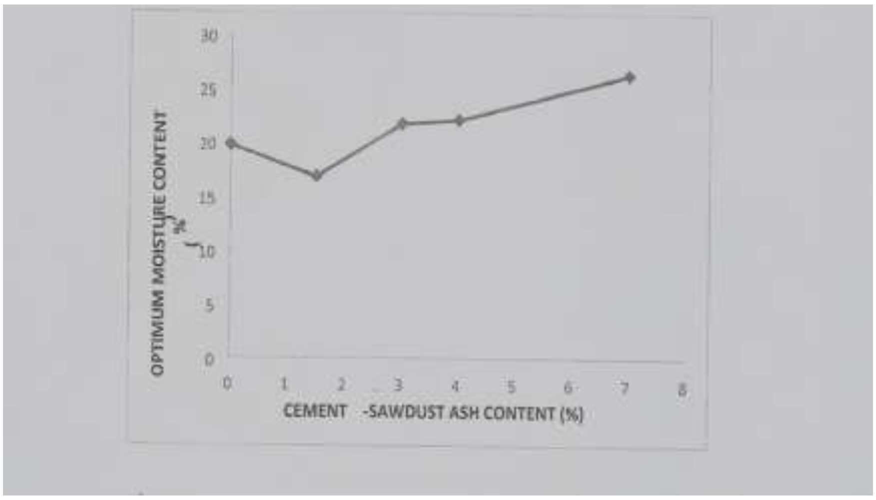

Figure 7: Effect of Cement –sawdust ash content on the optimum moisture content of the soil

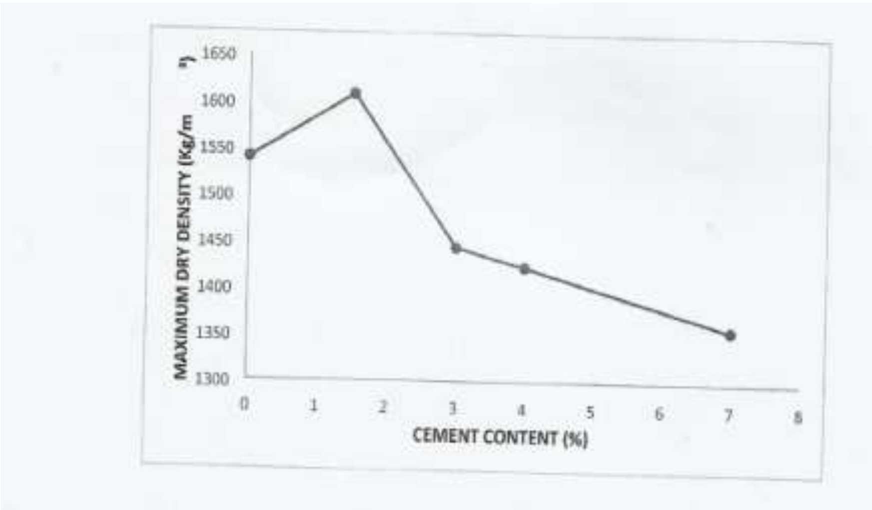

Figure 8: Effect of Cement content on the maximum dry density of the soil

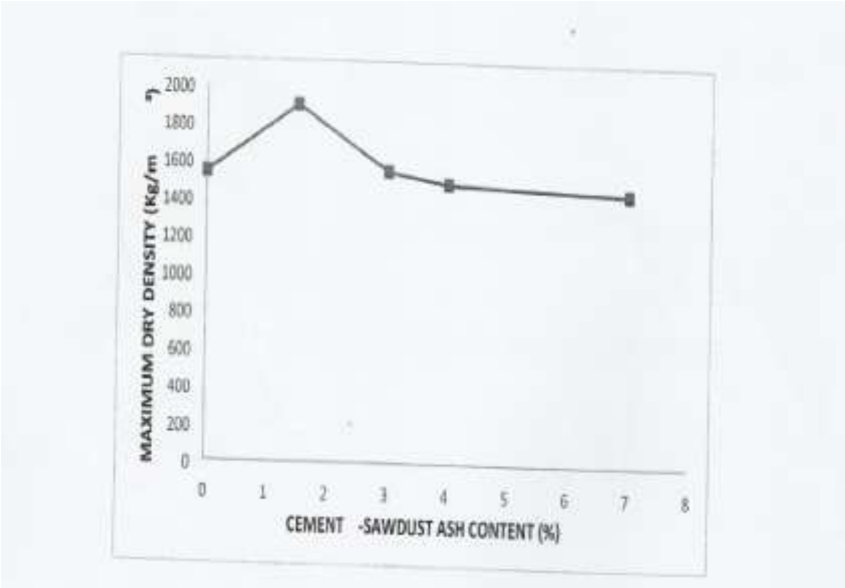

Figure 9: Effect of Cement –sawdust ash content on the maximum dry density of the soil

Direct Shear Strength

Direct shear strength was carried out on the control sample and stabilized soil sample to determine the effect of the stabilizers on the cohesion and angle of internal friction of the soil. The soil was mixed with the stabilizing agents 2 hours prior to testing so as to allow the stabilizers react the soil.

Table 4: cohesion of the soil with cement and cement –sawdust ash content

Stabilizer Content	Cohesion (KN/M²)	Angle of Internal Friction (°)
Control sample	18	28.02
1.5%cement	23	29.94
3.0%cement	30	32.36
4.0%cement	36	33.14
7.0%cement	45	35.02
1.5%cement-sawdust ash	20	28.50
3.0%cement-sawdust ash	24	30.40
4.0%cement-sawdust ash	30	31.19
7.0%cement-sawdust ash	40	32.00

Figure 10 shows that the cohesion of the soil increased generally with cement and cement saw-dust ash content

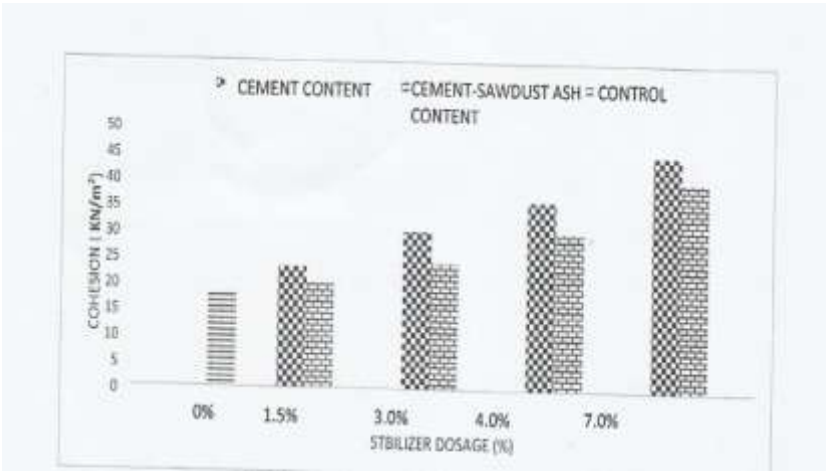

Figure 10: Variation of cohesion of the soil with respect to stabilizer dosage

From figure 4.11 the angle of internal friction increased with respect to increase in stabilizer dosage. However, it was observed that the increment of the angel of internal friction for the cement-sawdust ash stabilized soil was minimal compared to that of the cement stabilized soil

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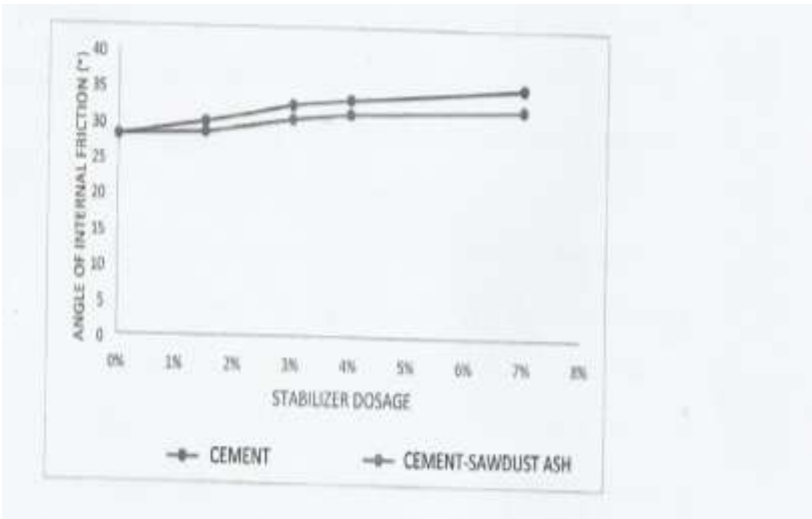

Figure 11: Variation of angle of angle of internal friction of the soil with respect to stabilizer dosage

Unconfined Compressive Strength

The unconfined compressive strength test was carried out on the stabilized soil at different curing day of 7, 14 and 28 respectively. The unconfined compressive strength of the control sample was gotten as 185.1Kpa. Table 4.5 shows the unconfined compressive strength of the soil with different binder dosages with respect to different curing days

Table 5: unconfined compressive strength of soil with cement and cement-sawdust ash content with respect to different curing days

Stabilizer content	7Days	14Days	28Days
1.5% cement	320.4Kpa	370.2Kpa	480.5Kpa
3.0% cement	586 Kpa	712.9Kpa	976.5Kpa
4.0% cement	925.5Kpa	1001.4Kpa	1059.5Kpa
7.0% cement	1140.4Kpa	1250.9Kpa	1356.5Kpa
1.5% cement-sawdust ash	216 Kpa	248.9 Kpa	313.2 Kpa
3.0% cement-sawdust ash	348.8 Kpa	391.6 Kpa	487.7 Kpa
4.0% cement-sawdust ash	402.2 Kpa	469.9 Kpa	512.6 Kpa
7.0% cement-sawdust ash	719 Kpa	835.8 Kpa	1003.8 Kpa

From figures 12 and 13, it was generally observed that the unconfined compressive strength of the soil increase as the cement and cement-sawdust ash content increased. The curing days of the stabilized soil also had an effect on their unconfined compressive strength as increase in strength with respect to increase in curing day was observed and also the individual strength of the cement and cement-sawdust ash stabilized soil attained their peak strength at 28days curing. However, it was also observed that the strength of the cement-sawdust ash stabilized soil was lesser than that of the cement stabilized soil. George and braid (2014) carried out stabilization of Nigerian deltaic laterites with saw ash and reported an increment in the soils unconfined compressive strength with increase in curing day. Also Sharam *et al.*, (2015) reported an increament in the stabilized soil's uncomfined compressive strength with increament in stabilizer content and curing day

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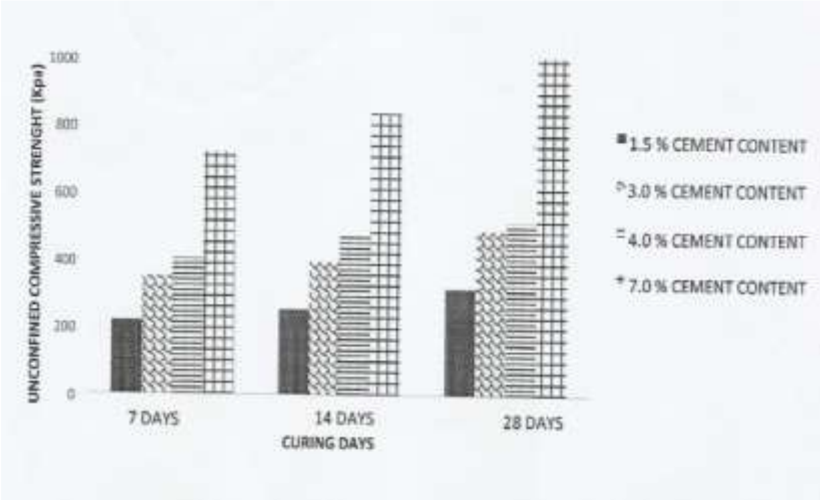

Figure 12: Effect of cement content on the unconfined compressive strength of the soil with respect to curing day

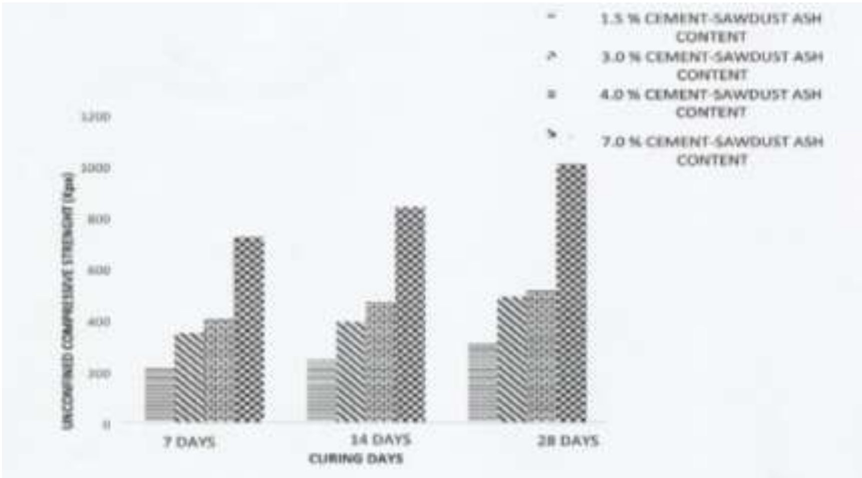

Figure 13: Effect of cement-sawdust ash content on the unconfined compressive strength of the soil with respect to curing day

CONCLUSION AND RECOMMENDATION

This study made a comprehensive examination of the effectiveness of cement and cement sawdust ash treatment on geotechnical properties of the soil used. Various laboratory test which include basic geotechnical tests like compaction and strength tests were carried out on the clayey soil sample (control) and the stabilized clayey soil samples. The results of the study provides details on the compaction, strength and cohesion characteristics of in situ soils as well as those mixed with different percentages of cement and cement-sawdust ash.

Based on the study, the following conclusions drawn:

i. Both cement and cement-sawdust ash stabilization increased the plastic limit of the soil. It also generally decreases the liquid limit and plastic index of the soil.

ii. Generally, there was initial decrease in the soil specific gravity with subsequent increase in both stabilizer dosages.

iii. Also, there was generally an initial decrease and increase in the soil's optimum moisture content and maximum dry density respectively on addition of the stabilizers. As the stabilizer dosage increased, it was observed that the optimum moisture content increase and also a decrease in maximum dry density were observed.

iv. Generally an increase in the cohesion was observed for both cement and cement-sawdust ash stabilized soil.

v. Of all the binder variation used, the 70% cement and cement-sawdust ash produce the highest strength characteristics and was deemed the most efficient.

vi. Addition of cement and also cement-sawdust ash led to significant increase in unconfined compressive strength of the soil.

    However it was noticed that the unconfined compressive strength and shear strength of the cement stabilized soil. This is due to the rapid hardening nature of Portland cement. Although, both the cement and cement-sawdust ash stabilization are viable, cement stabilization is more suitable for the improvement of the soils strength parameters.

RECOMMENDATION

From the result of this research work, I recommend that before any soil is used as a construction material, proper geotechnical investigation should be carried on the soil. Also, attention should be paid to the stabilization of clayey and weak soil using pozzalanic agro wastes as these are readily available.

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