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EFFECTS OF SNAIL SHELL ASH ON LIME STABILIZED LATERITIC SOIL

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Abstract: As a result of increase in population and socioeconomic activities, the rate of production of wastes over the years has been on the rise. A major approach towards managing these wastes is to consider the possibility of waste recycle and minimization. This study assesses the effects of Snail Shell Ash (SSA), a product of snail shell-which itself is a waste product, on lime stabilized lateritic soil. Preliminary tests such as; specific gravity, Atterberg limits and particle size distribution tests were carried out on natural soil sample, for the purposes of identification and classification. The soil sample based on AASHTO classification was classified as A-7-5. Hydrated lime was added to the soil sample at varying proportions of 2, 4, 6, 8 and 10% by weight of soil, thereafter, each of the mixes was subjected to Atterberg limits tests to get the optimal amount of lime required, which was 10% lime because it was at this amount of lime that the least value of plasticity index was gotten. The Snail Shell Ash was later added to the lime-treated lateritic soil at proportions of 2, 4, 6, 8 and 10%. Each of the mixes was subjected to compaction, California bearing ratio (CBR), Atterberg limits and unconfined compressive strength (UCS) tests. Results from these tests showed improvement in soil properties, also, the values of the CBR and UCS increased considerably. At soil natural states, CBR values of 9.5% and 5.5% increased to 67.20% and 53.60% at 6% SSA at unsoaked and soaked states respectively. Also, UCS value of 190 kN/m^2 at soil natural increased to 380kN/m^2 at 6% SSA. It can be concluded that the SSA performs satisfactorily as a cheap complement for lime in stabilizing lateritic soil.

Keywords: *Atterberg limit, lateritic soil, lime, snail shell ash, soil stabilization*

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1.0 Introduction

Wastes, whether solid or liquid are unavoidably products of a huge percentage of man's activities either in urban or rural areas. Their type, amount and composition are functions of activities which could be domestic, agricultural or industrial in nature. The waste that are produced due to agricultural, industrial, commercial and construction activities are composed of a broad spectrum of variety of materials, such as, food wastes, construction waste, paper, plastic and other discarded residual items. The rate of waste generated in the world over has also been on the rise over the years due to increase in population, socioeconomic activities and social development. On the basis of the statistical data given in the 1980's, the size of municipal solid waste in the urban centre has doubled in size. If this is not checked and properly managed, these wastes will be a source of land, air, surface and groundwater pollution. To mitigate the effect of these wastes, a strong approach is to consider the possibility of waste minimization and recovery (Oluremi *et al*. 2012; Amu and Babajide, 2011a). Snail shell ash (SSA) being an agricultural waste can lead to land population if not effectively managed. According to Neville (2000), over the years, cement and lime have been the two main materials used for stabilizing soils. These materials have rapidly increased in price due to sharp increase in cost of energy and high demand for them, thereby making the provision of good roads for citizens of third world countries like Nigeria, quite difficult especially in the rural areas that are mostly agriculturally dependent. Thus, necessitating the search for alternative, research on alternatives to cement and lime has so far centred on the partial replacement of cement and lime with different materials (Joel, 2000). This, has geared researchers towards using stabilizing materials that can be sourced locally at a very low cost (Bello *et al*. 2015).

Snail shell is a waste product which can be gotten from the consumption of the fleshy edible part of the snail. The shell comes in form of V-shaped spiral shell found in many coastal regions, especially here in Nigeria. The shells are a strong, hard and brittle material (fig. 1). The shells constitute waste and its disposal is posing problems in areas where they have no use for it (Zaid and Ghorpade, 2014a). It is in this light that this experimental study seeks to investigate into the suitability of snail shell ash as a complement for lime in soil stabilization by way of considering the effects of snail shell ash on lime-stabilized lateritic soil.

1.1 Lime Stabilization

Lime stabilization may refer to pozzolanic reaction in which pozzolana materials react with lime in presence of water to produce cementitious compounds. The effect can be brought about by either quicklime CaO or hydrated lime, $Ca(OH)_2$ (Makusa, 2012). Numerous researches have been conducted using lime with some other admixtures, these include; Amu and Babajide (2011b), Amu *et al*. (2005), Kang *et al*. (2005) and Oyediran and Okosun (2013).

1.2 Location and Geology of Study Area

Akure, Nigeria, being the study area lies within Longitude $7^0$18' N and $7^0$16' N North of the equator and between Latitude 5^0 09' E and 5^0 11.5^0 E of Greenwich meridian. The study area occurred within the pre-cambrian crystalline rocks of the basement complex of southwestern Nigeria. The predominant rock types in the study area are charnockites, granites gneiss and migmatitic rock. In some places in the study, these rocks have undergone deep weathering (Ogunribido, 2011a).

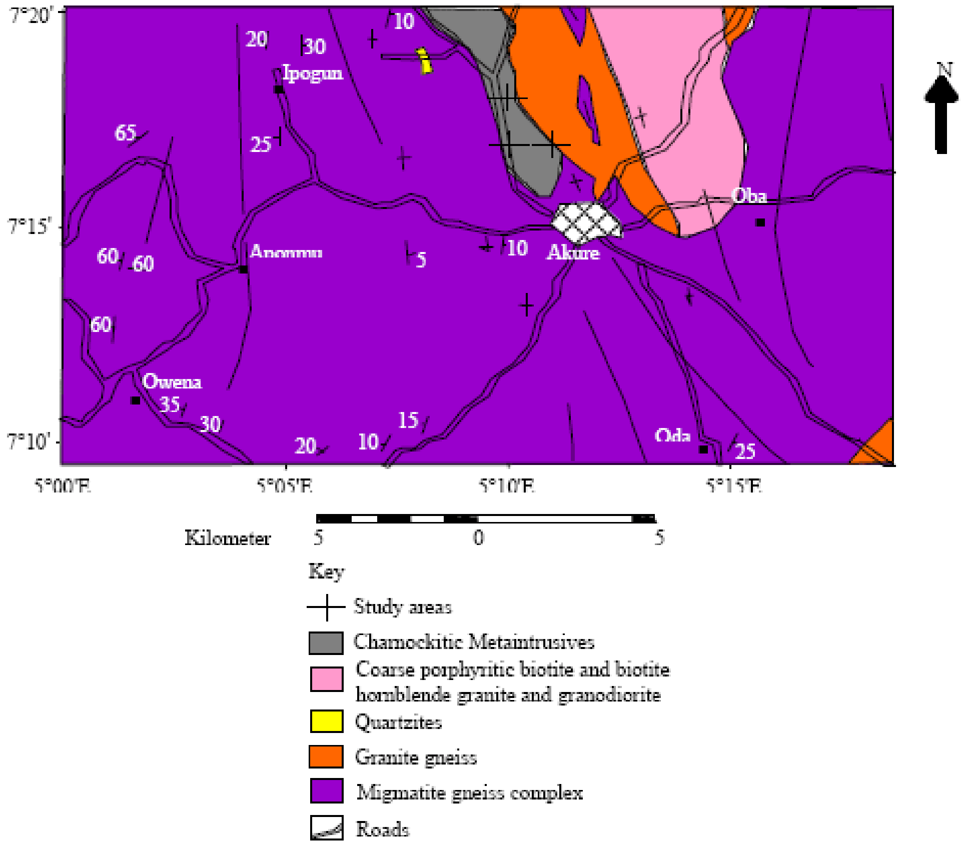

Figure 1: Study Area-Akure, Nigeria. Source: Olutoge *et al.*, (2012)

2.0 Materials and Methods

2.1 Materials

The Snail shells (fig. 2) were obtained from a snail vendor store. The fleshy parts were removed from the shells, the shells were thoroughly washed, dried and calcined in an electric muffle furnace at 1000^0C and were ground to fine particles using grinding machine. The ash (fig. 3) obtained was later sieved through 75µm to meet the requirements of BS 1924 (1990a) and ASTM C618-93 (1992).

The lateritic soil samples were collected in Akure at depths representative of soil stratum and not less than 1 metre (1m) below the natural ground level. It was thereafter brought to the Geotechnical Laboratory of the Federal University of Technology, Akure and marked indicating the soil description, sampling depth and date of sampling. The lateritic soil was air-dried for two weeks to allow for partial elimination of natural water which may affect the analysis, then sieved with sieve no 4 (4.75mm opening) to obtain the final soil samples for the tests. After the drying periods, lumps in the sample were pulverised under minimal pressure. The water was gotten from the running taps in the laboratory having borehole as its source. The water used was not distilled water but borehole to give near or actual results of in-situ conditions. The hydrated lime was purchased at a licensed chemical store in Akure, upon meeting the specification standards in accordance with ASTM C1097-13(2013).

Figure 2: Snail Shells


Figure 3: Snail Shell Ash

2.2 Methods

The preliminary tests such as specific gravity, Atterberg limits and particle size distribution tests were carried out on the natural lateritic soil sample for the purpose of identification and classification, thereafter, the engineering tests such as California bearing ratio tests, unconfined compressive strength tests and compaction tests were performed on the natural soil sample. Hydrated lime was added to the soil sample in proportions of 2, 4, 6, 8 and 10% and were later subjected to Atterberg limits tests, to detect the optimal amount of lime required which is the amount of lime added where the least value of plasticity index is recorded. The Snail Shell Ash (SSA) was added in proportions of 2, 4, 6, 8 and 10% by weight of soil to the lime-treated soil, thereafter, each of the mixes was subjected to the following tests: Compaction, California Bearing Ratio (CBR), Atterberg Limits and Unconfined Compressive Strength tests.

2.2.1 Atterberg Limits Test

The Atterberg limits tests were carried out in accordance with the British Standard Methods-BS 1377 (1990a). The lateritic soil sample was sieved through 0.425mm. Materials that were retained on the sieve was discarded and not used for the test. The soil sample was oven-dried for at least 2 hours before the test. For the stabilized specimens; the tests were carried out on the soils mixed with a fixed optimal amount of 10% lime and varying proportions of 2, 4, 6, 8 and 10% SSA.

2.2.2 Compaction Characteristics

The proctor standard compaction method was adopted for this study. The test was carried out according to BS 1377 (1990b), with the purpose of determining the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils. The soil mixtures (with or without additives) were thoroughly mixed with various moisture content and allowed to equilibrate for 24 hours before compaction. The first aspect of the compaction test involved determining the compaction properties of the natural soil sample. At the second stage, tests were performed to determine the compaction properties of soil sample upon stabilization with 10% lime-optimal amount of lime and the varying amount of SSA (2, 4, 6, 8 and 10%).

2.2.3 California Bearing Ratio (CBR)

The BS 1924 (1990b) stipulates the procedures to follow in carrying out this test. This, was however modified in conformity with the recommendation of the Nigerian General Specification, Federal Ministry of Works and Housing (1997a), which stipulates that specimens be cured for six days unsoaked, immersed in water for 24 hours and allowed to drain for 15 minutes before testing.

2.2.4 Unconfined Compressive Strength (UCS)

The BS 1924 (1990c) stipulates the procedure for carrying out this test and was adopted for the natural soil sample. For the stabilized soil mixtures, specimen was prepared by carefully and completely mixing dry quantities of pulverized soil with the fixed optimal amount of hydrated lime-10% by weight of soil and varying proportions of 2, 4, 6, 8 and 10% SSA. The needed amount of water was determined from moisture-density relationships for stabilized-soil mixtures was subsequently added to the mixture. For each of the mix, three specimens were prepared as stipulated by the Nigerian General Specification, Federal Ministry of Works and Housing (1997b).

3.0 Results and Discussion

Table 1 shows that the percentage that passed through on No. 200 BS sieve was 36.50%, therefore, suggesting that the soil belonged to one of the following groups; A-4, A-5, A-6 and A-7. Since more than 35% of its sample passed through the No 200 sieve, the soil sample therefore fell into the silty or clayey group with generating rating of fair to poor. The liquid limit of the soil is 48.85%, thereby, falling into the A-5 and A-7 groups. The value of the plasticity index is 16.25%, the soil therefore falls into the A-7 group. For soil sample to be classified into the A-7-5 subgroup; plasticity index $\leq LL - 30; 16.25 \leq 48.85 - 30\ (18.85)$. The soil sample therefore falls into the A-7-5 subgroup (Garber and Hoel, 2009a). Furthermore, the specific gravity of the soil sample is 2.08, the soil can be said to belong to the halloysite group, according to Das (2000), soils that possess specific gravity value within the range of 1.69-2.9 are classified as halloysites.

Table 1: Summary of the preliminary tests results

Property	*Amount*
Natural Moisture Content (%)	21.85
Percentage passing sieve No. 200	36.50
Specific gravity	2.08
Liquid limit (%)	48.85
Plastic limit (%)	32.60
Plasticity index (%)	16.25
Unsoaked CBR (%)	9.5
Soaked CBR (%)	5.5
Optimum Moisture Content (OMC) (%)	12.45
Maximum Dry Density (kg/m^3)	1650
Unconfined Compressive Strength (kN/m^2)	190
AASHTO Classification	A-7-5
USCS Classification	CL

In table 2, chemical investigation of SSA presents a conclusion that the SSA has the same active chemical constituents and properties as that of the hydrated lime, such as CaO, SiO_2, Al_2O_3, Fe_2O_3, MgO etc. The specific gravity of SSA is found to be 3.07 (Zaid and Ghorpade, 2014b).

Table 2: shows chemical composition of the snail shell ash and hydrated lime used for the study

Elemental Oxide	*Snail shell ash (Weight %)*	*Hydrated Lime (Weight %)*
SiO_2	0.70	1.71
Al_2O_3	0.50	0.72
Fe_2O_3	0.60	0.05
CaO	53.10	68.12
MgO	0.64	1.38
SO_3	0.21	-
K_2O	0.10	0.06
Na_2O	1.23	0.03
P_2O_5	0.22	-
TiO_2	0.02	-
Mn_2O_3	0.02	-
LOI	38.70	

Table 3. Effects of lime on soil properties

Lime (%)	*LL*	*PL*	*PI*	*MDD*	*OMC*	*Unsoaked CBR*	*Soaked CBR*
0	48.85	32.6	16.25	1650	12.45	9.5	5.5
2	47.25	31.35	15.90	1630	13.50	20.65	11.35
4	46.40	31.00	15.40	1605	14.30	35.75	25.65
6	43.80	29.00	14.80	1587	15.40	62.80	51.70
8	42.30	28.30	14.00	1570	16.55	56.88	43.40
10	40.20	27.20	13.00	1548	17.74	50.45	40.70

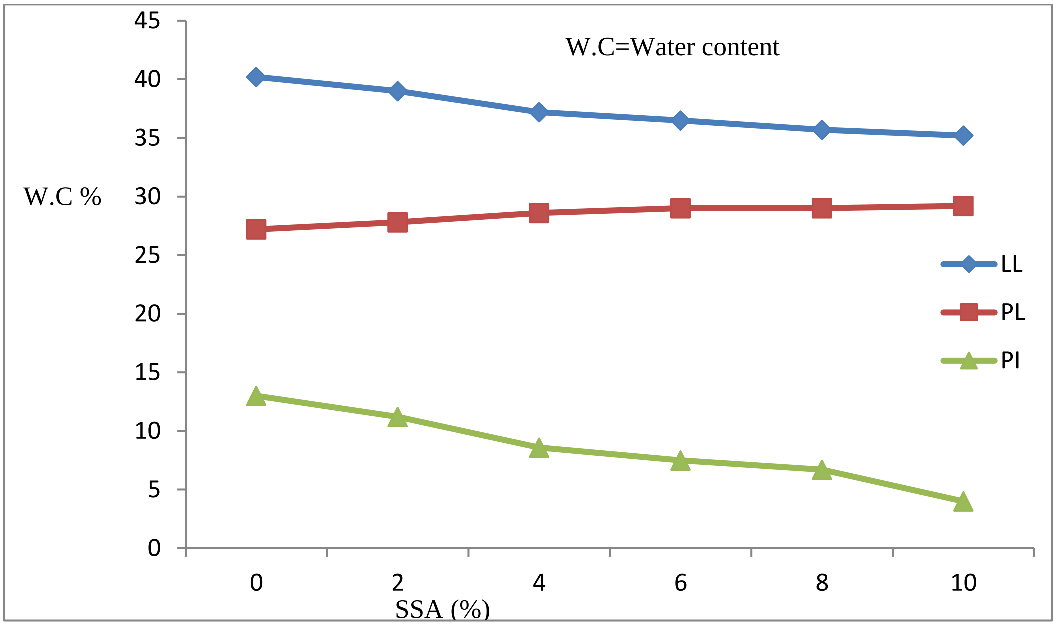

Figure 4. Effects of SSA on atterberg limits of lime-treated lateritic soil

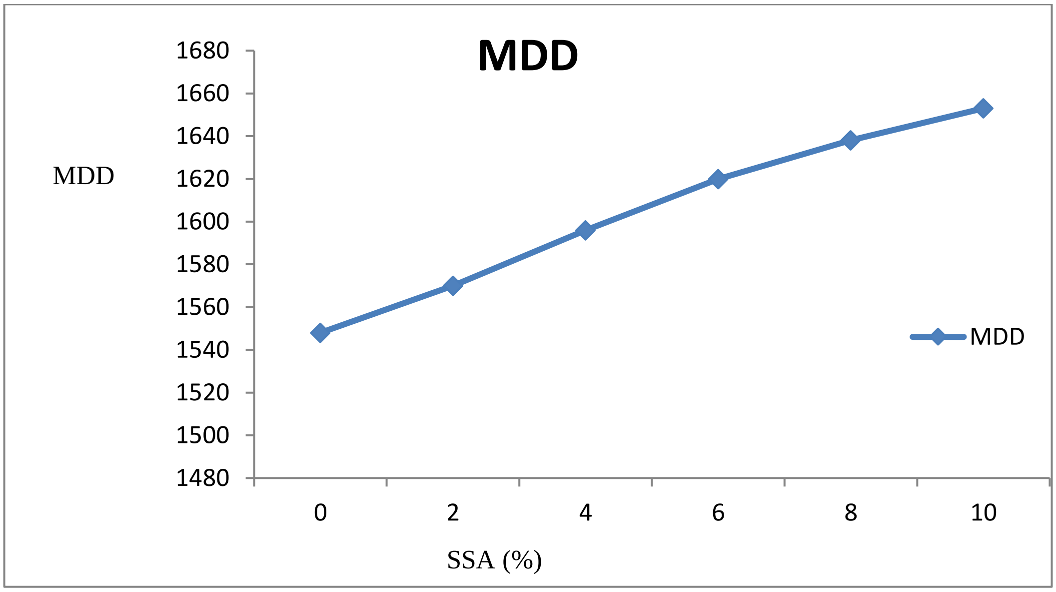

Figure 5. Effects of SSA on MDD of lime-treated lateritic soil

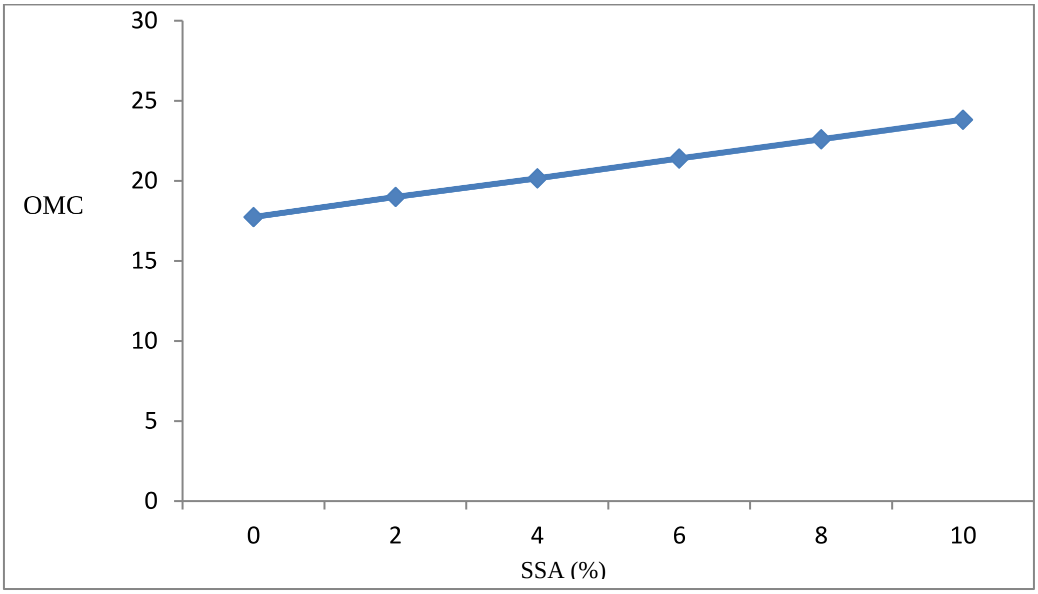

Figure 6. Effects of SSA on OMC of lime-treated lateritic soil

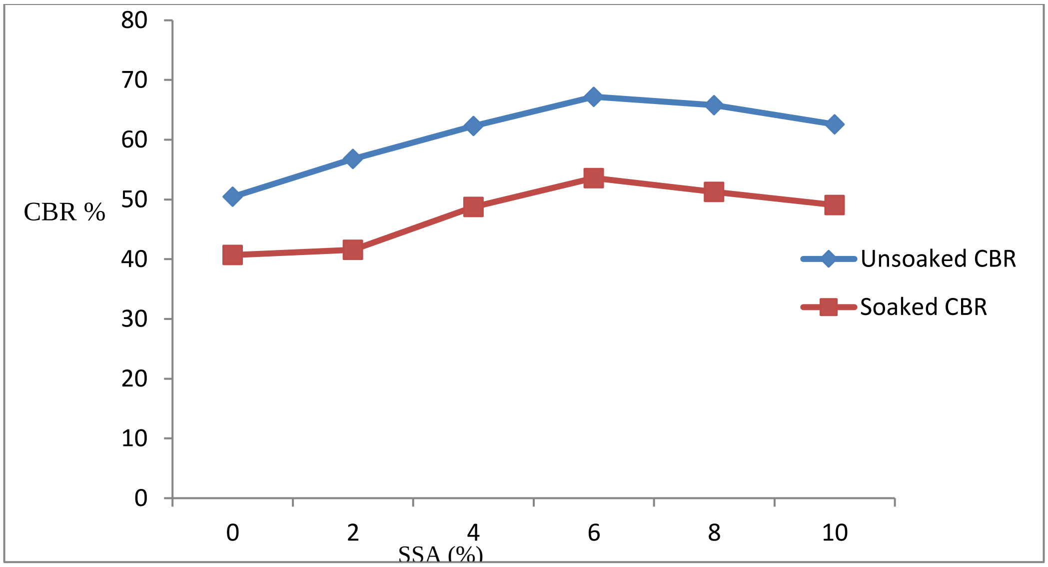

Figure 7. Effects of SSA on CBR of lime-treated lateritic soil

3.1 Effect on Compaction Characteristics

The variations of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) with stabilizer contents are shown in figures 5 and 6. Figure 5 indicates that Maximum Dry Density (MDD) increases with increase in Snail Shell Ash (SSA) content, MDD increased from 1548 kg/m^3 at 0% SSA by weight of soil to 1653 kg/m^3 at 10% SSA. According to Lambe and Whiteman (1979), increase in Maximum Dry Density (MDD) is an indication of soil improvement. The MDD increased progressively with higher SSA content. This increased values in MDD could be due to SSA occupying the voids within the soil matrix as well as the flocculation and agglomeration of the clay particles due to exchange of ions (Salahudeen, 2015; Osinubi, 2000; Oriola and Moses, 2010). Also, Optimum Moisture Content (OMC) increases with increase in SSA content. OMC increased from 17.74% at 0% SSA to 23.82% at 10% SSA by weight of soil. The increase in OMC is due to the addition of SSA which decreases the quantity of free silt and clay fraction and coarser materials with larger surface areas were formed (these processes need water to take place). This also implies that more water is needed to compact soil-SSA mixtures (Okafor and Okonkwo, 2009).

3.2 California Bearing Ratio

CBR test is commonly used to obtain an indication of strength of a subgrade soil, subbase and the base course materials for use in road and airfield design (Liu and Evett, 2003). Figure 7 shows values of unsoaked CBR increased from 50.45% at 0% SSA to maximum value of 67.20% at 6% SSA, while soaked CBR increased from 40.70% at 0% SSA to 53.60% at 6% SSA by weight of soil. In both cases, the values started falling at 8% SSA till 10% SSA. The increase in values of California Bearing Ratio (CBR) upon the addition of SSA may be attributable to the presence of adequate amounts of calcium required for the formation of Calcium silicate hydrate (CSH) and Calcium aluminate hydrate (CAH), which are the major compounds responsible for strength gain (Saheed *et al*., 2015). The reduction in CBR values at 8% SSA may be due to excess SSA and lime that was not mobilized in the reaction, therefore, reducing bond in the lime-SSA-soil (Ogunribido, 2011b).

3.3 Atterberg Limits

From table 3, the addition of lime to the lateritic soil sample resulted to the decrease in the values of liquid limit and plasticity indices of the soil sample. At 10% lime, liquid limit and plasticity index reduced to 40.20 and 13% respectively. The trend observed with the lime can be attributed to agglomeration of fine clay particles into coarse, friable particles by a base exchange with the calcium cations from lime displacing sodium or hydrogen ions, with a subsequent dewatering of the clay fraction of the laterite, referred to as cation exchange reaction (Joel and Edeh, 2015). According to Osinubi (1995), the reduction in the plasticity is attributed to the change in soil nature (granular nature after flocculation and agglomeration) and the modified soil as crumbly as silt soil, which is characterized by low surface area and low liquid limit because of the plastic nature of the lime. In fig. 3; the addition of snail shell ash to the lime-treated lateritic soil sample further reduced the liquid limit values and its plasticity index values. This, may be attributed to the higher release of Ca^{2+} and Si^{2+} cations with increased lime+SSA (Iorliam *et al.*, 2012). The addition of the SSA to the lime-treated soil reduced the plasticity index which is an indication of improvement of soil properties (Basha *et al.*, 2005, Iorliam *et al.*, 2013). In addition to this, Federal Ministry of Works and Housing (1997c) found that, subgrade or fill material is expected to have a liquid limit value of less than 50% and plasticity index should be equal or less than 30%, while for sub base, liquid limit is expected to be equal or less than 30% and plasticity index should be equal or less than 12%. With the addition of SSA to the lime-treated soil, the plasticity index of the soil reduced to a level where it can be adequately used for sub base in Nigerian roads since soils with plasticity index higher than 12% are not suitable for use as sub base materials for roads in Nigeria (Oyediran and Kalejaiye, 2011). On the basis of AASHTO classification, the A-7-5 lateritic soil turned into A-1-a since upon the addition of 10% SSA to lime-treated lateritic soil, value of plasticity index reduced to 4% (Garber and Hoel, 2009b).

Table 4. Effect of lime on unconfined compressive strength properties of lateritc soil

Lime (%)	*7 days (kN/m^2)*	*14 days (kN/m^2)*	*28 days (kN/m^2)*
0	190	190	190
2	205	235	270
4	238	268	306
6	280	310	340
8	270	302	328
10	255	290	315

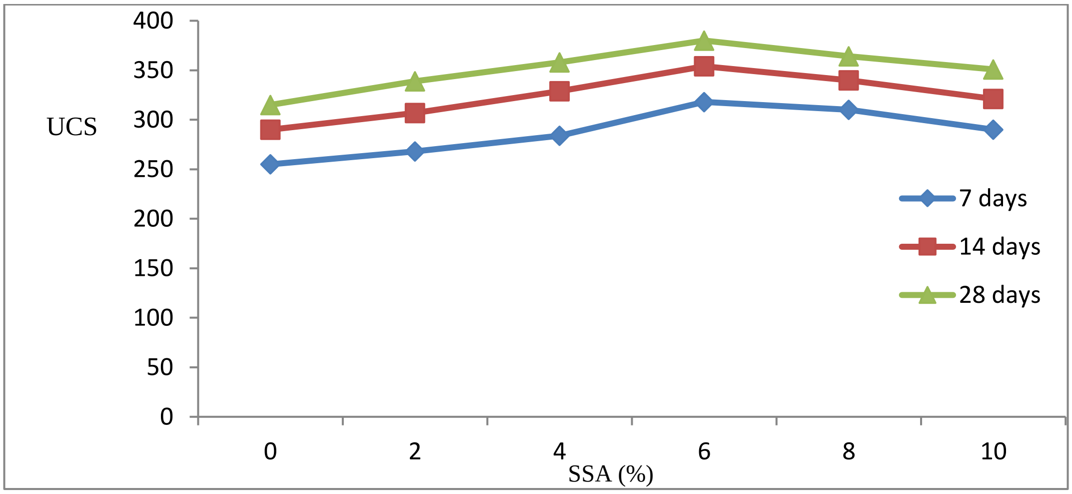

Figure 8. Effect of SSA on UCS of lime-treated lateritic soil

3.4 Unconfined Compressive Strength

Based on table 4, the Unconfined Compressive Strength (UCS) values increased as more percentages of lime were being added till it got to maximum values of 280, 310 and 340 kN/m^2 for 7, 14 and 28 days at 6% lime from natural state of 190 kN/m^2. On reaching these peak values, the UCS started decreasing till it got to 255, 290 and 315 kN/m^2 at 10% lime content for 7, 14 and 28 days respectively. Figure 8 shows that with the increased addition of SSA, UCS values increased from 255, 290 and 315 kN/m^2 at 0% SSA at 7, 14 and 28 days to peak values of 318, 354 and 380 kN/m^2 respectively all at 6% SSA, before declining in values at 8% and 10%. The resultant increase in values of Unconfined Compressive Strength (UCS) upon the addition of SSA may be attributable to the formation of cementitious compounds between the CaOH present in the soil and SSA and the pozzolans present in SSA. The decrease in UCS values after the addition of 4, 6 and 6% Snail Shell Ash (SSA) may be due to the excess SSA introduced to the soil and therefore forming weak bonds between the soil and the cementitious compounds formed (Fattah *et al*., 2013).

4.0 Conclusions

From the results of the study, the following conclusions can be drawn;

i. The lateritic soil is classified as A-7-5 using AASHTO classification system and CL using the USCS. Thus, making the soil a poor soil.
ii. The optimal amount of lime required is 10%, because at 10% lime the least value of plasticity index was recorded. The addition of snail shell ash (SSA) further reduced the plasticity index values from 13% at 0% SSA to the least value of 4.0%, thus, meeting the requirement for use as sub base, since the maximum value of 12% plasticity index is stipulated by clause 6201 of the Nigerian General Specifications, Federal Ministry of Works and Housing (1997) for sub base materials.
iii. The maximum dry density (MDD) and optimum dry density (OMC) of lime-treated soil increased with the addition of SSA.
iv. Upon the addition of SSA to the lime-treated soil, the values of unsoaked and soaked CBR improved considerably, from 50.45% (unsoaked CBR) and 40.70% (soaked CBR) to highest value of 62.30% (unsoaked CBR) and 48.75% (soaked CBR) at 6% SSA, though this value did not meet the recommended 80% CBR value for base course, it met the requirement for sub base.
v. The addition of SSA to the lime-treated soil improved the unconfined compressive strength (UCS) values to peak values of 6% SSA. UCS values also increased with curing ages of 7, 14 and 28 days.
vi. It can therefore be concluded that the snail shell ash can serve as cheap

complement for lime stabilization because the snail shell is a waste material which could be obtained at little or no cost. Also, the SSA improved the geotechnical properties of both the poor natural soil and lime-treated lateritic.

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