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Abstract. Black cotton soil stabilization with various agricultural additives has attained a lot of success due to increase in the demand for agricultural products. The engineering properties of black cotton soil due to the swelling and shrinkage problem, a research was carried out on the effect of snail shell ash in the black cotton soil properties such as the Optimum moisture content (OMC), Maximum dry density (MDD), Atterberg limit, Shrinkage limit, and California bearing ratio (CBR) were studied. It has been observed by the experiments conducted on the sample by using snail shell ash of varying percentages (0%, 4%, 8%, 12%, 16% and 20%) by weight of dry soil. Based on the results from the various tests carried out- (Specific gravity, Atterberg limit, Compaction test, Hydrometer Analysis, Shrinkage limit and California bearing ratio) it shows that the black cotton soil under the AASHTO soil classification and USCS soil classification, the black cotton soil is highly organic, so that leads to the use of hydrometer analysis- calibration method. The natural liquid limit value of the soil before the stabilization process is 54.8%, at 16% SSA it decreases to 40.4%. The OMC of its natural state is 18.82%, so at 12% SSA it decreases to 11.72%, while the MDD at the natural state is 1357Kg/m³, so at 16% SSA it increases to 1738 Kg/m³. The CBR value of the soil in natural state is 27.19, so at 16% SSA it increases to 40. The results demonstrated the positive effect of snail shell ash in black cotton soil at 16% snail shell ash improving the strength of the engineering properties.

Keywords: Black cotton soil, snail shell ash, engineering properties, stabilization, strength

1. Introduction

Urban sprawl has led to a reduction in available land for use in the construction of structures and other civil engineering projects. As a result, it is an undesirable area which should be looked at. The weak or soft soils are soils that are classified as an expansive soil that are weak in shear strength, shrink, swell, and high compressibility (highly plastic). Design on black cotton soil has always been a difficult task for the engineers as the structure resting on the expansive soil tend crack without warning. This is because the soil properties change depending upon their constituents i.e. water content, bulk density, angle of friction; shear strength etc. [1-6]. The black cotton soils are organic clay, which consist of high argillaceous content of medium to high compressibility, which undergoes excessive volume changes and low strength, making their use in the construction project very difficult [7]. To enhance the properties of low bearing capacity soil, many methods like soil stabilization, soil reinforcement, grouting, and addition of admixture is being adopted. Use of industrial waste as additives is recently under study, but it raises questions of toxicity [8]. A waste is an unwanted material or substance discarded after primary use and can be agricultural, domestic and industrial waste. In recent years, the volume of wastes increased due to development in socio-economic activities and increase in

population, which is now a major problem in the environment due to the landfill problem caused by the waste. In other to reduce the problem of landfills cause by these wastes, a step has to be taken by looking into the possibility of reusing or recycling the waste. Snail shells are inspiring engineering materials in science and technology development, they have been used as raw materials to produce new or refine some other products by lot of researchers e.g. used in treating of waste water, purification of aqueous solutions and strengthening of soil [9]. Use of snail shell as traditional additives to stabilize the soil for construction purposes compare to the use of cement or lime, which are costly due to its wide range of usage. The concrete remains and will remain the most widely used material in construction around the world and more interesting in soil stabilization. The high and steady increase in cost of cement has made construction very expensive because the deleterious effect of CO_2 generated from the cement production on the environment makes the use of cement more challenging [10].
[11], which makes the soil unstable for construction purposes but working on the use of groundnut shell ash will stabilize the black cotton soil, which will improve its engineering properties. The peak California bearing ratio value is achieve at 6% and 8% of groundnut shell ash, which proves that California bearing ratio at 80%, which is recommended for untreated base course materials. The effect of fly ash in [12], investigation on black cotton soil shows an attempt made for the utilization of fly ash. The result shows that addition of fly ash and cements decreases plasticity and improved California bearing ratio value; also improve the swell characteristics. In [13], research study on the use of cashew nut shell ash and lime for stabilization of black cotton soil. This investigation of 5%, 10%, 15%, 20% and 25% of cashew nut shell ash and 5% of lime (for all mix ratio) was added to the black cotton soil. It was observed that at 20% of cashew nut shell ash and 5% of lime is better for stabilizing the black cotton soil. This research study carried by [14] on the usage of Nano-copper content of three different percentage (i.e. 1%, 1.5% and 2.5% by weight of soil) with various test to improve the geotechnical properties of black cotton soil. It was observed that at 1.5% of Nano-copper content, maximum strength for the black cotton soil was obtain. A research made by [15], on basic oxygen steel slag and lime on the stabilization of a clay soil (Kaolinite), the basic oxygen steel slag to treat the clay soil at 10%, 15%, and 20% and lime at 3% and 5%. It is observed that the higher the lime content combine with basic oxygen steel slag significantly improves kaolinite resistance to freezing and thawing [16-20].
In the past, soil stabilization has increased the number of agricultural additives by technology for stabilizing purposes e.g. Fly ash, Periwinkle shell ash, Groundnut shell ash, lime, Plastic bag, ground granulated blast furnace slag, Stone dust, Rice husk ash, Plastic bottle etc. Rechannelling snail shell waste from waste to reusable material to reduce the problem of landfill in the environment and for a possible use of the reusable material therefore, there is need to investigate the effect of this agricultural waste material –Snail shell ash (SSA) on the black cotton soil as form of stabilizing for use in any road or structure construction project.

2. Material and Methods

2.1. Snail Shell Ash

The snail shell use for this study was collected from Mushin market in Lagos state, of latitude 6°32’6.84” N, and longitude 3°20’56.28” E, Nigeria. The snail shell is wash thoroughly to remove the droppings and decomposition of dead snail present in the snail shell. The shell is oven dry first in an open air, also intense sunlight to dry up the washed shell (to remove moist from the shell), and then given thermal treatment to eliminate any kind of impurities and then crushed. The fine aggregate is then pass through British standard No 200 (0.075 mm aperture) sieve and kept to be use in mixing fine aggregate at different proportions in the with the black cotton soil.

2.2. Black Cotton Soil

The soil is gotten from Nigeria Defence Academy in Kaduna state and transported to Yaba college of Technology laboratory where it was dried ant sieved through several standard sieves and tested. The

snail shell ash was added to the black cotton soil gotten from Kaduna in 0%, 4%, 8%, 12%, 16% and 20%. The optimum percentage of the snail shell ash was determined. The black cotton soil, burning of snail shell and crushed burnt snail shell are related in the figure 1a, 1b and 1c respectively.

Figure (1a) black cotton soil | Figure (1b) burning snail shell | Figure (1c) snail shell crushed after burning

3. Result and Discussion

Engineering Properties of the Black Cotton Soil

Table 1: The black cotton soil engineering properties

Property	Black Cotton Soil (BCS)
Natural Moisture Content	15.9
Soil Color	Black
Specific Gravity	2.45
Liquid limit (%)	54.8
Plastic limit (%)	38.1
Plasticity Index (%)	16.7
Linear shrinkage (%)	21.4
Optimum Moisture Content (%)	18.82
Maximum Dry Density (Kg/m^3)	1357
Unconfined Compressive Strength (Kg/cm^2)	1.12
California Bearing Ratio	27.19

The Table 1 shows the natural engineering properties of the black cotton soil used for this study. The improvement of the engineering properties is observed in the process of the various laboratory test using snail shell ash as an admixture at different proportions. The results of the atterberg test is related in the table 2.

Atterberg Limit Test Result

Table 2: showing the result of Atterberg test on SSA

SAMPLE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
Black cotton soil + 0% Snail Shell Ash	54.8	38.1	16.7
Black cotton soil + 4% Snail Shell Ash	59.9	44.6	15.3
Black cotton soil + 8% Snail Shell Ash	53.5	38.1	15.4
Black cotton soil + 12% Snail Shell Ash	45.7	30	15.7
Black cotton soil + 16% Snail Shell Ash	40.4	29.3	11.1
Black cotton soil + 20% Snail Shell Ash	51.8	20.8	31

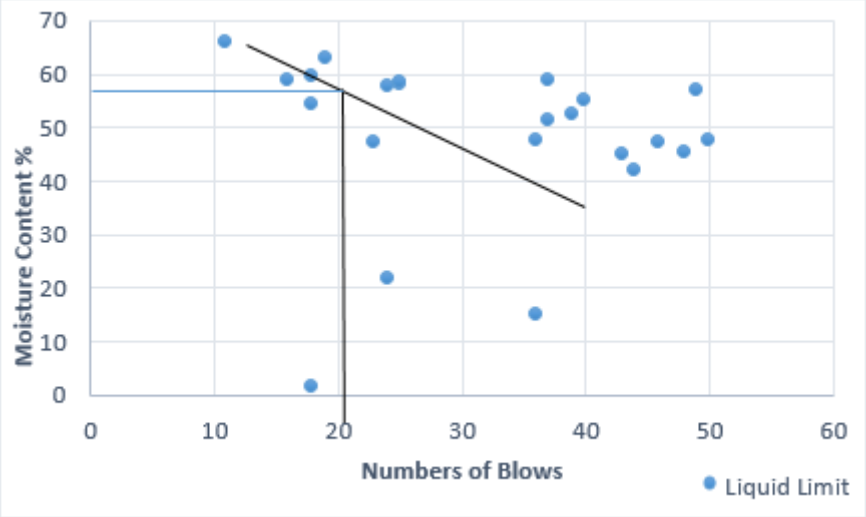


Fig 2: Liquid limit result of the snail shell ash addition to black cotton soil

The graph of the liquid limit of the black cotton soil with the addition of the snail shell ash shows corresponding to 25 blows as it attains 59% of moisture content as presented in the figure 2.

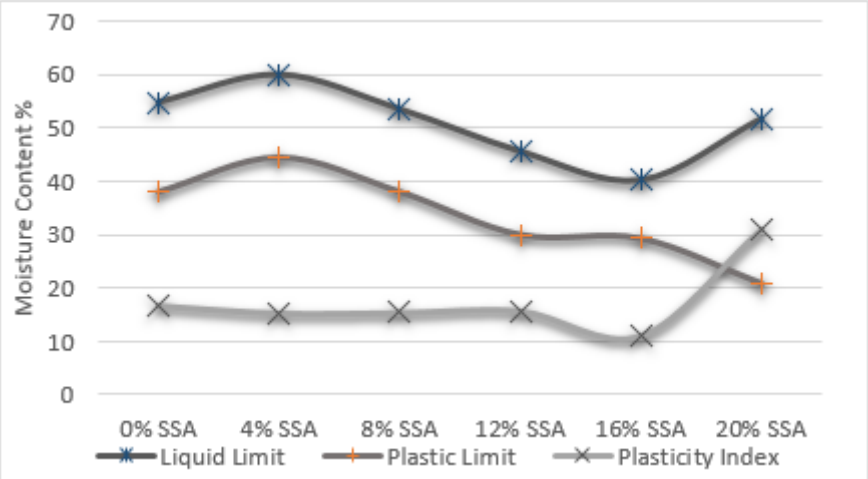


Fig 3: Atterberg limit result of the Snail Shell Ash with Black Cotton Soil

Due to the result obtained, and with the properties of the soil, it reveals from the figure 3 that the soil is highly clay. So, structure or pavement design construction cannot be done on it unless it is stabilized. Therefore, the result obtained using snail shell ash to stabilize the black cotton soil shows improvement in the soil. The relationship between the liquid limit, plastic limit, and plasticity index shows that the liquid limit at 4% of snail shell ash (SSA) increases to a high value and begins to decrease in value from 8% of snail shell ash (SSA) to 16% Snail shell ash (SSA), at 20% snail shell ash (SSA) it increases. The plastic limit at 4% snail shell ash (SSA) also increases but decreases from 8% to 20% snail shell ash. The plasticity index increases at 16% to 20% snail shell ash (SSA).

Compaction Test Result

The standard proctor test of snail ash with black cotton soil is presented in the table 3.

Table 3: Standard Proctor test of Snail shell ash with Black cotton soil

Sample	OMC (%)	MDD (Kg/m^3)
Black Cotton Soil + 0% Snail Shell Ash	18.82	1357
Black Cotton Soil + 4% Snail Shell Ash	14.47	1509
Black Cotton Soil + 8% Snail Shell Ash	16.32	1582
Black Cotton Soil + 12% Snail Shell Ash	11.72	1668

Black Cotton Soil + 16% Snail Shell Ash	12.18	1738
Black Cotton Soil + 20% Snail Shell Ash	12.22	1724

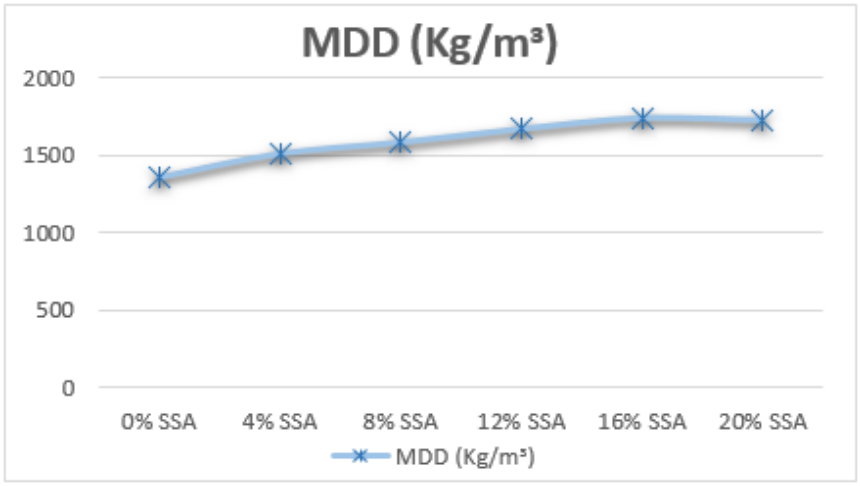


Figure 4. Maximum Dry Density of the Snail Shell Ash addition

Figure 4 shows the maximum dry density of the black cotton soil with the addition of snail shell ash, it is observed that the value of the dry density gradually increases from 0% to 16% snail shell ash and decreases at 20% snail shell ash. The value at 16% snail shell obtained was 1738Kg/m³, but at 12% snail shell the value 1724 Kg/m³ decreases.

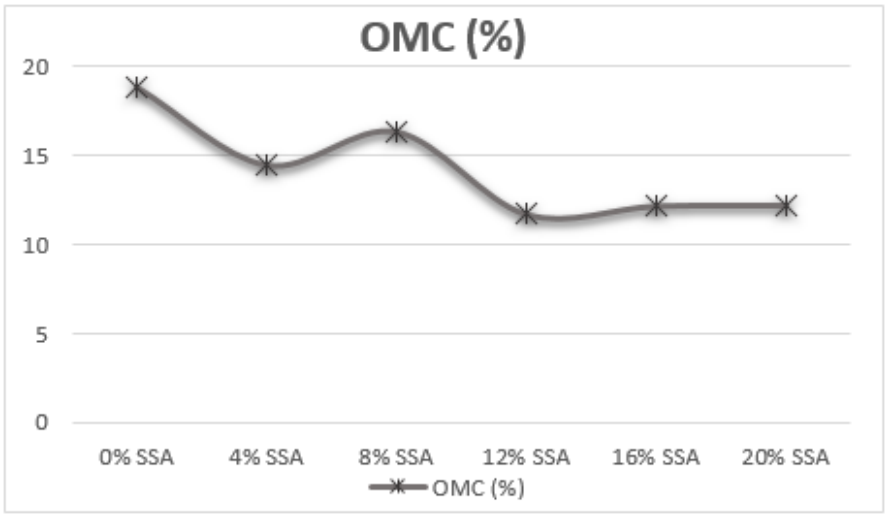


Figure 5. Optimum Moisture Content of the Snail Shell Ash addition

From the figure 5, the optimum moisture content of the black cotton soil with the addition of the snail shell ash. At 0% snail shell ash, the optimum moisture content decreases but began to increase at 4% snail shell ash, also at 8% snail shell ash the value decreases, then at 12% snail shell ash the value gradually increases. This result shows that at 12% of snail shell ash we observe a decreased value in the optimum moisture content from 16.32% to 11.72%. At 16% the value increases to 12.18% then to 12.22% at 20% snail shell ash.

Hydrometer Analysis: Calibration Method Result

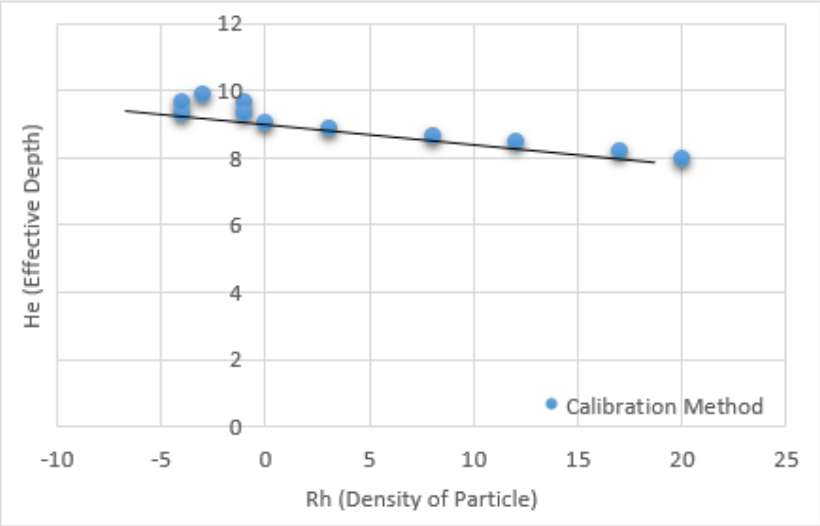


Figure 6. Calibration method for hydrometer analysis

From the figure 6, the hydrometer analysis of the black cotton soil using calibration method due to the organic nature of the soil i.e. highly argillaceous (finer particles).

California Bearing Ratio Result

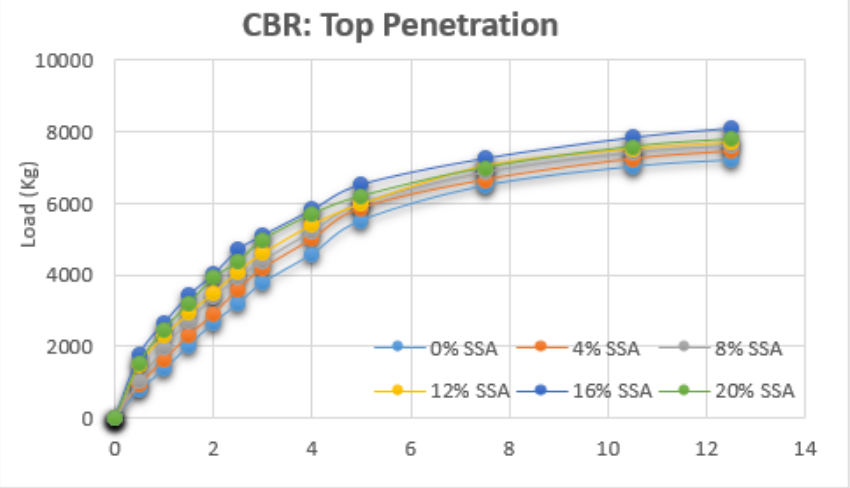


Figure 7. California bearing ratio result of the Snail Shell Ash addition: Top Penetration

From figure 7, the top penetration of the California bearing ratio result of the snail shell ash with black cotton soil. At 0% snail shell ash, the value attains its peak at 7209Kg. At 4% snail shell ash, the value attains its peak at 7448Kg. At 8% snail shell ash, the value attains its peak at 7608Kg. At 12% snail shell ash, the value attains its peak at 7714Kg. At 16% snail shell ash, the value attains its peak at 8113Kg. At 20% snail shell ash, the value attains its peak at 7794Kg. For the CBR top penetration, the peak value of the test was obtained at 16% of the snail shell ash addition to the black cotton soil. Figure 7 shows the graphical illustration of the strength of 16% of snail shell ash in the black cotton soil. The strength began to decrease at 15mm penetration, which means that the maximum strength was observe at 10mm to 12.5mm penetration giving a stress of 7874Kg to 8113Kg after conversion.

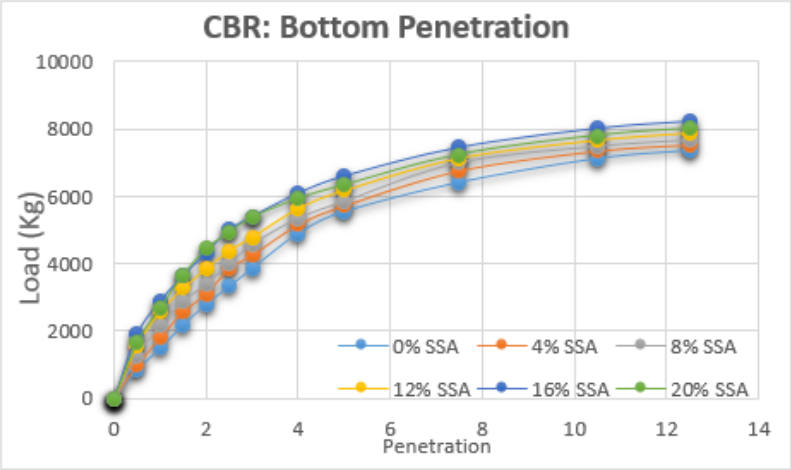
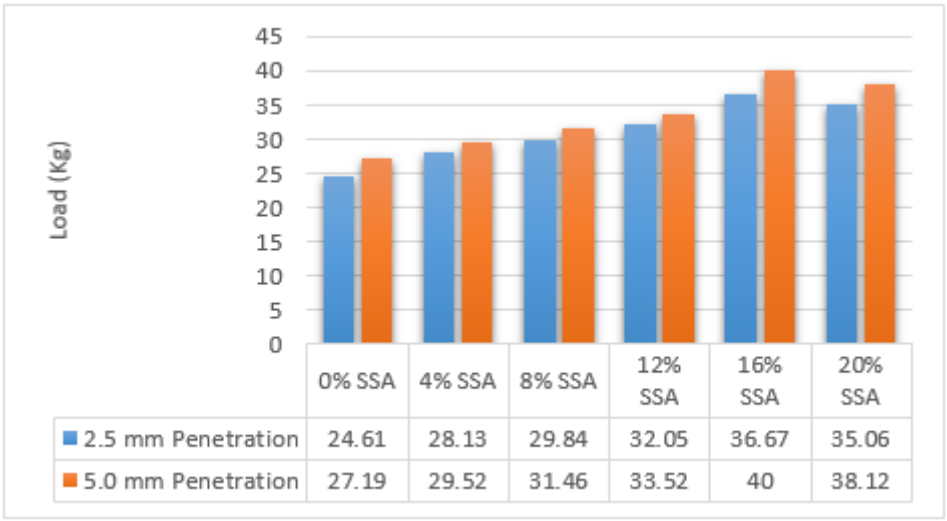


Figure 8. California bearing ratio result of the Snail Shell Ash addition: Bottom Penetration

From figure 8, the bottom penetration of the California bearing ratio of the snail shell ash with black cotton soil. At 0% snail shell ash, the peak value- 7342Kg. At 4% snail shell ash, the peak value- 7528Kg. At 8% snail shell ash, the peak value- 7661Kg. At 12% snail shell ash, the peak value- 7874Kg. At 16% snail shell ash, the peak value- 8219Kg. At 20% snail shell ash, the peak value- 8113Kg. The peak value of the bottom penetration test was obtained at 16% of the snail shell ash addition to the black cotton soil. Figure 9 shows the graphical illustration of the strength of 16% of snail shell ash in the black cotton soil. The strength began to decrease at 15mm penetration, which means that the maximum strength was observe at 10mm to 12.5mm penetration giving a stress of 8219Kg to 8007Kg after conversion greater than the stress obtain at the top penetration.



	0% SSA	4% SSA	8% SSA	12% SSA	16% SSA	20% SSA
2.5 mm Penetration	24.61	28.13	29.84	32.05	36.67	35.06
5.0 mm Penetration	27.19	29.52	31.46	33.52	40	38.12

Figure 9. California bearing ratio result of the Snail Shell Ash addition

Figure 9 shows the California bearing ratio of the black cotton soil mixed with snail shell ash at various proportions. It is observe that the strength increases gradually from 0% of snail shell ash to 16% of snail shell ash, which made the highest value to be at 16% of snail shell ash then, decreases at 20% of snail shell ash from 36.67% of 2.5 mm penetration to 35.06% and of 40% of 5.0 mm penetration to 38.12%.

Linear Shrinkage Result

The Linear shrinkage percentage for the snail shell ash with black cotton soil is presented in the table 4.

Table 4. Linear shrinkage percentage for the snail shell ash with black cotton soil

Mix proportion	0% SSA + BCS	4% SSA + BCS	8% SSA + BCS	12% SSA + BCS	16% SSA + BCS	20% SSA + BCS
Shrinkage %	21.4	19.6	14.2	10.2	6.7	8.0

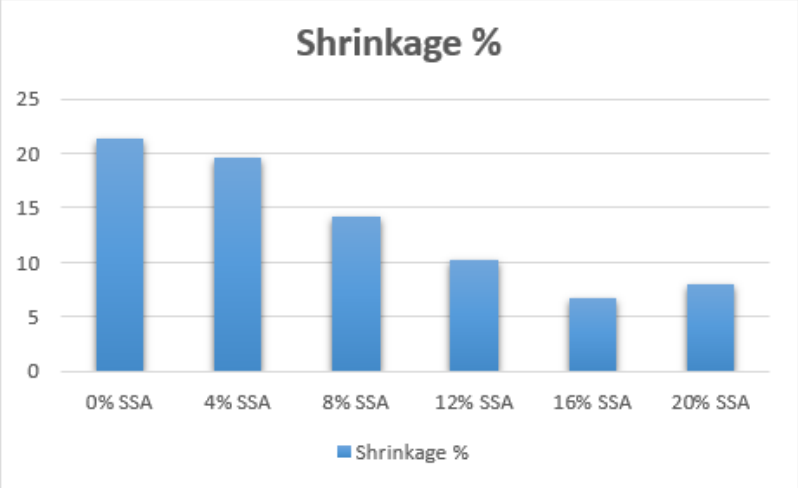


Figure 10. Shrinkage of the black cotton soil with snail shell ash

From the result of figure 10, it is clearly identified that for the replacement of soil by stabilizing with snail shell ash shows that the linear shrinkage gradually decreases from the 21.4% to 4.4% at 16% of snail shell ash added to the black cotton soil.

Unconfined Compressive Strength Result

The result of the compressive strength is presented in the table 5.

Table 5. Compressive strength result

Sample	**0% SSA**	**4% SSA**	**8% SSA**	**12% SSA**	**16% SSA**	**20% SSA**
UCS	1.12	1.52	1.61	1.89	2.09	1.99

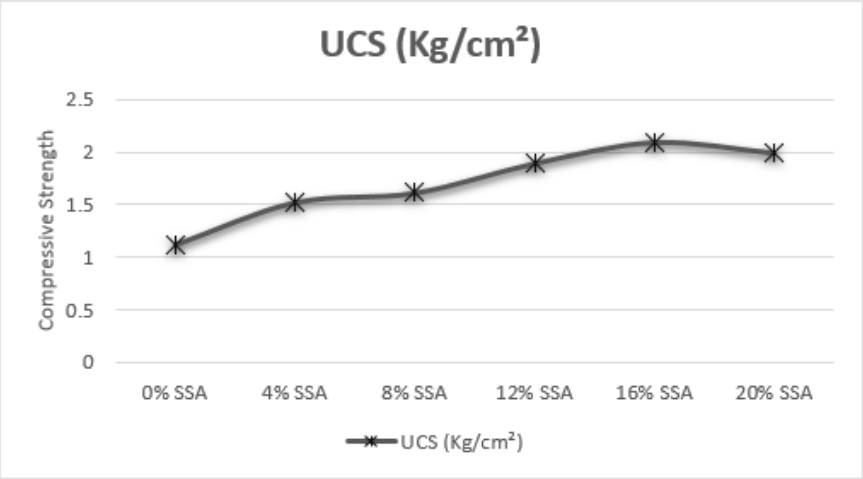


Figure 11. Unconfined Compressive strength result

Figure 11 shows the compressive strength of the black cotton soil when mixed with snail shell ash. As the percentage of the snail shell increases the compressive stress increases. At 16% of the snail shell addition, there is an observation, which shows in the graphical illustration that the value of the compressive stress is 2.09Kg/cm² increased from 1.89Kg/cm² of 12% snail shell addition.

4. Conclusion

The test generally indicates that the increase in the addition of snail shell ash in maximum dry density gradually increases the value, so at 16% of snail shell ash the maximum dry density obtained a high value then at 20% of snail shell ash, it began to decrease. The optimum moisture content gives a rise and fall value as the snail shell ash increases, but at 16% of snail shell ash, it obtained a low value, while at 0% of snail shell ash it obtained a high value.

Further, adding the snail shell ash gives a decrease in value from 4% of snail shell ash to 16% of snail shell ash for liquid limit test but at 20% of snail shell ash it increases. Therefore, the highest value for the liquid limit is obtained at 4% of the snail shell ash but at 16% of snail shell ash, it gives the lowest value. For the plastic limit there is decrease in the value as the percentage of the snail shell ash increases, at 20% of snail shell ash, the lowest value for plastic limit is obtained, while at 4% of snail shell ash, the highest value was obtained. The California bearing ratio obtained a high value of strength at 16% of snail shell ash. The unconfined compressive strength shows increase in compressive stresses as the addition of the snail shell addition increases.

Recommendation

From this experimental study, the strength parameter increases with increase in the snail shell ash (SSA) up to 16%. Therefore, the optimum value of snail shell ash (SSA) is 16%.

Acknowledgement

The authors appreciate Covenant University for their support.

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